Accounting for the start of life

Shifting practices, costs, and value in an IVF clinic

Maura Leusder

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Accounting for the Start of Life

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If you want to truly understand something, try to change it.
Kurt Lewin, 1995

Chapter 1

Introduction

> *An old name is used for the new phenomenon: accountability. Its dual credentials in moral reasoning and in the methods and precepts of financial accounting go back a long way. But over the last two decades, and in numerous contexts, it has acquired a social presence of a new kind (Strathern, 2000, p. 1).*

1.1 Relevance and background

Rising healthcare costs impact us all, regardless of our health. Although economic models suggest that supply rises in response to demand, the same is not true for the daily encounters between patients and healthcare professionals (HCPs). The 'supply' of materials, nurses, or medical specialists does not magically multiply just because you, like many others, suddenly find yourself in an accident, develop cancer, or notice that your family member struggles with depression. When we are ill, the amount of time and effort HCPs can spend on us is limited, given that there are (many) others waiting in line. When we are healthy, we pay rising health insurance fees to cover new diseases and their corresponding, innovative treatments as and when they are invented. Healthcare costs, and how resources are allocated and 'put to use' during healthcare delivery, therefore impacts us all. If not directly, then indirectly.

Across scholarly disciplines, healthcare costs are considered a defining global challenge of our time[1]. Accelerated by changing demographics (aging populations, declining fertility rates, increasing prevalence and treatment of chronic diseases, high costs of end-of-life care) and the rapid advancement of medical sciences and technologies, costs of care have not only risen, but also grown in complexity, making them difficult to estimate or manage in practice (Johnson, 2023; Preston, 1992). By simultaneously identifying new diseases and developing corresponding treatments—effectively driving 'demand' through innovation, the healthcare landscape generates a market in which the 'product' and the underlying costs of care delivery are constantly changing (Preston, 1992, p. 86). These two factors – demographic shifts resulting in increased need, our growing ability to diagnose and treat diseases, – constitute the 'cost crisis' in healthcare and present a paradoxical, wicked problem that places an increasing burden on professionals to engage in challenging tradeoffs between resource use (now) and potential future outcomes like greater patient wellbeing or affordability of care (Brackley et al., 2021; Conceição et al., 2023; Heberle et al., 2024; Maguire & Murphy, 2022; Oppi et al., 2019).

1. Research on healthcare costs cuts across disciplines, including but not limited to medicine (Brownlee et al., 2017; Chen et al., 2023; Sullivan et al., 2011), economics and finance (Cummings, 2022; Jain, 2024; La Forgia & Bodner, 2024; Mazzucato & Adhanom, 2024; Špacírová et al., 2022), psychology (Jesser et al., 2024; McGrady et al., 2017; Pynnönen et al., 2023), sociology (Berghout et al., 2020; Johnson, 2023; Mennicken & Espeland, 2019; Schuurmans et al., 2023), and the political sciences (Battistoni, 2024; Blumenau et al., 2023; Salais & Mennicken, 2021). Organizational and managerial scholarship on this topic, and on the implementation of cost management systems in healthcare organizations specifically, is rare because such work requires access to and collaboration with healthcare organizations, and data on cost or practice variation is scarce (Llewellyn & Northcott, 2005; two notable examples include Campanale et al., 2014 and Eldenburg et al., 2010).

Considering this, healthcare providers (e.g., hospitals, clinics, nursing homes) now experience significant pressure to not only pursue medical excellence, but also to measure and demonstratively improve resource efficiency (Broadbent & Guthrie, 1992; Broadbent & Laughlin, 1998; Chua & Preston, 1994; Lowe, 2000; Begkos et al., 2023). Such perceptions of scarcity introduce time and resource limits during daily care delivery, through changes to protocols initiated within the organization, and budget cuts or financial constraints imposed by other organizations such as insurance companies (Johnson, 2023; Le Theule et al., 2023). Pressures to do more with less, and to ration resources, are intimately related to workforce issues and a global shortage of skilled clinical staff. In the aftermath of COVID-19, healthcare providers struggle to recruit and retain sufficient clinical staff, who face rising levels of burnout and stress (Walshe et al., 2024; World Health Organization [WHO], 2022). In this thesis, I argue that these two issues are related and explore how cost management infrastructure not only enables value improvements but also contributes to individuals' wellbeing.

As we will see in the following chapters, clinicians experience significant accountability for costs and resource use, but such considerations play out in trade-offs against other concerns like the sustainability of care, workload, and performance. Cost considerations, I find, come to matter by impacting individual's practical understanding of what can and should be done next in the flow of daily actions during clinical practice – what makes sense to do, for one specific patient, given the various goals and rules at play. Central to this investigation is the fact that, to become embedded in daily practice, such cost management systems must be shaped or co-created with users. Investigating how cost considerations interact with potentially competing concerns at the patient level, how this generates cost variation rather than standardization, and how enabling cost management systems can support staff wellbeing, are core themes in this dissertation.

Organizational and managerial research has been slow to address issues of cost management in healthcare, even though the costs of healthcare delivery are wholly dependent on the organization of care delivery – the norms, routines, and practices in one organization such as a hospital (Maguire & Murphy, 2022). Costs, when defined as the combination of resources required to deliver a treatment or serve a patient, are the outcome of organizational practices. How care is organized in daily practice – what equipment is used, how medical processes and tasks are organized, and how patients move from one specialist or treatment to another whilst 'consuming care' – are organizational choices, specific to one clinic or hospital department, that causally determine the costs, performance, and thus 'value' of care delivery.

Regarding this, management accounting literature has suggested that clinicians 'drive' healthcare production by allocating their time and organizational resources to patients during care delivery (Llewellyn et al., 2022; Llewellyn & Northcott, 2005). Recognizing this, other streams of research emphasize the concept of "value" in healthcare strategies and associated valuation practices (Le Theule et al., 2023; Maguire & Murphy, 2022). For example, in the US and The Netherlands, "value-based healthcare" (VBHC) is a strategy increasingly used to measure and improve value, where 'value' is defined as the health outcomes achieved in relation to total costs incurred, per patient (Porter & Teisberg, 2006; Steinmann, 2023; van der Nat, 2022). This notion of value is assumed to align accountabilities – it is assumed to keep healthcare professionals, organizations and governmental agencies accountable to deliver valuable and cost-efficient care, tailored to the individual patient's needs (Llewellyn et al., 2022; Porter, 2010; Zaki et al., 2021). Yet, if costs aren't allocated to patients in practice, and clinicians don't have access to cost estimates in most hospitals, how can or do clinicians and medical managers distinguish between actions that are valuable, or value-less, for specific patients?

Traditional strategic and economic perspectives assume that healthcare providers act as rational enterprises able to estimate the 'value' of the care delivered and the 'profits' generated by treatments. They assume that healthcare providers optimize their 'production processes', so how treatments are provided to patients, to reduce costs and pursue profits in response to pricing models within healthcare markets (Gajadien et al., 2023). Yet, research shows that healthcare providers find it difficult or impossible to allocate costs to treatments or patients in practice (Storkholm et al., 2017), don't estimate or allocate costs (Cossio-Gil et al., 2022; Eldenburg et al., 2010), and – if they do estimate them – that they find it difficult to incorporate cost information in managerial and/or medical decisions (Carr & Beck, 2020; Chapman et al., 2022; Conceição et al., 2023; Demeere et al., 2009; Gebreiter & Ferry, 2016; Ramos et al., 2021). How, then, are cost considerations weighed up against medical performance goals, or patient's subjective needs, in daily practice?

Whilst these disciplines have made important contributions at the nexus of strategy, management, and organization in healthcare, many organizational questions have remained unanswered (Johnson, 2023; Maguire & Murphy, 2022). Some have suggested that fine-grained cost insights are required for managers and healthcare professionals to pursue 'value' tailored to individual patient's wishes and needs[2]. On the contrary, managerial, sociological and behavioral research suggests that cost and performance information have, traditionally, never impacted the 'core' of medicine (Kurunmäki, 2004; Kurunmäki et al., 2003), and that the growing use of accounting in medicine is harmful, particularly if it is externally imposed and used for regulative purposes (Chua & Preston, 1994; Kurunmäki & Miller, 2008). Consequently, little to nothing is known about how to develop and implement such cost systems in practice (Defourny et al., 2023; Eldenburg et al., 2010; Malmmose & Lydersen, 2021; Storkholm et al., 2017), particularly in complex care settings featuring multi-year long treatments, multiple specialists, and uncertain outcomes – here, fragmented data systems and lacking infrastructure have been cited as technical barriers to further research, which has also limited our ability to study if, how, or why clinicians weigh cost concerns against potentially competing goals like medical performance.

In this thesis, I explore how cost considerations impact medical and managerial decisions in daily healthcare delivery, how costs of care can be estimated to improve value in practice, and how pressures to reduce or manage costs generate both intentional (e.g. cost savings and value improvements) and unintentional consequences (e.g. overwork, cost variation, and financial losses for clinics as treatments are improved). Clinicians and managers' actions and decisions come to define the value of care provided (Kurunmäki et al., 2003; Llewellyn et al., 2022; van Engen, 2025) and are therefore the focus point of the dissertation. The research project is predominately interventionist in nature[3], because it traces the conceptualization, implementation, and impact of a novel patient-level cost estimation system and performance dashboard in one healthcare organization over 4 years. Three technological and care pathway changes implemented over the years improved cost efficiency and patient outcomes at the clinic. This project is traced ethnographically, but informed by a systematic review, and followed by a survey-based study. The systematic review and survey span across medical contexts and organizations, which informed the development and execution of the novel quantitative method tailored to the fertility care setting, and generated more generalizable findings informed by the

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2. Practitioner-oriented articles make very bold claims about how managerial accounting techniques like time-driven activity-based costing (TDABC) will 'save' healthcare and 'solve' the global resource shortages in healthcare through market-based premises of competition, in which they assume that measuring costs is automatically accompanied by organizational changes and cost management practices (Kaplan & Anderson, 2004; Kaplan & Porter, 2011; Porter, 2010; Zaki et al., 2021). Throughout the chapters, I (attempt to) show how challenging this can be in healthcare organizations (featuring fragmented data systems and institutionalized practices), and in the fertility care setting in particular, where cost concerns are weighed against outcomes like pregnancy and childbirth.
3. Further explained in section 1.4.

interventionist project. The overarching question, and related sub-questions[4], are as follows:

How do costs manifest in daily work, impact practice, and how can and should cost management be implemented to improve the value of healthcare delivery to patients, the organization, and society?

1. How do cost considerations manifest in clinical practice and impact the value of care provided?
2. How can and should costs be estimated to facilitate medical and/or managerial decision-making in the implementation of VBHC as an organizational strategy? How and where can value be improved in contemporary Dutch fertility care?
3. How and why does enabling cost information improve workforce wellbeing, and how does it facilitate cost management in daily practice?

This line of research has both practical and theoretical relevance. Improving our knowledge of how clinicians and/or managers experience, deal with, and combat rising costs would significantly contribute to research on sustainable care delivery (Keller & Chambers, 2022; Geeta Nargund & Datta, 2022; Sachs et al., 2019). The relative workforce willing and able to deliver healthcare is shrinking (Walshe et al., 2024; WHO, 2022). For instance, European health expenditures are rising at an increasingly rapid rate, across countries and disease groups, and now equate to just over 10% of total GDP (European Commission, Eurostat, 2024). Simultaneously, specialized medical staff are reporting significant work pressure, and desires to retire early and/or seek other employment (Federatie Medisch Specialisten, 2022; Walshe et al., 2024). The workforce crisis introduces real, material limits to how much care can be delivered[5] (e.g., Le Theule et al., 2023). For these reasons we will need to deliver more care with less staff in future (WHO, 2022), and healthcare staff experience pressure and lacking tools or support to do so (Ahumada-Canale et al., 2023; Iedema et al., 2005). Consequently, when we think about reducing the costs of care within organizations like hospitals, we must consider the broader implications of resource usage, not just the 'profitability' of treatments, although healthcare organizations

4. In the discussion, I expand some of these sub-questions.
5. In the wake of COVID-19, healthcare organizations face difficulties in recruiting and retaining sufficient clinical staff, who are increasingly experiencing burnout, workplace stress, and psychological distress globally and in the Netherlands specifically. This introduces human and/or material resource scarcity, which can necessitate decision-making about how to meet demand that day, and can cause stress. Further, some health and care work is poorly compensated, leading some clinicians to seek other employment (Abdul Rahim et al., 2022; Howard & Houry, 2024; WHO, 2022, 2024). In the Dutch setting, this not only applies to nurses but also to specialized medical professionals, as (for instance) 42% want to retire early due to high work demands (Federatie Medisch Specialisten, 2022).

must generate some degree of profit to fund innovations. Finally, discourse of an ecological crisis points to other, equally relevant reasons to make healthcare more resource efficient by avoiding waste or excessive use of plastics and disposables, specialists' time, or capacity (Bebbington & Unerman, 2018), beyond reducing the workload and psychological stress of clinical and/or managerial staff.

Theoretically, much remains unclear about if, how, or when clinicians experience accountability towards cost-related outcomes they cannot see, experience, or anticipate. Whilst it is commonly assumed that more detailed or accurate cost information can support managerial and clinical decision-making (Cossio-Gil et al., 2022; Porter & Lee, 2013), it remains unclear if or how cost information can inform decisions as patients' trajectories unfold. At the point in time that a healthcare professional can make decisions that could benefit the patient, and result in better outcomes or lower costs, the costs of that patients' trajectory are still uncertain. This is because specialized care delivery constantly evolves (in terms of protocols followed) and is significantly tailored to patients – here, average cost estimates have often been viewed as uninformative or irrelevant by clinicians, because such averages may not reflect the specific choices made for one specific patient, and may not reflect the norms, practices, and routines in their specific organization. In this thesis, we conceptualize such moments as 'valuations' (e.g., Annisette & Richardson, 2011; Detzen & Löhlein, 2023), which involve trade-offs between incomparable goals or outcomes like pain, becoming a parent, and the costs of resources used. Further, relatedly, it remains unclear how or why accounting system co-creation impacts acceptance or use in future, and what the role of motivation and autonomy are herein. For instance, while it is commonly asserted that clinicians have significant professional autonomy and have tended to resist accounting systems, it can be reasoned that medical protocols and rules restrict autonomy. Simultaneously, strategies like VBHC are advertised to enhance autonomy, improve motivation, and reduce the risks of burnout by enabling clinicians to choose resource efficient care tailored to patients (Porter and Teisberg, 2006; Teisberg et al., 2020). These assertions, although promising, require conceptual attention and empirical investigation.

Methodologically, tracing organizational and accounting practices[6] and their impact on organizational outcomes like costs benefits from deep immersion in a specific field (Li & Jarzabkowski, 2025; Lukka & Vinnari, 2017; Watson, 2011). Additionally,

6. In this dissertation, I conceptualize accounting as an organizational practice, in line with a rich literature about how accounts – e.g. performance measures, cost estimations, or other quantitative indicators – exist as objects produced and reproduced in daily organizational life (Ahrens & Chapman, 2006; Christos Begkos & Antonopoulou, 2021; Christos Begkos et al., 2020; Burchell et al., 1980; Giovannoni et al., 2025; Hopwood, 1983, 1987, 1994; Vollmer, 2024).

developing situationally useful accounting systems requires co-production and immersion amongst future users, to understand the unique decision-making needs of individuals in the organization (Clark, 1923; Eldenburg et al., 2010). This follows from the argument that "accounting should be known for what it does in specific contexts" rather than what it may do in generalized and abstract terms (Broadbent & Guthrie, 1992; Hopwood, 1985). Therefore, several chapters focus on a single setting that exemplifies the aforementioned challenges in healthcare: Medically assisted reproduction (MAR). Although I did not select this setting and instead happened upon it due to the availability of funding for this research and an enthusiastic and willing partnering organization, this setting exemplifies the cost crisis I outlined earlier and features characteristics that make it particularly suitable to the research aims (outlined below).

The ability to reproduce is fundamental to human life, and an inability to do so is recognized as disease. Subfertility and infertility are an escalating global epidemic, summarized in **Box 1.1** (Keller & Chambers, 2022; Levine et al., 2017; WHO, 2023). As of 2023, subfertility impacts one in six individuals (17.5% of adults worldwide), and more than 180 million individuals worldwide (WHO, 2021, 2023). This corresponds to 11% of US residents and 15% of EU residents (American Society for Reproductive Medicine [ASRM], 2017; European Society of Human Reproduction and Embryology [ESHRE], 2021; Keller & Chambers, 2022). Both Dutch and international fertility clinics have been struggling to keep up with this rising patient volume, and the increasing demand for treatment, and many patients are unable to access treatments or face long waiting times (Gerris & Fauser, 2020; Geeta Nargund & Datta, 2022). Reducing the durations of treatments and reducing the number of treatments required for patients to reach pregnancy, is considered one of the most important goals of value-based fertility care because it would drastically improve both patient outcomes and resources used per patient across the entire continuum of care (Bensink et al., 2023). This choice also benefits the research practically, because Dutch fertility clinics typically operate as independent practice units (IPUs) and take responsibility for the entire medical condition from first consultation to pregnancy.

In the following section (**1.2**), I provide an overview of the studies conducted and their main contributions to literature and practice. Additionally, I present a multidisciplinary introduction to the literature on value, costs, and strategy in healthcare organizations in **section 1.3**, in which I motivate the three sub-questions in greater detail.

Box 1.1 Organizational challenges relating to cost management in fertility clinics.

Characteristics of global infertility challenges
Prevalence • 1 in 6 (17.5%) adults • 186 million individuals, across high-income and low-income countries • Up to 9% of children now conceived using MAR **Causes** • Declining sperm counts; 62.3% decline between 1973-2018 • Changing age and lifestyle factors (e.g. obesity, stress) • Trends toward delayed parenthood • Technological advancements in MAR have been rapid and have increased the resource requirements of treatments (as they have become more invasive and technically advanced). **Economic and patient burden** • Patient trajectories are long and very invasive • Treatment costs vary immensely across type and countries (from US$412 to US$50233 ≈ €400 to €50000) • Estimated total market size of US$27 billion by 2026 **Organizational challenges for clinics and/or hospitals** • Because many specialists contribute to patient's trajectories, costs have not only increased but also have become challenging to manage or estimate. • Because hospital systems produce fragmented data and are only 'loosely coupled' to actions, fertility clinics lack infrastructure to analyze patients' trajectories or allocate costs. • Because reimbursements (DRGs) reimburse one fixed fee for each treatment, they make each treatment appear administratively identical in terms of costs, even if different actions are taken per patient, or different technologies are used in the lab. • This prevents clinics from identifying, exploring, or targeting cost and resource use variation across patients receiving the same treatment, or alternative methods of delivering the same treatment. • This prevents clinics from estimating the potential impact of new technologies on local costs and resource consumption. • Because reimbursements (DRGs) reimburse fixed fees per treatment, they do not support the analysis of entire patient trajectories from initial consultation to pregnancy, even though time-to-pregnancy is considered the most important performance measure.

Throughout the dissertation, I combine quantitative research methods with longitudinal, ethnographic and interventionist fieldwork[7] in a Dutch fertility clinic. This choice – to combine organizational ethnography with quantitative analyses of clinical and management accounting data, and survey data – is rare in practice because it requires different skills and data and can be difficult to navigate (Bjerre-Nielsen & Glavind, 2022). I motivate my approach and reasoning in **section 1.4**, which details how and why this combination of methods enabled both local impact and theoretical advancements. In short, the quantitative and qualitative chapters

7. This is also known as action research. For further explanation, and the potential benefits and drawbacks of mixing methods, see section 1.4 of this introduction.

enabled each other, and allowed us to study the process of system co-creation, which shed light on what clinicians and managers find important, useful, or enabling with regards to cost management systems. Due to the absence of cost allocation systems in Dutch hospitals, building this system was a *prerequisite* for studying how clinicians and managers shape such systems, make them situationally useful, and are impacted by them. The changes implemented throughout the dissertation project (described in the following chapters) have reduced resource usage and costs, and improved performance in terms of time-to-pregnancy[8], illustrating that this combination of methods holds great potential for theory-driven research with real-world impact.

1.2 Outline of the chapters and contributions

I opened this introduction with a multidisciplinary introduction to the topic of healthcare costs, in which I established that the daily decisions and actions of clinicians and managers causally determine the costs and outcomes (thus value) of care delivery. Here, I provide an outline of the chapters, how they relate to each other, and a summary of the contributions.

The relationships between the chapters, and how the qualitative and quantitative chapters informed each other, is summarized in **Figure 1.1**. The intervention tailored to the fertility care setting was informed by a systematic literature review of medical literature (**chapter 2**) and an in-depth ethnographic study (**chapter 3**) of how cost concerns currently manifest during fertility care delivery in the form of valuations – moments during which the costs of resources are weighed against the potential chances of improving a patients' chance of parenthood. This informed the development of the quantitative method and system to estimate and improve

8. In MAR, time-to-pregnancy has been shown to be the outcome patients value the most, and is considered the most important patient-centered performance measure (Bensink et al., 2023). It refers to the total duration of a pregnancy trajectory, which consists of many repeated treatment rounds. This fact – that pregnancy trajectories consist of many repeated treatment rounds – necessitated a novel quantitative method to be developed to (a) capture total costs across the trajectory from first consultation to pregnancy, and (b) necessitates exploration of how decisions made during one treatment impact costs and performance later, during later treatments. For example, a common 'patient trajectory' in medically assisted reproduction consists of 5 cycles of ovulation induction treatment, followed by a cycle of in-vitro fertilization (IVF), followed by repeated frozen embryo transfer (FET) cycles. In total, such a trajectory can take years to complete. The method developed in chapters 4-5 estimates costs per patient, from consultation to pregnancy, without assuming that each treatment incurs the same costs. For instance, the method accounts for the number of consultations delivered, and number of embryos cultured, to produce per-patient cost estimates that clinicians found relevant and informative.

per-patient costs and outcomes, across the whole medical condition[9] covering all treatments currently available (**chapter 4**), given that patient's trajectories can take months to years to complete and consist of repeated treatment rounds. Implementing time-driven activity-based costing (TDABC) with process mining allowed us to identify and implement three value-improving technologies and protocols through care delivery redesign (**chapters 5, 7**), which had significant financial impact once implemented by reducing per-patient care delivery costs and treatment durations. This informed a similar study in a different setting also featuring personalization of care delivery – colorectal cancer treatments in Australia (**chapter 6**). The quantitative and qualitative insights gained from the Dutch project informed a national survey study, conducted in the Netherlands across all medical contexts (**chapter 8**), to further explore how individuals' perceptions of cost information impact their psychological wellbeing and daily cost management practices. The survey builds on insights gained through prior chapters, which revealed that individual's' perceived autonomy and motivation play significant roles in their ability to manage costs, and that clinicians can experience significant emotional attachment to sustainability and cost concerns. Lastly, **chapter 9** analyses the skills and practices required of junior scholars conducting such interparadigmatic research projects, which extends the literature on interdisciplinary & transdisciplinary knowledge production, and which offers practical advice to inform future projects focused on cost reduction and workforce wellbeing. The discussion offers overarching contributions, recommendations for policy, and methodological reflections synthesized across the chapters.

Chapter 2 synthesizes how costs are viewed and estimated in medical literature and contributes four best practices for cost estimation to the VBHC implementation literature (e.g., Cossio-Gil et al., 2022). To improve value through cost estimation in practice, cost estimates must be based on local resource consumption and enable comparisons based on local practices, expenses, and ways of working. Based on a review of 3874 studies, we find that time-driven activity-based costing appears most promising, due to its relative simplicity and high potential granularity, but that the vast majority studies only report one-off cost evaluations without any organizational

9. Generating cost and outcome information across the entire continuum of care is considered important, because it is thought to act as an accountability device that streamlines resource use towards outcomes that matter to patients and society, rather than encouraging volume (i.e. more care delivery) without value (Porter & Lee, 2013; Porter & Teisberg, 2006). A medical condition is "a set of patient health circumstances that benefit from dedicated, coordinated care. The term medical condition encompasses diseases, illnesses, injuries, and natural circumstances such as pregnancy. A medical condition can be defined to encompass common co-occurring conditions if care for them involves the need for tight coordination and patient care benefits from common facilities" (Porter & Teisberg, 2006, p. 44). In the case of fertility treatments, the medical condition stretches from the initial consultation with a gynecologist to achieving an ongoing, 12-week pregnancy.

implementation. Further, current implementations only estimate treatment-level costs, but do not account for patient-level variation in costs, which significantly limits their impact in practice, given that care delivery processes constantly evolve and are tailored to patients. Because all prior work focused on routine, standardized care, and only considered partial patient trajectories, estimating per-patient costs from initial consultation to pregnancy and childbirth in fertility care requires a novel quantitative approach.

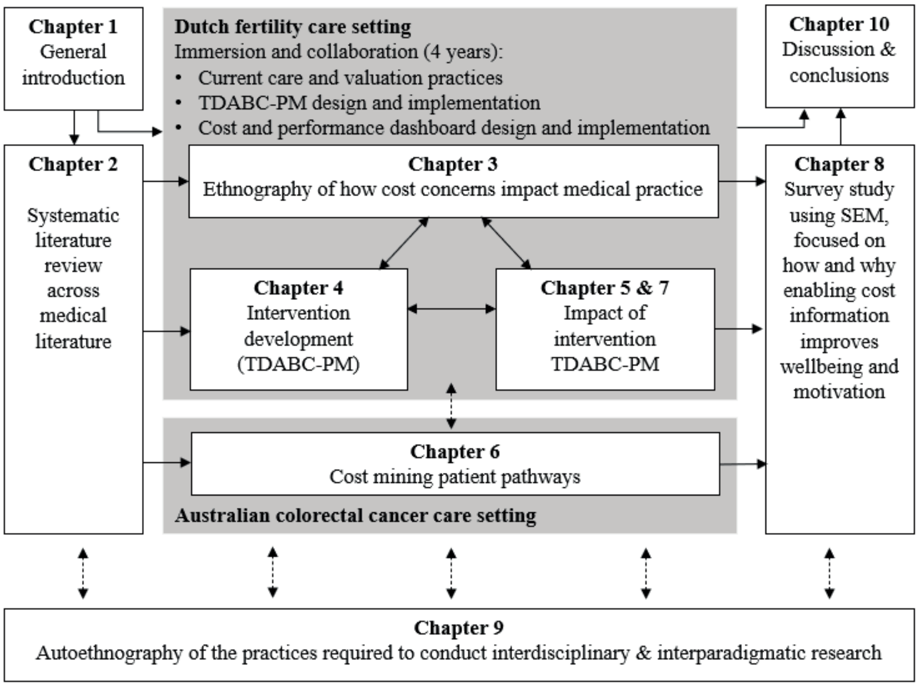

Figure 1.1 Relationships between chapters.

Note: arrows represent relationships (e.g., one chapter informed another), whereas dotted arrows represent a reflection on the research. SEM: Structural equation modelling; TDABC-PM: Time-driven activity-based costing with process mining.

Chapter 3 presents an ethnography of how cost considerations manifest in the daily practices of IVF clinicians. Building on Theodore Schatzki's site ontology (1996, 2002, 2010), a form of practice theory, the chapter develops a theory of valuation to conceptualize how IVF clinicians consider costs and strive for 'value' in their daily work and at the patient level. Cost considerations feature heavily during day-to-day medical decisions, and clinicians experience felt accountability towards both patient and cost outcomes. Clinicians weigh distant goals like achieving parenthood against immediate, short-term cost outcomes like using more petri dishes, but not the long-term cost outcomes of e.g. cultivating as many embryos as possible. The chapter explores the interplay of practical understandings and rules and illustrates that the degree to which cost concerns factor into decisions is limited by clinicians' practical understandings of how decisions (now) lead to (cost) outcomes in future, irrespective of protocols. Treatment-level protocols generate cost variation (not standardization) in practice, and how task-based performance measures (e.g. number of embryos cultured during one task during IVF treatment delivery) can lead to overwork and cost increases. The chapter builds upon Schatzki's practice theory (1996, 2002, 2005, 2010), by developing the concept of *teleological indeterminacy* and contributes to our practice-based understanding of accounting in organizations, and the managerial accounting literature concerned with healthcare cost accounting and strategy.

Informed by the prior chapters, **chapter 4** develops a novel cost estimation method we have named time driven activity-based costing with process mining (TDABC-PM) tailored to the fertility care setting, and **chapter 5** reports on the implementation and local impact of this system in the Dutch setting which contributes to literature on VBHC and TDABC implementation. This method is novel because it (a) incorporates patient-level cost variation, which is significant in fertility treatments (**chapter 3**), and (b) estimates costs across entire patient trajectories, from initial consultation to pregnancy, rather than only costing individual treatment rounds, and (c) uses repeated participant observations to identify sources of cost variation. This generated granular, per-patient cost insights into process (in)efficiencies within the organization, which clinicians found legitimate and actionable, and which generated some rapid practice changes. Together, chapters 2-5 contribute to the VBHC implementation literature, by illustrating how and why such systems benefit from high granularity, and how (in this specific case) granularity enabled various specialists to improve value by pursuing changes within the confines of their expertise and autonomy. This is novel and valuable, because patient-level cost estimation is the under-implemented and understudied element of VBHC (Cossio-Gil et al., 2022; Steinmann, 2023), and the chapters not only offer highly practical contributions but can also inform design choices in future settings. **Chapter 7** zooms in on one of the ways in which staff embraced cost accountability during system construction, by focusing on how embryologists rapidly implemented vitrification as an improved method of embryo freezing and thawing[10], which generated new compromises between laboratory

10. Throughout the project three care delivery shifts were identified and implemented, informed in part by the novel quantitative method developed. They are described in more detail in chapters 5 and 7. Such technologies shift the day-to-day practices of care delivery, and the protocols followed to deliver care, which is why they impact resource consumption and costs.

workload, costs incurred, and the dynamics of entire patient trajectories from initial consultation to pregnancy and birth. By conceptualizing technologies as collections of practices in line with chapter 3, and by exploring how the care delivery pathways associated with new technologies change resource consumption patterns across patients' trajectories from first consultation to pregnancy, this chapter sheds light on how new technologies introduce compromises that can improve value to patients and society but endanger the financial sustainability of healthcare organizations. Paradoxically, although these changes improved the resource efficiency of treatments and improved value, some of these shifts are now causing financial difficulties for the clinic, and chapters 5 and 6 explore these problems associated with current Dutch reimbursements in fertility care. Building on these findings, **chapter 6** presents a patient-level costs of care analysis in the colorectal cancer (CRC) context in the Australian setting. Akin to the findings in chapter 7, the analysis in chapter 6 demonstrates that the costs of treatments depend significantly on the relative timing of treatments during patients' trajectories.

Chapter 8 builds on the insights gained from previous chapters to pose and test hypotheses about the role of cost information in relation to the psychological wellbeing of lower and middle managers in healthcare organizations. This chapter explores the relationship between cost concerns and staff wellbeing, based on the empirical findings from chapters 3-6. Here, we develop the concept of *Enabling Cost Information* to (a) conceptualize when and why some cost information is perceived as enabling, whilst other forms of cost information are not, and (b) test if *Enabling Cost Information* positively relates to wellbeing in terms of individuals' psychological needs (autonomy, competence, relatedness). Using Self-Determination Theory (Deci et al., 2017) and responses from 217 healthcare managers, we find that *Enabling Cost Information* is significantly related to manager's wellbeing (psychological needs) and daily cost management practices. This chapter contributes to the VBHC implementation literature, as well as the growing managerial literature on enabling cost management practices in healthcare organizations.

As this introduction has alluded to, studying and improving the value of care delivery in an organization benefits from interdisciplinary research focused around one medical context (Maguire & Murphy, 2022). In this dissertation, I have combined qualitative and qualitative methods, drawn on social theories and economic methods, developed a novel method of cost estimation, and in doing so have adopted multiple (conflicting) research paradigms across the chapters (e.g. constructivism, positivism). In **chapter 9**, we analyze the skills and practices required to conduct such interdisciplinary research using a practice-theoretical approach. This chapter, rather than contributing to our understanding of healthcare costs, offers insights into *how* interdisciplinary challenges (like healthcare costs) can be studied and addressed in future, and the skills, practices, and support researchers may need to do so. Finally, in the concluding discussion, I expand and answer the research questions and offer several overarching contributions to literature, policy, and practice.

Table 1.1 Overview of data collected and infrastructure generated.

Data	Chapter
Quantitative	
10 years patient-level clinical data covering 18 445 activities, 13 203 treatment cycles, 6800 patients, 4190 pregnancy trajectories, 8 treatment types, 3 care redesign initiatives: • Shift from cryopreservation to vitrification protocols • Shift from manual embryo evaluation to evaluations with artificial intelligence (AI) • Shift from either IVF or Intra-cytoplasmic sperm injection (ICSI) to combination cycles using both techniques in one treatment.	3-5, 7
Annual financial data of clinic, covering all yearly expenses incurred	3-5, 7
Survey responses of 217 middle managers and/or healthcare professionals with managerial responsibilities, across all medical contexts	8
Qualitative	
3874 studies, analyzed abductively following systematic review guidelines.	2
Three years of immersion in a fertility clinic, 258 hours of care delivery observations and informal interviews, 190 hours of meeting observations whilst constructing the TDABC system and performance dashboard, 16 hours of interviews with elite informants involved in system creation and covering 3 care redesign initiatives.	3-5, 7
Four years of autoethnographic field notes, collected by 3 PhD students, approx. 600 pages of field notes, 25 “mixed methods anonymous” meetings (50 hours, recorded and transcribed).	9
Infrastructure and tools generated	
Database of how costs are estimated in VBHC initiatives globally	Appendix D
Medical metro lines (activity-level flow charts) covering all treatments analyzed, from initial consultation to pregnancy.	Appendix G
Patient-level cost estimation tool, to enable maintenance and use in other clinics or settings.	Appendix J
“Enabling cost information” construct, tailored to the healthcare setting (Dutch and English)	Appendix N

1.3 Research questions and embedding

In the previous section, I outlined the chapters. Here, I motivate the sub-questions underpinning the overarching research aims by embedding them in prior, related research. The questions sit at the nexus of research on organizational strategy, managerial accounting in healthcare organizations, and the small but growing VBHC implementation literature across economic and social/organizational domains.

1.3.1 Rising cost concerns have led to goal multiplicity in contemporary clinical practice

Contemporary healthcare organizations, like other public sector organizations, are evaluated on multiple, seemingly conflicting goals. Nowadays, they are expected to strive for cost control, quality improvement, and increased patient satisfaction simultaneously, which can appear contradictory or paradoxical (Begkos et al., 2023, 2019, 2020; Carr & Beck, 2020; Fırtın, 2022; Huber et al., 2021; Johnson, 2023; Miller et al., 2008; Pflueger, 2016). Accounting "has come to play a central role in the management and organization" of public services including healthcare provision (Gebreiter, 2021, p. 1190), which is associated with a naturalization of scarcity and the perception that medical services are assets to be traded and allocated efficiently (Le Theule et al., 2023; Wallenburg et al., 2019). How can clinicians achieve more with less, and improve patient's subjective experiences whilst reducing time and resources spent?

This **goal multiplicity** is evident in the rising emphasis on value-for-money in healthcare organizations globally (Arnaboldi et al., 2015; Maguire & Murphy, 2022), and the adoption of strategies such as "value-based healthcare" (VBHC) (Fredriksson et al., 2015; van der Nat, 2022). However, terms like cost, quality, and performance operate at individual, organizational and national levels (Begkos & Antonopoulou, 2021), making them difficult for clinicians to operationalize (Aidemark & Lindkvist, 2004; Iedema et al., 2005). Oftentimes, the concept of 'value' relates to various notions of worth like societal value, organizational efficiency, and professional development, which are impossible to compare in quantitative terms (Altomonte, 2022; Annisette & Richardson, 2011; Genie et al., 2021; Griffiths & Hughes, 2000; Lagerlöf et al., 2024; Larsen et al., 2018), and instead require compromises during daily care delivery – compromises between growing cost concerns, patients' individual needs, and clinicians' desires to achieve patient satisfaction and medical performance (Kuijper et al., 2022; Morinière & Georgescu, 2022).

In Europe for instance, the concept of 'value' in healthcare is now defined as personal value (achieving patients' personal goals), allocative value (equitable distribution of resources across patients), technical value (best possible outcomes with available resources), and societal value (contribution of healthcare to social participation and connection)(Calabro et al., 2022). But how clinicians and managers make compromises between such forms of value, and operationalize them in daily work as care is personalized to patients, has remained unclear (Morinière & Georgescu, 2022) and understudied (Bal & Wallenburg, 2023; Llewellyn & Northcott, 2005). Understanding how clinicians (can or do) strive for cost efficiency per patient, and how cost concerns play out against other (potentially competing) goals like medical performance and patient satisfaction, is crucial for understanding how cost estimates might come to enable cost reductions, improve the value of care delivery, and thereby support VBHC implementation or resource-efficiency more generally (Bal & Wallenburg, 2023). In other words, understanding how cost concerns impact medical decisions during the organization of care is critical to understanding how, why, and when cost information can enable individuals in healthcare organizations to achieve cost reductions.

The popularization of VBHC as a national and organizational strategy has generated renewed interest, within healthcare organizations, to implement cost estimation systems (Porter & Teisberg, 2006; Ramos et al., 2021). VBHC was introduced in 2006, and has received sustained attention in research and practice, particularly in the Netherlands and US. It emphasizes cost measurement and management, which are required for each element of the strategy listed in **Table 1.2** (Porter & Lee, 2013; van der Nat, 2022). Nonetheless, within Europe, cost estimation has remained the most under-implemented aspect of VBHC (Cossio-Gil et al., 2022; Steinmann, 2023; van Elten et al., 2023; Vijverberg et al., 2022), due to both technical and social implementation challenges.

Table 1.2 The original (1-6) and new (7-10) strategic agenda items of "value-based healthcare".

The strategic agenda to improve 'value' in healthcare
Original elements: 1. Organize into integrated practice units (IPUs) around the patient's medical condition, i.e. multidisciplinary teams accountable for coordinating and delivering care tailored to the patient across the entire pregnancy trajectory. 2. Measure outcomes and costs for every patient across the full cycle of care. 3. Move to bundled payments for care cycles. 4. Integrate care delivery across separate facilities. 5. Expand excellent services geographically. 6. Build an enabling information technology (IT) platform. Additions: 7. Develop value-based quality improvement practices. 8. Integrate value in patient communication. 9. Invest in a culture of value creation (education). 10. Build learning platforms for healthcare professionals.

Here, value as I have defined it in this book is viewed as an accountability device (Amelang & Bauer, 2019; Porter & Teisberg, 2006; Steinmann et al., 2020). This fuzzy notion of 'value' is considered key to aligning incentives and accountabilities amongst healthcare providers, insurers, and governmental institutions (Grossi et al., 2022;

Porter, 2010, p. 2478). Similar strategies or mantras to VBHC include “high-value care” (e.g., Owens et al., 2011), “cost-conscious care” (e.g., Moleman et al., 2022), or “the triple aim” (e.g., Whittington et al., 2015; Alami et al., 2023). These strategies all, at their core, emphasize ‘weighing up’ the financial burden of care delivery against outcomes, at the patient level, across an entire are continuum from initial complaint or diagnosis, up to a point of recovery or exit from the healthcare system[11]. These current popular terms and strategies are summarized in **Table 1.3** and speak to the ongoing ‘hybridization’ of the medical profession (Campanale & Cinquini, 2016; Kurunmäki, 2004).

Table 1.3 Current strategies in medical literature emphasizing value-for-money.

Emerging strategies emphasizing value-for-money
• Value-based healthcare (VBHC) • The Triple, Quadruple, Quintuple, or Sextuple Aim • Patient-centred cost-conscious care • High value cost-conscious care • High value care • Low value care • Patient-centered value-based care • Appropriate care

Notions of value-for-money in healthcare can be found in literature long before the introduction of VBHC. Such debates can be traced back to the 1970s, when medicine developed into a profession, driven by scientific advancements that encouraged specialization, education, professional societies, and centralization in hospitals (Foucault, 1975; Vogel, 1980, p. 78). This development, when medicine evolved from simple and homogenous bedside care into a complex service drawing on various specialists, materials, and equipment, made healthcare delivery extremely difficult to appraise or value in monetary terms (Cardinaels & Soderstrom, 2013; Chua, 1995; Gebreiter, 2016, 2021; Gebreiter & Jackson, 2015; Llewellyn & Northcott, 2005; Lowe, 2000; Malmmose, 2019; Preston, 1992; Preston et al., 1992; Rautiainen et al., 2022; Robson, 2008; Samuel et al., 2005). In other words, these developments made it increasingly difficult to estimate the costs of delivering treatments to patients (Vesty et al., 2023), and this historical perspective explains why pragmatic approaches (e.g. relying on historical averages, negotiations, or reimbursements) are prevalent in contemporary practice (Malmmose & Lydersen, 2021). For this reason, hospitals are considered organizations in which cost and performance measures are only ‘loosely’

11. For a definition, see footnote 9.

coupled to or even 'decoupled' from activities[12], which may explain why managers and clinicians find them insufficient for their decision-making needs (Begkos et al., 2023; Kurunmäki et al., 2003).

Due to their **high professionalized autonomy**, clinicians' decisions causally determine the costs, performance, and value of care delivered (de Harlez & Malagueño, 2016; Llewellyn et al., 2022; Pizzini, 2006), and many proponents of VBHC argue that clinicians must act as resource stewards by deciding what is valuable and efficient to do for specific patients (Moleman et al., 2021, 2022; Teisberg et al., 2020). To be impactful and support VBHC initiatives, cost estimates must therefore influence both clinical and managerial decisions, i.e. come to impact the 'core' of medicine. Because specialized care delivery (van Weert & Hazelzet, 2021), such as the delivery of fertility treatments, is personalized to patients I argue that VBHC initiatives must focus on changes in the situated knowledge, understanding, and practices of HCPs who decide how to interpret clinical guidelines and allocate their time and resources to patients. This implies that, as they are tasked to prioritize value, they engage in valuation practices to judge what resources are necessary for specific patients (Le Theule et al., 2023), rather than following the same protocols or steps for each patient.

However, the consequences of this implied 'deep interpenetration' of accounting and organizational practices (Hopwood, 1989b, p. 37) on the medical work floor has received limited attention in prior research (Cardinaels & Soderstrom, 2013). As Bal and Wallenburg (2023, p. 1) state, issues of costs and quality or wellbeing need to be studied in tandem, because cost-related trade-offs are ethically challenging and context-dependent. Related recent work has demonstrated that clinical staff increasingly interact with accounting and performance measures in their daily work (Le Theule et al., 2023), which can create moral struggles due to clashing values (Llewellyn et al., 2022; Morinière & Georgescu, 2022). Le Theule et al. (2023) shadowed geriatricians in their ethnography on accounting and valuation practices concerning palliative care patients and demonstrated that DRG accounting systems result in the misrepresentation of patients who received different care than accounted for. A recent case study in nephrology further focused on trade-offs between different and conflicting goals in daily performance discussions amongst clinical and managerial staff. The authors concluded that "valuation is a core operation on a day-to-day

12. The terms 'loosely coupled' or 'decoupled' refer to the fact that, in hospitals, accounting systems do not directly reflect the actions taken by staff (Kurunmäki et al., 2003; Weick, 1976). For instance, two different patients may require different degrees of work and resources whilst receiving administratively identical treatments, and such actions or resource consumption is not typically recorded in EHRs. Departmental performance rates of metrics are, therefore, difficult to relate to daily actions or decisions.

basis" and that further work was needed "at the micro level and the moral struggles brought about by the conflicting nature of hybridity" and performance measurement (Morinière & Georgescu, 2022, pp. 806, 819). Within such struggles, if clinicians are increasingly engaged in managerial accounting methods or increasingly striving for cost-efficiency, calculative practices may offer 'pragmatic solutions' to organizing and influence actions even if such calculations are always incomplete (Fırtın, 2022; Giovannoni et al., 2025, p. 4). For instance, halfway through a patients' treatment trajectory, the total costs of care cannot yet be known, but clinicians may have to engage in valuations that entail bringing together financial and non-financial aspects in precarious ways (Kastberg Weichselberger et al., 2023; Power & Mennicken, 2015). In such moments of valuation, they must judge what resources are appropriate or justified for a specific patient, as illustrated in chapter 3 **Figure 3.1.** Such judgements ultimately lead to both cost, performance, or other outcomes reached once a patient trajectory has ended. Therefore, I ask:

> **RQ1: How do cost considerations manifest in clinical practice and impact the value of care provided?**

Answering this question implies studying how cost variation occurs in practice, as protocols are applied to individual patients, and whether (or how) clinicians experience accountability for costs when they must engage in valuations to choose what resources are appropriate to use for patients' needs and situations.

Central to this question will be the role of care personalization, during the interplay of rules (such as standard operating procedures) and practical understandings of what makes sense to do for one specific patient – a clinicians' or manager's "feel for the game" in fertility care, as it were (Bourdieu, 1990, pp. 66–67). This applies to healthcare settings, because treatment-level rules, protocols, or accounting figures are always incomplete when used to decide how to proceed for one specific patient. Here, I hypothesized, clinicians may develop informal, fluid or contested accounting practices to manage cost pressures, because treatment-level or department-level accounting information is inherently incomplete when applied to specific patients. However, pressures to reduce costs, or increased cost management practices, may impact such moments indirectly by shaping clinicians' perceptions of what makes sense to do in the moment. Alternatively, it might give rise to informal or fluid forms of emergent accounting that might operate next to or in conjunction with formal systems (Hopwood, 1987, pp. 214; Plante et al., 2022; Power, 1999; 2015; 2019; 2022; Quattrone, 2016).

This is a particularly relevant question in fertility care, in which the outcomes, costs, and value of treatments are highly uncertain at the point in time that a clinician must choose how to proceed (Franklin, 2013; Perrotta & Hamper, 2021), and in which clinicians and managers are increasingly striving for cost efficiency through care personalization to avoid waste, overtreatment, and reduce waiting times (La Forgia & Bodner, 2024; Geeta Nargund & Datta, 2022; Perrotta & Hamper, 2021; Souter et al., 2022). In **chapter 2**, I answer this question by exploring how managerial cost accounting methods are used in the medical literature, and by synthesizing four best practices in cost estimation to support value improvements. **Chapter 3** draws on my first two years of ethnographic immersion in the fertility clinic, zooms in on how cost considerations shape medical practices, and explores how clinicians grapple with these 'moral struggles' (Morinière & Georgescu, 2022) involved in weighing up costs, outcomes, and sustainability concerns in their daily medical work.

1.3.2 The lack of managerial cost allocation practices in healthcare organizations

Although healthcare organizations like hospitals generate vast quantities of data, such data is rarely used to allocate costs to patients, or to generate actionable metrics intended for decision-making (Begkos et al., 2023; Chua & Preston, 1994; Ellwood, 2000; Fırtın, 2022; Kurunmäki, 2004; Llewellyn & Northcott, 2005; Lowe, 1997, 2000; Malmmose & Lydersen, 2021; Ramos et al., 2021; Rautiainen et al., 2022; Storkholm et al., 2017). This has both institutional and practical reasons, and presents major technical and social challenges to reducing costs and improving value in clinical practice in the eyes of managers and clinicians (Brackley et al., 2021; Cossio-Gil et al., 2022; Maguire & Murphy, 2022; Steinmann et al., 2021). In the following sections, I offer a brief historical perspective on this issue, then examine the evolving perspectives of clinicians regarding cost information, along with the organizational challenges involved in implementing a patient-level cost estimation system in the context of a fertility clinic. This review leads to, and informs, the second research question concerning how costs *can* and *should* be estimated in a fertility clinic to reduce the total resources required to help patients reach pregnancy and parenthood, and the total duration of these treatments, to improve 'value' as I have defined it. From a practice theoretical perspective, this implies not only estimating the costs of treatments but enabling clinicians to make value-improving decisions consistently, during their daily work, because care delivery is tailored to individual patients, and because treatment processes are constantly evolving (Perrotta & Geampana, 2020).

Early research on cost and performance measurement in healthcare organizations focused on externally mandated pricing systems, and reported medical managers and clinicians[13] as very resistant towards such accounting initiatives (Bourn & Ezzamel, 1986; Chua & Preston, 1994; Gebreiter, 2015; Jacobs, 2005b; Kurunmäki, 2004; Rea, 1994; Wright et al., 2021). Driven by New Public Management (NPM) ideals, new pricing initiatives sought to make medicine 'calculable' and 'manageable at a distance' in a top-down fashion, by bundling healthcare activities (e.g. consultations, surgeries, medications) into defined products or services (treatments) with associated prices (Kurunmäki, 1999b; Kurunmäki et al., 2003; Kurunmäki & Miller, 2008) – these prices are now known as "Diagnosis Related Group" prices (DRGs)[14]. These healthcare products, and their associated prices, were defined by specific diagnoses and associated activities and their assumed or average resource consumption, resulting in a list of products and (assumed to be static) prices. Thus, care was made commensurate, comparable, and governable across organizations by means of (1) classification via diagnosis-related group (DRG) codes (Preston, 1992)[15], and (2) quantification by means of static pricing. These movements introduced economic rationales to medicine by simultaneously defining medicine by DRG codes and enforcing this calculative infrastructure upon the healthcare sector through payment schemes dependent on these codes (Preston, 1992). However, crucially, such DRGs do not reflect the flow of resources within an organization and are often considered irrelevant or uninformative by clinicians and middle managers (Chapman et al., 2022; Jacobs et al., 2004; Kurunmäki, 2004; Naranjo-Gil & Hartmann, 2006), who now actively seek creative solutions to organizing care in times of real or perceived scarcity (van de Bovenkamp et al., 2023), and which can cause stress for health systems, organizations and individuals (Schuurmans et al., 2024).

In contrast to this historical perspective, contemporary reports suggest clinicians and medical managers are increasingly open to cost and performance data, or even actively request it, because they experience pressure to manage scarce resources and

13. 'Medical managers' refers to staff with formal managerial responsibilities and training, whereas clinicians perform healthcare services without managerial responsibilities. One individual can hold both clinical and managerial responsibilities, which is typically called a 'hybrid' role (Christos Begkos et al., 2020; Llewellyn, 2001). In the Netherlands, many clinicians hold hybrid roles.
14. In the Netherlands, DRGs are called "Diagnose Behandelcombinatie" (DBC), and are often referred to as 'zorgproducten' which literally translates to 'care products'. They are sometimes called 'cost prices' or 'kostprijzen', which can be misleading because they are not always based on the costs incurred by a healthcare provider, and can instead be prices that are agreed on during negotiations between care providers and other organizations. In this process, it is typically assumed that care providers know their per-patient or per-treatment costs, but chapters 2-5 establish that this cannot be assumed generally (chapter 2) or in Dutch fertility care specifically (chapters 3-5, 7).
15. Similar systems are used across Europe, the UK, and the US with slight name variations and methodological differences (Busse et al., 2011; e.g., France: Le Theule et al., 2023; e.g., UK: Llewellyn et al., 2022; e.g., US: Preston, 1992; e.g. Germany: Reilley & Scheytt, 2019; for a review see Špacírová et al., 2022).

'do more with less' (Arnaboldi et al., 2015; Moleman et al., 2022). Currently, clinicians and managers experience a significant lack of actionable cost and performance data to support decision-making (Ahumada-Canale et al., 2023; Conceição et al., 2023; Heberle et al., 2024). This new evidence contradicts prior work, which emphasized clinicians' resistance to accounting practices (Gebreiter, 2021; Kurunmäki et al., 2003) and considered accounting as a legitimizing mechanism or as 'ammunition' for negotiations in e.g., resource or budget allocation decisions (Burchell et al., 1980). Recent research has shown that medical managers and staff now actively request local, real-time accounting information that indicates 'real' organizational costs, rather than just DRGs (Eldenburg et al., 2010), and view accounting as a technology to pursue organizational strategies from the ground up to address the 'wicked problem' of resource scarcity (Maguire & Murphy, 2022). From this technological perspective, accounting is viewed to "enable us not only to see and know, but also to act on the organization" in specific ways (Berlinski & Morales, 2024, p. 10). This is exemplified by the adoption of strategies like 'value-based healthcare' in the Netherlands, but has long been observed internationally, e.g. in Scotland and Sweden (Forsberg et al., 2002; Scarparo, 2006), Finland (Kurunmäki, 2004), Germany (Jacobs et al., 2004; Reilley & Scheytt, 2019), France (Juven, 2019), Italy (Jacobs, 2005b) and Australia (Macintosh, 1991). Recent studies on clinicians and managers suggest that automated performance or cost management systems are often associated with a "programmatic dream to have unbounded knowledge" of everything (Power, 2022, pp.7). This may, however, be difficult to achieve for cost management systems specifically, which need to be tailored to the concrete decision-making needs of users (Clark, 1923). These challenges are outlined below.

Practically speaking, allocating organizational costs to treatments or patients is challenging, because (a) treatments increasingly draw on a widening array of resources (different specialists, nurses, equipment, technology) across hospital departments, (b) treatment processes are constantly evolving (Eldenburg et al., 2010; Preston, 1992), and (c) clinicians increasingly tailor care to patients (van Weert & Hazelzet, 2021). This suggests that cost estimation requires constant re-assessment as processes, costs of materials and inputs, and medical technologies evolve (Chapman et al., 2014; Conceição et al., 2023; Špacírová et al., 2020). Here, 'cost allocation' refers to a systematic way of tracing the consumption of resources to cost objects (Clark, 1923; Zimmerman, 2011), such as a treatment or trajectory. For instance, how an IVF treatment is delivered now is different to how an IVF treatment was delivered 1, 3, or 5 years ago because the processes used, equipment utilized, and amount of labor required by various specialists has changed (Gerrits, 2016; Veiga et al., 2022). Most (Dutch) healthcare organizations rely on negotiated DRGs to account for care delivery in an economics sense, and such DRGs are assumed to reflect the average costs of treatment delivery across patient groups (Busse et al., 2011).

1.3.3 Towards patient-level cost estimation and value improvements in a fertility clinic

Proponents of VBHC have positioned 'time-driven activity-based costing' (TDABC) as an ideal method of cost allocation in healthcare organizations (e.g., Etges et al., 2020; Kaplan & Porter, 2011; Kaplan & Shehab, 2020), which deserves some degree of skepticism[16]. This method was developed for the manufacturing sector, and many implementation studies of ABC have reported challenges and failures. It remains unclear whether TDABC implementation can reduce costs in non-standardized care settings (Llewellyn et al., 2022, p. 18), and if yes, how it should be designed and implemented to enable organizational cost management practices (Eldenburg et al., 2010). TDABC belongs to a subcategory of cost allocation systems intended to allocate organizational costs to products based on "causal consumption" using

16. A healthy degree of skepticism towards the applicability and usefulness of TDABC in healthcare is and remains warranted, because (1) the method was born out of a controversial set of case studies, and constantly rebranded in efforts to sell this method as 'old wine in new bottles' through consultancy firms (Gosselin, 2006; Kaplan & Anderson, 2007, pp. 17–20). This has been explored in prior research (Davidson, 1963; Gervais et al., 2010; Jones & Dugdale, 2002; Shank, 1989). Secondly (2), there is very limited research on successful implementation of ABC or TDABC in healthcare or public sector organizations generally, and this research features a long history implementation struggles and failures (Collier, 2006; Gosselin & Journeault, 2021; Briers and Chua, 2001), including healthcare settings (Arnaboldi & Lapsley, 2004; Conceição et al., 2023). Notable exceptions include Campanale et al. (2014) and Eldenburg et al. (2010). Thirdly (3), ABC and TDABC were created based on rudimentary production processes, and their success was wholly dependent on the standardization of production processes through automation (Jones & Dugdale, 2002). It is generally thought that "cost accounting systems could not "take off" until production was standardized" (Llewellyn & Northcott, 2005, p. 561), and Porter himself noted that "cost accounting, for example, was impossible until manufactured products, as well as machinery and the workers were highly standardized" (Porter, 1995, p. 42). This standardization does not apply to fertility care delivery, and does not hold for other settings in which treatment processes are tailored to patients' indications, desires, or circumstances (van Weert & Hazelzet, 2021). In other words, as care is becoming more personalized to patients, the assumption that treatments can be costed as "comparable packages" may no longer hold (Kurunmäki, 1999a, p. 123). Such technical arguments, however, ignore the potential social aspects of TDABC system co-creation, which might (I hypothesized) generate practical understandings of how, where, and why resources are consumed. This may foster a sense of cost accountability or motivation amongst individuals even if some pragmatic or inaccurate assumptions must be made during system construction.

cost drivers or predictors (Clark, 1923)[17]. Such systems allocate organizational costs based on the premise that products or services that require more resources should absorb organizational costs proportionately – e.g., treatments (or specific instances of one treatment provided to one patient) that require more equipment, staff time, materials and so on should absorb more costs than using fewer resources. In the case of TDABC, all costs incurred are allocated based on the time spent by healthcare professionals actively delivering care to patients. This pragmatic approach, it has been argued (Kaplan & Porter, 2011; Porter & Lee, 2013), may make implementation more feasible and less cumbersome than traditional ABC approaches, and may make such systems more sustainable by enabling quicker updating as treatment methods and protocols change.

Prior research has focused on the difficulties of introducing ABC systems into public sector organizations (e.g., Collier, 2006; Gosselin & Journeault, 2021; Jones & Dugdale, 2002) and reveals that most VBHC studies only offer one-off cost calculations (of emergent technologies or care pathways) without embedding real-time systems or enabling longer-term organizational cost management practices (Etges et al., 2020). Such one-off calculations, based on economic assumptions of market optimization, are typically used to challenge payment policies and DRGs (**chapter 2**). However, if such systems are only used to challenge or raise DRGs (rather than identify and reduce costs locally), they may not aid in reducing the total costs or resource usage of care delivery, and thus would not contribute to tackling the 'wicked problem' of healthcare costs or resource shortages (Maguire & Murphy, 2022). Further, if they are

17. Causal cost allocation systems are one subcategory of managerial cost allocation methods (Clark, 1923). In short, these systems aim to allocate costs to production processes (thus healthcare delivery) based on a causal measure of resource consumption, typically called cost drivers. Time-driven activity-based costing is one variant of this type of cost allocation method, because TDABC allocates costs (indirect and direct) based on the amount of time spent on a treatment or patient by a physician or HCP – so, using a single cost driver (time), that is assumed to be static for entire processes (Kaplan & Anderson, 2004). We develop an extension of this method in chapters 4 and 5 of this dissertation. These systems distinguish between 'used' capacity and 'wasted' capacity, because not all yearly, financial costs incurred are absorbed by 'production processes' i.e. healthcare delivery – some are wasted, which is realistic in complex care settings and uncertain day-to-day demand. For an extended discussion of the difference between such cost allocation systems and alternative ways of estimating costs, see Clark (1923, p. 32). In comparison to DRGs, an organizational cost allocation system considers the specific work processes used within the organization, and the expenses incurred by the organization (e.g. salaries, materials, equipment) including administrative tasks and allocates these to patients or treatments (Špacírová et al., 2022). For this reason, I hypothesized that it may contribute to user's understandings of how their decisions lead to cost outcomes (e.g., through greater internal operational transparency), and may invite users to improve resource efficiency in daily practice by adapting routines or processes. Some prior research, focused on 'enabling' systems, considers such adaptations 'repair' work in line with research on 'enabling' infrastructures (Adler & Borys, 1996; Jordan & Messner, 2012).

only calculated to challenge DRGs, but not implemented in healthcare organizations, they may not improve motivation and wellbeing as previously claimed (van Engen et al., 2025) and may fail to enable local learning of what is resource efficient and sustainable to do.

Effective TDABC systems, I hypothesized, must make visible how and where costs can be reduced, based on the current routines and practices within the unit, to not only enable cost management but also to satisfy clinicians' growing desires for enabling infrastructure to manage scarce resources (Blomgren, 2003; Jacobs et al., 2004). Qualitative research supports this position, and frequently documents that implementation attempts fail or are abandoned due to inadequate or insufficiently specific cost information, lack of access to the 'raw' data required to conduct such analyses, and difficulties with combining the data required for entire continuum-of care-evaluations (Cossio-Gil et al., 2022; Malmmose & Kure, 2021; Ramos et al., 2021; Storkholm et al., 2017). Unsurprisingly, therefore, "per patient cost estimation" and the implementation of "enabling data infrastructure" remain the two least implemented elements of VBHC (Cossio-Gil et al., 2022; Steinmann, 2023; Vijverberg et al., 2022). In this regard, I hypothesized that co-construction of the system would be vital to successful implementation, as this would allow clinicians to choose some cost accountabilities to accept and some to reject throughout the process of system construction. For instance, historical research points to the increasing interest among clinicians to make some select elements of medicine more visible and calculable (Gebreiter, 2021), but if, why, and how clinicians accept cost accountability remains unknown.

Against the background of *goal multiplicity*, *high clinician autonomy*, and the rising trend of *value-based healthcare* strategies that popularize or assume cost management, I ask:

> **RQ2: How can and should costs be estimated to facilitate medical and/or managerial decision-making in the implementation of VBHC as an organizational strategy? How and where can value be improved in contemporary Dutch fertility care?**

In this question, "can" refers to the technical challenges I have outlined, and "should" refers to the social and organizational challenges I have identified in the preceding discussion. These are summarized in **Table 1.4**. Both a technical solution, and a means to facilitate learning and practice shifts, are required to impactfully intervene in the costs (in terms of resource usage) of fertility treatment care delivery. This speaks for the development of a situationally useful co-constructed management accounting system that is capable of informing local clinical and managerial decision-making, tailored to the organization (Bouten & Hoozée, 2022; Broadbent & Guthrie, 1992, 2008; Hoozée & Ngo, 2018), as actors may 'figure out' what valuable fertility care is through a process of re-presentation of accounting facts (Busco et al., 2023).

As decades of research has illustrated the negative effects of 'accountingization', so the introduction of more explicit cost categorizations in public sector organizations (Hood, 1995, p. 93; see also van der Kolk, 2022), attention must be paid to how such systems are designed. From a practice-based perspective, emerging accounting systems are not fixed technologies with defined purposes, but rather emerge over time and have the power to introduce new calculative and/or organizational practices (Giovannoni et al., 2025; Orlikowski & Scott, 2023; Pflueger, 2015; Preston et al., 1992, p. 1), and within those practices, new or different accountabilities (Amelang & Bauer, 2019; Gebreiter & Ferry, 2016). In studying new cost estimates, and in co-constructing them with clinicians, I argue that attention must be paid to how these accounts are passed across actors, whether or not such accounts change perceptions of accountability, and whether these new accounts 'come to matter' in practice by consequentially leading to practice shifts (de la Bellacasa, 2011; Jerak-Zuiderent, 2015). Practice shifts can, for instance, relate to the use of a new protocol or technology at the treatment level, but also practice shifts as care is personalized to patients when abstract protocols must be applied to specific cases.

Table 1.4 The organizational challenge of implementing costing systems in healthcare organizations.

The dual challenges when designing and implementing organizational cost allocation systems (such as TDABC) focused on complete patient pathways in healthcare organizations:
Technical challenges • Healthcare delivery is a tailored service, not a standardized production process, so per-treatment averages may not apply to individual patients. • Hospitals typically do not record the 'raw data' required to build costing systems. • Healthcare delivery is constantly evolving, through changes in protocols and technologies, which change the resources used to deliver treatments. • To *inform* managerial decisions (e.g. technological investments), costing systems would need to predict how new technologies impact patient pathways before they are implemented. • To accurately *reflect* differences in cost between patient groups, costing systems need to incorporate patient-level variation, and record resource consumption as it occurs.
Social challenges • Clinicians and lower or middle managers have limited autonomy to adjust ways of working, due to protocols. • Clinicians can reject cost information when it is insufficiently specific, or when they do not reflect current local ways of working. • Notions or perceptions of rationing can clash with clinicians' professional values • Healthcare delivery, and in particular fertility treatments, are co-produced between patients and clinicians. Patients must carry out tasks, adhere to certain protocols and schedules, and thus partially determine the costs and outcomes achieved.

1.3.4. Cost management practices and staff wellbeing

Building on the prior discussion, I explore the relationship between cost management concerns and the wellbeing of the healthcare workforce. These literatures have, to the best of my knowledge, not been bridged before. Although VBHC is claimed to improve motivation and autonomy, and address issues such as burnout by empowering clinicians (Teisberg et al., 2020), these assertions require conceptual and empirical investigation. Closely related literature has, for instance, explored the importance of metric quality and trust for unit performance (van Elten & van der Kolk, 2024), and illustrated that individuals face significant pressure to manage and reduce costs (Ahumada-Canale et al., 2023; Heberle et al., 2024; Le Theule et al., 2023; Morinière & Georgescu, 2022), as clinicians find themselves "facing medical–scientific, socio-cultural, medico-legal and inter-professional complexities" without sufficient organizational support to navigate these in daily work (Iedema et al., 2005, p. 848). In the UK, for instance, medical managers attempt to engage clinicians in accounting practices to steer their actions towards performance goals and cost efficiency (Begkos & Antonopoulou, 2021; Begkos et al., 2023), faced with increasingly tighter budgets and regulation (Kurunmäki et al., 2023). In France, geriatric care staff experience significant pressure to allocate their scarce resources and time to patients (Le Theule et al., 2023), and can experience such pressures as demotivating and challenging, because protocols or broad treatment classifications hide differences between patients' needs and actual work done.

Central to this debate are the concepts of autonomy and motivation, because clinicians must act on their (limited) autonomy to pursue value in practice (Larsen et al., 2018) and must be motivated to take on this challenge and engage in VBHC (Maguire & Murphy, 2022; van Engen et al., 2024). In **chapter 3, 5,** and **7**, we found this to be extremely challenging in the fertility care context, because care is personalized to patients and costs vary depending on circumstances. What is valuable to do for one patient, at one moment in time, can be disadvantageous to do for a different patient receiving the same treatment. In the VBHC literature, it is commonly asserted or assumed that clinicians lack the motivation to measure healthcare delivery costs (Steinmann, 2023), and that this lack of motivation explains why cost estimation is the least implemented element of VBHC in Europe (Cossio-Gil et al., 2022). However, recent empirical evidence demonstrates clinicians' active requests for detailed and granular cost accounting information (Conceição et al., 2023; Jacobs et al., 2004; Larsen & Skjoldborg, 2004; Moleman et al., 2022; Oppi et al., 2019) and organizational support for resource allocation decisions specifically (Ahumada-Canale et al., 2023; Johnson, 2023), which is why we draw on recent advancements in the managerial literature on enabling systems to explore these relationships explicitly (Gagné et al., 2022; e.g., Van der Hauwaert et al., 2022). This literature has suggested that to positively impact wellbeing and motivation, performance management systems must be perceived as 'enabling' by empowering individuals to take actions that align with their goals and ambitions, by enhancing individual's psychological well-being. Using Self-determination theory (Deci et al., 2017), we therefore hypothesize that the presence of an enabling cost management system relates to motivation, mediated by psychological well-being, in healthcare managers who currently experience significant pressure to manage costs and allocate their scarce time and resources. Therefore, I ask:

> **RQ3: How and why does enabling cost information improve workforce wellbeing, and how does it facilitate cost management in daily practice?**

In **chapter 8**, we apply the concept of 'enabling' formalization to the healthcare context (Adler & Borys, 1996), by developing hypotheses about when and why cost management systems can be perceived as enabling. We measure and test the extent to which enabling cost information leads to psychological wellbeing (*autonomy, competence, relatedness*), motivation, and cost usage behavior. Using a sample of 217 lower or middle managers, who need to operationalize strategies like VBHC in their daily work and often carry both clinical and managerial responsibilities (Kurunmäki, 2004; Rautiainen et al., 2022), we find support for our hypotheses that enabling cost management systems lead to motivation and behavior, mediated by psychological needs satisfaction.

1.4 Methods, data, and theories

This research project draws on 4 years of collaboration with Dutch outpatient fertility clinics (**chapters 3-6**), preceded by a systematic review (chapter 2), and followed by a theory driven survey study (**chapter 8**) and personal reflection of the underlying work involved in conducting interdisciplinary research (**chapter 9**). The insights from the fieldwork informed the survey, in which we tested the insights gained during the quantitative and qualitative fieldwork.

I classify this intervention and the underlying project as an action-oriented, interventionist research[18], with periods of engaged observation and periods of intervention (Jönsson & Lukka, 2006; Lukka & Becker, 2023; Lukka & Wouters, 2022; Quarchioni & Serena, 2023). Parts of the fieldwork are presented as quantitative evaluations (**chapter 4-5**) but also served as input to a cost and quality dashboard developed in the clinic that is now in active use in multiple clinics. Other chapters are presented ethnographically, as studies of how resources are allocated, and valuations are made, in daily practice (**chapter 3, 7**). These chapters primarily rely on participant observations and thick descriptions, to account for the ethnographic nature of the research (Spradley, 1980; Cordery et al., Wiegmann et al., 2024; e.g., Nicolini & Korica, 2021).

This combination of organizational ethnography, quantitative research, and intervention in practice is rare (Bjerre-Nielsen & Glavind, 2022) and presents challenges that should be considered explicitly (Modell, 2005, 2009, 2015; Jönsson & Lukka, 2006)[19]. Although this interventionist research (IVR) approach with ethnographic immersion is time-consuming (Lukka & Wouters, 2022, p. 13), some suggest it can balance practical, theoretical, and societal relevance in research through knowledge co-production and close proximity to the field (Lukka & Suomala, 2014; Suomala et al., 2014; Van De Ven & Johnson, 2006). This approach makes it slightly more possible (but not easy) to "to understand what was said, done and understood in a particular situation" (Miller, 2007, p. 291) thanks to strong involvement in and access to practice (Lukka & Vinnari, 2017). Yet, it must be emphasized that mixing methods in this way does not offer a more "complete" or "objective" perspective – at best, mixing methods or paradigms can contribute to the construction of a credible,

18. This research approach has different names in different disciplines. The accounting literature typically calls this 'interventionist research' (Lukka & Becker, 2023). In the health sciences, this is more commonly referred to as 'action research' or 'participatory research' (Jönsson & Lukka, 2006). In labelling the research approach, a distinction should be made between the research method that is chosen for the overarching project (as I am discussing here in section 1.4 of this introduction), and the way in which the research is written up in the chapters as stand-alone publications tailored to one discipline (Lukka & Wouters, 2022, p. 3). For instance, interventionist field work or action research can be written up as a (mixed methods) case study, ethnography, or even an interview-based study depending on the stance the researcher takes towards the research phenomenon and data (De Loo & Lowe, 2011; Myers, 2019). The interventionist research approach I am describing here refers to the project conducted, overall. The interdisciplinary nature of this thesis relates to the fact that I, whilst studying how accounting works in practice, also developed and published on the quantitative results generated (e.g. chapter 5). Whilst the chapters are published in multiple disciplines, and therefore differ in style, the chapters build on each other sequentially (see figure 1.1).

19. I offer additional reflections on the benefits and drawbacks of this mix of methods in **chapter 10**. **Chapter 9** analyses the practices underlying such research when it spans disciplines and paradigms.

trustworthy, and convincing (but not necessarily more accurate) account of specific events in one context (De Loo & Lowe, 2011, p. 25; Riessman, 1993). It does not, however, offer a 'metapicture' or complete account, and the findings of this thesis are restricted in the sense that they offer deep and detailed understandings in one setting and context. Nonetheless, because prior interventions have failed to generate cost insights that clinicians found sufficiently specific and tailored to their needs, I hypothesized that ethnographic immersion and participant observations of care delivery were necessary to inform the quantitative analyses and answer the research questions. Not only to make the costing system sufficiently specific, so that clinicians would experience them as 'real' (Eldenburg et al., 2010, see also **chapter 2, 5, 7**), but also to generate theoretical advances to our understanding of how accounting can change organizational practices and outcomes through co-construction.

Whilst interpretive ethnography remains a niche methodology in accounting or organizational research and may be considered out of fashion by some (Cordery et al., 2023; Gendron & Rodrigue, 2021), this emphasis on exploring what is surprising (Van Maanen, 2011b), original (Guthrie & Parker, 2017), or marginalized is particularly important in addressing interdisciplinary research questions. It may be more appropriate and relevant here, in comparison to (for instance) ethnographic approaches using grounded theory (Deng, 2023, p. 16; Van Maanen, 2011a), and focuses on gathering and interpreting potentially contradictory insights (De Loo & Lowe, 2011, p. 27; Denzin, 1989).

To combine ethnographic and quantitative data as mentioned above, I adopt a practice-based perspective (Schatzki, 2005; Nicolini, 2016). This is rooted in the 'practice turn' of contemporary social theory and managerial accounting research, which has recognized shortcomings in other perspectives relating to the topics like intentionality and consequentiality (Li & Jarzabkowski, 2025; Ahrens, 2010; Schatzki et al., 2001). Practice theories draw our attention to the 'mundane' or 'invisible' practices that underlie cost estimation and management practices within healthcare organizations (Nicolini, 2012), such as recording resource usage (required to allocate direct and indirect costs, **chapter 2**), deciding whether to invest in a new technology or not (**chapter 5, 7**), or deciding whether to use additional materials or spend additional time in treatment some patients over others (i.e. personalizing care). Practice theories are post-structuralist, meaning that they do not view phenomena as 'out there' for us to discover in a normative sense (Tekathen, 2019), but rather as constantly emerging in the interactions between people and things[20]. This, I argue,

20. The assumptions of practice theory and their implications for studying healthcare costs and 'value' as I have defined it here are explored in detail in chapter 3.

makes it highly suited to IVR, because it acknowledges the researcher's intervention in the field by (for example) constructing and implementing a cost estimation system, by which new practices (like value comparisons between alternative care delivery methods) are potentially enabled or generated in one. From this strategy-as-practice perspective (Li & Jarzabkowski, 2025), the actions and decisions made in an organization come to shape the organizational strategy over time (e.g. VBHC), and any researcher co-constructing new technological infrastructure (such as a cost estimation system, a performance dashboard) is actively intervening in local practices and routines (Anthony et al., 2023; Li & Jarzabkowski, 2025).

This practice-theoretical approach to IVR is generates rich and deep understandings, which is suitable to sub-questions 1 and 2. However, this approach offers limited generalizability, because these deep explanations may not apply to other settings (Watson, 2011), and practice theory explicitly ties practices to specific sites. This is acceptable here, because the research questions concern mechanisms, and require rich data (Lukka & Becker, 2023; Lukka & Vinnari, 2017). Nonetheless, to complement the depth of the understandings generated in **chapters 3-5** and **7**, I made choices that offer some degree of generalizability beyond this one context.

First, to contribute to generalizability, the quantitative analysis conducted in **chapter 5** was conducted at a clinic that follows European standards and that serves a large patient population. Additionally, to improve generalizability, we designed a survey study informed by the findings from the intervention, aimed at all medical contexts (**chapter 8**), and conducted a systematic literature review across medical contexts and organizations (**chapter 2**). While **chapter 2** and **8** are broad in context, with greater generalizability, **chapters 3-7** offer less generalizability, in favor of depth and achieving real-world impact through care delivery changes. Achieving change in this way is in line with the position that accounting systems must be tailored to the needs of their users to benefit practice (Broadbent & Guthrie, 1992, 2008), which necessitates (in this case) a system tailored to clinicians and managers delivering fertility treatments, such that they might experience it as 'enabling' (Adler & Borys, 1996; Heberle et al., 2024) and such that it improves their wellbeing in terms of their ability to deal with high cost management pressures and the struggles this can cause in practice. This emphasis on understanding, rather than generalizability or 'grand theorizing', is in line with the fact that research itself is the outcome of actions and practices that change over time (De Loo & Lowe, 2011). This also applies to cost management systems, which is why all choices made in constructing this system are detailed in a lengthy appendix.

Part 1: Daily valuations

Chapter 2

Cost measurement in value-based health care: a systematic review

Published in BMJ Open (2022)

This chapter has benefitted from suggestions provided at the European Health Management Association (EHMA, 2022) conference, research seminar participants at ESHPM (2022), and other members of the value-based healthcare consortium, involving Amsterdam UMC, Erasmus Medical Center, Radboudumc and Erasmus University Rotterdam, led by J.G.M. Jelsma and M.C. de Bruijne. We thank W.M. Bramer, biomedical information specialist from the Erasmus MC, for his assistance with the search string. Some of the results of this chapter were discussed on a publicly available webcast published by the Linnean group (link available in Portfolio). This work was supported by Dutch Ministry of Health, Welfare and Sport (VWS) through grant number 330843.

Abstract

Objective

Although value-based healthcare (VBHC) views accurate cost information to be crucial in the pursuit of value, little is known about how the costs of care should be measured. The aim of this review is to identify how costs are currently measured in VBHC, and which cost measurement methods can facilitate VBHC or value-based decision making.

Design

Two reviewers systematically search the PubMed/MEDLINE, Embase, EBSCOhost, and Web of Science databases for publications up to 1/1/2022 and follow PRISMA guidelines to identify relevant studies for further analysis.

Eligibility criteria

Studies should measure the costs of an intervention, treatment, or care path and label the study as 'value-based'. An inductive qualitative approach was used to identify studies that adopted management accounting techniques to identify if or how cost information facilitated VBHC by aiding decision-making.

Results

We identified 1930 studies, of which 215 measured costs in a VBHC setting. Half of these studies measured hospital costs (110, 51.2%) and the rest relied on reimbursement amounts. Sophisticated costing methods that allocate both direct and indirect costs to care paths were seen as able to provide valuable managerial information by facilitating care path adjustments (39), benchmarking (38), the identification of cost drivers (47) and the measurement of total costs or cost savings (26). We found three best practices that were key to success in cost measurement: process mapping (33), expert input (17) and observations (24).

Conclusions

Cost information is crucial to VBHC. Time-driven activity-based costing (TDABC) is viewed as the best method although its ability to inform decision-making depends on how it is implemented. While costing short, or partial, care paths and surgical episodes produces accurate cost information, it provides only limited decision-making information. Practitioners are advised to focus on costing full care cycles and to consider both direct and indirect costs through TDABC.

2.1 Introduction

To make sound value-based decisions in healthcare, hospital practitioners and healthcare providers require patient-level information on the costs incurred and outcomes achieved in hospitals and other healthcare organizations (Kaplan & Porter, 2011). This will enable care providers to steer towards better patient-reported outcome measures, better patient-reported experience measures, and clinical outcomes at equal or lower cost (Porter, 2010). With detailed cost and outcome information, care paths can be continuously optimized (Etges et al., 2020). Consequently, value-based healthcare (VBHC) is considered one solution to the financial pressures our global healthcare system places on managers and administrators based on its promise to streamline care by focusing on desirable outcomes. Additionally, hospitals may benefit from cost information by gaining insight into the sources of costs, to guide cost-containment strategies over time. Cost information may therefore facilitate process and quality improvement initiatives pursued by management (Bodar et al., 2020; Dziemianowicz et al., 2021; French et al., 2016; Ilg et al., 2016; Isaacson et al., 2017). Furthermore, insight into patient-level or treatment-level costs enables hospitals to negotiate appropriate prices with insurance firms, especially given the trend towards new payment models and away from fee-for-service payments (Cattel & Eijkenaar, 2020; Counte et al., 2018). Finally, it is suggested that such treatment-level cost information enables market-based competition among hospitals based on outcomes and prices (Porter & Teisberg, 2006).

Considerable research has addressed the outcome side of Porter's value equation (Rathert et al., 2022). This value equations suggests that healthcare should pursue 'value', where value is defined as desirable and relevant patient level outcomes divided by the costs of delivering care, per patient (Kaplan & Porter, 2011; Porter, 2010). Many studies have measured patient-level outcomes from both the patient perspective (e.g., patient-reported outcome measures, patient-reported experience measures) and clinical outcome perspective (Gibbons et al., 2021; Zanotto et al., 2021). Less is known about the cost side of this equation. Often, the term 'cost' is conflated with the price paid by insurance firms or patients to the hospital (Jain et al., 2018; Rice-Townsend et al., 2014). However, prices do not reflect the costs incurred by hospitals (Bodar et al., 2020; Fang, Shaker, et al., 2021; Fang et al., 2022; Wise et al., 2020). Prices paid by insurance firms are negotiated sums that include profit margins for both the insurer and the hospital (Keel et al., 2017). They are also impacted by political factors, such as the hospital-payor mix that refers to the range of private and public insurance schemes that make up the hospital's income stream (Hoenigl et al., 2021). Finally, fee-for-service payments fail to account for patient-level differences in required care. Reimbursements are therefore considered a poor indicator of costs.

Some authors argue for time-driven activity-based costing (TDABC) as the 'gold standard' of cost measurement in healthcare organizations (Etges et al., 2020; Martin et al., 2018; Zanotto et al., 2021). TDABC, in a fine-grained way, matches direct and indirect costs to activities based on the time an activity or process takes. A care path is made up of many activities, each generating costs. The costs of a care path can thus be calculated by first identifying all costs relevant to each activity, and then summing these costs across the activities (Keel et al., 2017).

Although the research is growing and results are promising, there is relatively little empirical evidence to support TDABC being the best costing method to enable VBHC since studies rarely compare methods, and often simply use whichever system the investigated hospital or care provider uses. Costing methods differ by how they allocate indirect costs to products or services (Zimmerman, 2011). Moreover, indirect costs cannot causally be attributed to patients and therefore need to be appropriately allocated. An example of such indirect costs are the salaries of administrative personnel such as the front office staff who welcome patients, coordinate schedules, and manage equipment. While some costing methods ignore this (e.g., direct costing), other methods average indirect costs across days or months, or systematically allocate them to patients. These methods range from imprecise to fine-grained, with TDABC towards the fine-grained end of the scale. This insight is particularly relevant to healthcare since indirect costs are high. The most fine-grained method is known as activity-based costing (ABC) and allocates indirect costs based on actual units of resources used per activity. In comparison, TDABC allocates indirect costs based on a per-minute cost, making it considerably easier to implement. Costing methods that ignore the indirect costs of a care path underestimate the true costs of the care delivered.

Previous systematic reviews have found that TDABC was able to facilitate VBHC, often highlighting cost savings as a result but without comparing it to alternative methods (Etges et al., 2022; Etges et al., 2020; Zanotto et al., 2021). Therefore, we do not know how TDABC compares to other cost measurement methods currently in use. While TDABC may be able to facilitate VBHC (Martin et al., 2018; Zanotto et al., 2021), it is unclear how its benefits compare to other costing methods. For these reasons, the cost side of the value equation remains unclear. To address this challenge, we pose two research questions:

RQ1: Which costing methods are currently being used by practitioners to facilitate VBHC?

RQ2: What are the consequences of applying a specific costing method in VBHC?

These organizational consequences or benefits may include whether the method enables cost reduction with equal or better health outcomes, or provides sufficient information to further improve a particular care path or routine within the organization.

This comprehensive review draws on management accounting literature to categorize costing methods reported in empirical VBHC literature published over the last two decades (January 1, 2003 to January 1, 2022) into cost measurement methods defined in the literature (Zimmerman, 2011), such as direct costing and absorption costing. Compiling studies in this way revealed four ways through which cost information facilitates VBHC and three best practices.

2.2 Materials and methods

2.2.1 Literature search strategy

To identify relevant studies, we systematically searched four major databases: Embase, Medline, Web of Science, and CINAHL EBSCOhost. Our search string is available in **appendix A**. The search string was developed by assessing previously identified relevant papers for relevant keywords, and was designed to catch all studies that address VBHC and measure the costs of an intervention, care path, or treatment by including the following specific terms:

> *cost*, microcost*, macrocost* AND [meaning in combination with] value-based, value based, OR valuebased

Initial search string testing showed that restricting the search to the phrase "value-based healthcare" excluded too many relevant studies because authors use phases such as "value-based perspective" or "value-based equation" when referring to VBHC. Conversely, the term "value" was too broad and yielded more than 40,000 mostly non-specific results. By using wildcard terms indicated by stars we included many variations on the term 'cost'.

2.2.2 Eligibility criteria, record selection, and data collection

We limited ourselves to peer-reviewed empirical research that measured or estimated costs in a VBHC context. All the inclusion criteria and variables extracted are detailed in **appendix B**. The following variables, inspired by Porter (2010) and the cost measurement methods defined in the accounting literature (Zimmerman, 2011), were extracted and categorized:

- Cost types included (direct vs. indirect).
- Cost perspective (provider, payer, patient).
- Portion of the care path costed (full, partial).
- Cost measurement method used (as labelled by authors, verbatim).
- Cost measurement categories based on accounting definitions, e.g., direct costing, absorption costing, step-down allocation, and other recognized methods (Zimmerman, 2011).
- Managerial consequences of the costing information generated.

Patient and public involvement
This study did not involve patients or the public in designing, executing, or reporting the research.

2.3 Results

2.3.1 Record selection
Our four-person (ML, PP, HvE, KA) research group identified 3,275 relevant papers, of which 1,930 remained after removal of duplicates. We conducted a trial screening of 30 papers to test and further specify screening criteria. The screening process comprised two rounds as shown in **Figure 2.1**. In Round 1, ML and PP screened the titles and abstracts independently. When there was uncertainty about the eligibility of a paper, it was retained for full-text screening following Bramer (Bramer et al., 2017). We accepted 674 studies based on titles and abstracts, with a Cohen's kappa inter-rater reliability score of 0.78, indicating substantial agreement (Pérez et al., 2020).

In Round 2, both ML and PP screened the full text of all 674 studies independently. Of these, 215 studies were seen as relevant for RQ1, with a Cohen's kappa of 0.76 between ML and PP. HvE was included in any resolution discussions needed. Finally, we assessed whether each paper discussed if or how the costing information facilitated VBHC (RQ2), yielding 49 instances where the costing method facilitated VBHC. This review was not registered.

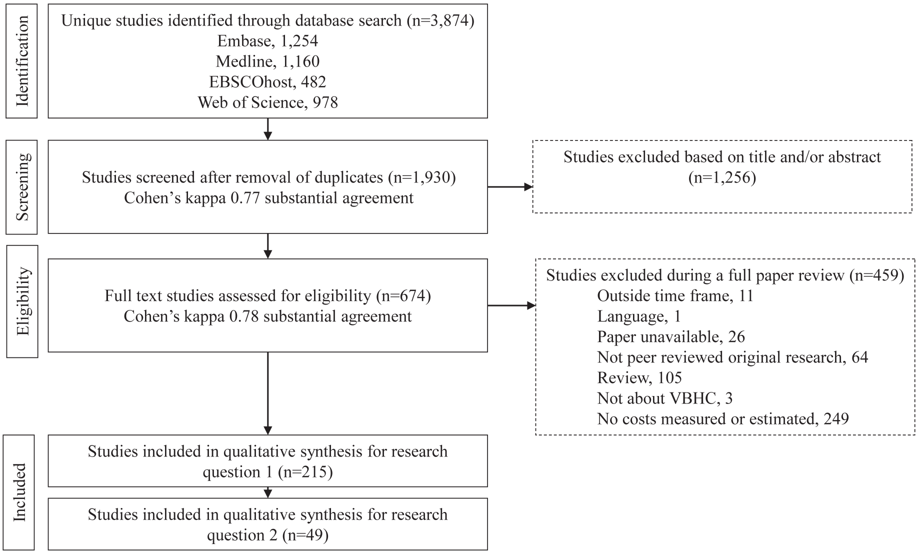

Figure 2.1 PRISMA flowchart of screening, inclusion, and exclusion processes with two reviewers.

2.3.2 Descriptive characteristics

An overview of the included studies is provided in **Table 2.1**. Our earliest study is from 2005, with an upsurge in studies from 2017 onwards. Just under half (n=98, 45.6%) of studies were published in the last two years. An overwhelming majority are from the US (n= 178, 82.8%). Europe is the second most common continent with 22 (10.6%) studies of which 9 (4.2%) relate to Dutch healthcare.

The three largest medical specialty groups represented are surgical (n=99; 46.0%), oncology (n=37; 17.2%), and pediatrics (n=19; 8.8%). Extracted data, and detailed inclusion and exclusion criteria, are available in **appendix B**. A complete list of the 215 studies included in this review is provided in .

Table 2.1 Characteristics of value-based healthcare studies that measure costs (n=215).

Characteristic	n	%	Characteristic	n	%
Year published			Topic		
2005-2009	3	1.4%	Cardiology	5	2.3%
2010-2013	6	2.8%	Dermatology	1	0.5%
2014	6	2.8%	Emergency & acute care	11	5.1%
2015	7	3.3%	Endocrinology	3	1.4%
2016	9	4.2%	Surgical, of which	99	46.0%
2017	17	7.9%	Appendicitis, 2		
2018	28	13.0%	Abdominal, 6		
2019	41	19.1%	Bariatric, 2		
2020	43	20.0%	Cardiac/Thoracic, 12		
2021	51	23.7%	Colon/Rectal, 2		
2022 as per 1/1/2022	4	1.9%	Endocrine, 2		
Geography			Ear/Nose/Throat, 2		
Americas		84.3%	Gallbladder, 2		
Brazil	3		Liver, 2		
Canada	1		Neurosurgical, 5		
US of which	178		Orthopedic arthroplasty, 25		
Boston, 8			Orthopedic fracture, 12		
California, 18			Orthopedic rotator cuff repair, 2		
New York, 23			Orthopedic other, 3		
Texas, 12			Plastic surgery, 2		
Pennsylvania, 9			Spine, 13		
Other states, 108			other surgical, 5		
Asia		2.3%	Geriatrics	1	0.5%
China	1		Gynecology & obstetrics	8	3.7%
Iran	1		Infectious disease	1	0.5%
Kuwait	1		Internal medicine	12	5.6%
Lebanon	1		Multiple	3	1.4%
Singapore	1		Nephrology	1	0.5%
Europe		10.6%	Neurology	2	0.9%
Andalusia	1		Oncology	37	17.2%

2

Table 2.1 Continued

Characteristic	n	%	Characteristic	n	%
Germany	1		Ophthalmology	3	1.4%
Italy	3		Orthopedic	1	0.5%
Norway	1		Pain medicine	3	1.4%
Serbia	1		Pediatrics of which	19	8.8%
Spain	2		Appendicitis, 3		
Netherlands	9		Emergency & acute care, 2		
UK	4		Neonatal, 3		
Oceania		1.9%	Oncology, 1		
Australia	4		Surgical, 5		
Transcontinental		0.9%	Surgical, plastic surgery, 2		
Russia	1		Other pediatric, 3		
Turkey	1		Toxicology	1	0.5%
			Urology	4	1.9%

2.3.3 Which cost measurement methods are currently being used to facilitate VBHC?

To answer RQ1, we look at how costs were measured. A summary of our findings is presented in **Table 2.2**. The literature contains many overlapping and contradictory terms, as 'costs' can refer to insurer costs, reimbursements, hospital costs, or patient costs. About half of the studies (n=110, 51.2%) take a provider perspective, with costs calculated for the hospital or care facility. Many studies use charges or payments because hospital cost data are unavailable, considering charges to be a relevant proxy. Some studies use terms such as 'costs', 'charges', 'prices', 'payments', and 'reimbursements' interchangeably, making it difficult to differentiate (Burnett et al., 2021; Cronin et al., 2020; Jain, Brock, et al., 2018; Rice-Townsend et al., 2014; Robles et al., 2018; Sun et al., 2012). For example, Jain, Brock, et al. (2018) stated, "The terms reimbursement, cost, and payment have been used interchangeably throughout the text to represent actual amounts paid by insurers." Similarly, Robles et al. (2018) explained, "Total hospital charges were utilized in this standardized costing analysis. Hospital charge data provides a relative measure of the 'cost' of episodes of care, as actual cost data are generally not ascertainable in the healthcare setting." When calculating costs using TDABC, Ahluwalia et al. (2021) called these costs 'prices.' To try to address this confusion, some recent studies refer to provider costs as the 'true cost' of care (Bodar et al., 2020; Fang, Shaker, et al., 2021; French et al., 2016; Ilg et al., 2016). Some studies that compare several cost types (Fang, Shaker, et al., 2021; Fang et al., 2022) also differentiate 'traditional hospital accounting' costs from 'true costs' calculated with TDABC (Bodar et al., 2020; Fang et al., 2022; Ilg et al., 2016; McLaughlin, Upadhyaya, et al., 2014; Wise et al., 2022).

Table 2.2 Characteristics of costing methods in value-based healthcare

Panel A: Perspectives used by authors				
	Studies		**Perspectives**	
Characteristic	**n**	**%**	**n**	**%**
Cost perspective				
Provider	110	51.2%	111	51.6%
Insurer	103	47.9%	106	49.3%
Patient	2	0.9%	5	2.3%
N*	215		222	

Panel B: Types of costs included; all studies (left) and per perspective (right)				
	All studies (n=215)		**Provider only**	**Payer only**
Cost types included				
Direct	28	13.0%	24	2
Direct and indirect	177	81.9%	84	93
Unspecified	10	4.6%	2	8
Costs measurement implementation				
No, costs measured for purpose of study	34	15.7%	33	
Yes, costing method is implemented	39	17.6%	39	
Unspecified or not applicable	142	66.2%	38	102
Costs coverage				
Full care path	47	21.8%	30	16
Full care path (full surgical episode)	17	7.4%	13	4
Partial care path (full surgical episode)	22	8.3%	19	3
Partial care path	86	42.1%	37	49
Unspecified	43	19.9%	11	31

Note: N differs between studies and perspectives because seven studies measured two cost types.

We categorized studies based on the cost types included. Both direct and indirect costs were considered in 177 (81.9%) studies, while 28 (13.0%) papers only included direct costs. Next, we looked at whether costs were calculated for a complete care path. We found 64 (29.8%) studies that measured costs for a full care path, of which 16 (7.4%) refer to full surgical episodes and label them as such without considering all the pre- or post-surgical costs. The remaining 86 (42.1%) measure costs of a partial care path.

Table 2.3 categorizes studies based on the costing method used. In those papers measuring costs within a care provider, we identified two clear categories that were in line with the management accounting literature (Zimmerman, 2011). The first is 'direct costing' (n=23), where direct costs of care are summed and indirect costs ignored. This implies that, if costs cannot be causally attributed to the treatment of a specific patient, they are not considered and hence overlooked when making managerial decisions (Zimmerman, 2011).

The second category of studies considers both direct and indirect costs and uses 'absorption costing', whereby indirect costs are allocated to patients based on an allocation key (a type of formula used for allocating indirect costs) (Ahluwalia et al., 2021). These studies include but are not limited to TDABC (n=31) and ABC (n=7), where costs are allocated to individual care activities (such as a consultation or treatment step). The remaining absorption costing papers (n=47) also consider direct and indirect costs but do not report how indirect costs are allocated to activities. In the absorption costing studies, authors may state that cost information was calculated based on diagnosis-related group costs, micro-costing, bottom-up clinical costing, or hospital accounting systems not further classified. A full list of all the terms used by authors is available in the database of extracted data **(Appendix D)**.

Table 2.3 Overview of cost measurement methods used in value-based healthcare

Perspective	Method	n
Provider	Direct costs only	
	Direct costing	23
	Absorption costing	
	ABC	7
	TDABC	31
	Other	47
	Not specified	3
Insurer	Charges and reimbursements	
	Charges, reimbursements, claims	81
	Charges adjusted with cost-to-charge ratio	25
Patient	Out-of-pocket costs to patient	5

Note: The total number of studies here is 222 because 7 studies measure two cost types. Studies are classified based on actual costs included and methods described, not necessarily the labels used by the studies' authors. The same table, but with references to each included study, is provided in **appendix C**.

2.3.4 How do these costing methods facilitate VBHC?

To answer RQ2, we extracted all the consequences related to the costing method as described in the papers. Here, like Etges et al. (2020), we were looking for how the costing information facilitated VBHC. Note that not all the studies included to address RQ1 describe facilitating VBHC or the consequences of the cost information generated. The reported consequences were grouped inductively, revealing four categories:

1. Identification of cost drivers, in terms of cost items (e.g., staff costs, material costs) or activities (e.g., surgery, initial consult; n=48).
2. Comparison of costs across patient groups, care providers, or procedures (n=39).
3. Measured cost difference, or cost saving, while achieving equal or better care (n=26).
4. Suggested or measured care path improvements (n=40).

These studies are presented in **Table 2.4.** The studies reporting these facilitators used ABC (n=6), TDABC (n=28), other absorption costing methods (n=12), or direct costing (n=3).

2.3.5 Activity-based costing

The six studies applying ABC justified this on the basis that it was the care provider's existing costing method. Three of these studies measured costs for a full surgical episode as part of a longer care path (McLaughlin, Martin, et al., 2014; McLaughlin, Upadhyaya, et al., 2014; Wise et al., 2020), two measured costs for a full care path (Jacobs et al., 2020; Vanni et al., 2020), and one measured costs of a partial care path (Abbott & Meara, 2011). While these studies all applied ABC, the ability to facilitate VBHC differed. Jacobs et al. (2020) measured costs for a complete care path for patients with adult spinal deformity, a complex care path spanning about one year. The authors compared costs across patient groups and patients, identified major cost drivers, and suggested where to concentrate cost containment. Similarly, McLaughlin and colleagues measured costs (McLaughlin, Martin, et al., 2014; McLaughlin, Upadhyaya, et al., 2014), identified cost drivers, and evaluated targeted cost containment initiatives. In one paper (McLaughlin, Upadhyaya, et al., 2014), the cost containment initiatives were informed by the cost information: activities with the highest costs were targeted for savings and a 25% reduction in total costs was achieved. In their other study (McLaughlin, Martin, et al., 2014), they identified comorbidities and demographics that were strongly related to the total costs of patients undergoing neurosurgery, whereas Wise et al. did not for geriatric hip-fracture patients while identifying cost drivers and comparing costs across patient groups (2020). Vanni et al. successfully predicted about €2 million annual cost savings associated with an enhanced recovery pathway (Vanni et al., 2020).

2.3.6 Time-driven ABC

Most of the papers we identified and used to answer RQ2 involved TDABC. Significant cost drivers were identified linked to activities in a care path, and some suggested where to target improvement initiatives (Bodar et al., 2020; Etges et al., 2022; Dziemianowicz et al., 2021; French et al., 2016; Isaacson et al., 2017; Kurt et al., 2019; Thaker et al., 2021; Wise et al., 2022). Many of the TDABC studies were able to suggest (Abbott & Meara, 2011; Ahluwalia et al., 2019; Alibrahim et al., 2022; Basto et al., 2019; Bodar et al., 2020; Dziemianowicz et al., 2021; Fang, Hagar, et al., 2021; Fang, Pagani, et al., 2021; Fang et al., 2022; Ganske et al., 2021; Hernandez et al., 2019; Isaacson et al., 2017; Jacobs et al., 2020; Kaplan et al., 2015; Kukreja et al., 2021; Kurt et al., 2019; McClintock et al., 2021; McCreary et al., 2019; McLaughlin, Martin, et al., 2014; Ning et al., 2020; Thaker et al., 2021; Vanni et al., 2020; Wise et al., 2022) or measure (Ahluwalia et al., 2021; Caloway et al., 2020; Ilg et al., 2016; Martin et al., 2018; Mattar et al., 2021; Yu et al., 2017) care path improvements (see **Table 2.4**).

The lengths and specificities of the care path costs varied widely. Some studies were narrow in scope, calculating costs for subsections of a single care path or surgical procedure (Basto et al., 2019; Bodar et al., 2020; Isaacson et al., 2017; McClintock et al., 2021; Sethi et al., 2021). Isaacson et al. calculated costs for cleaning a single reusable piece of equipment (Isaacson et al., 2017), while others costed single surgical days (Bodar et al., 2020), compared alternative surgeons (Sethi et al., 2021), or anaesthesia solutions within a care path (Basto et al., 2019). Within this group, McClintock et al. took the broadest perspective by mapping individual patient journeys (2021).

The largest group (n=10) of TDABC studies measured costs across care paths within a single provider and for a single diagnosis (Ahluwalia et al., 2021; Dziemianowicz et al., 2021; Ganske et al., 2021; Ilg et al., 2016; Kukreja et al., 2021; Mattar et al., 2021; Ning et al., 2020; Thaker et al., 2021; Wise et al., 2022; Yu et al., 2017). Typically, these studies compared costs between a new intervention and the 'usual' care (Ahluwalia et al., 2021; Caloway et al., 2020; Dziemianowicz et al., 2021; Ilg et al., 2016; Ning et al., 2020; Yu et al., 2017), or between alternative care paths in order to measure cost savings (Ganske et al., 2021; Mattar et al., 2021; Thaker et al., 2021; Wise et al., 2022).

Some studies were broader in scope, costing multiple care paths or treatments within one specialty (Fang et al., 2022; French et al., 2016; Kaplan et al., 2015; Martin et al., 2018), an entire department (Alibrahim et al., 2022; Kurt et al., 2019), multiple practice units (Hernandez et al., 2019), or providers (Etges et al., 2022). Some compared 'true costs' calculated using TDABC across care providers within specialties or care paths (Etges et al., 2022; Ganske et al., 2021), while others argued that TDABC costs were too subjective to be compared across hospitals (Dziemianowicz et al., 2021; McClintock et al., 2021). While most studies compared costs across care paths, some also compared costs across patient groups (Fang, Hagar, et al., 2021; Fang, Pagani, et al., 2021; Fang, Shaker, et al., 2021), or even individual patient journeys (McClintock et al., 2021; Thaker et al., 2021).

Technology played a prominent role in studies aiming to reduce costs. One study was able to suggest how to use technology more efficiently (Bodar et al., 2020), and some, by integrating technological investments in the calculated TDABC costs, show how technology can reduce costs (Ganske et al., 2021; Ning et al., 2020; Thaker et al., 2021). Conversely, studies using unspecified absorption methods did not include investments in technology (Danilyants, MacKoul, Baxi, et al., 2019; Danilyants, MacKoul, van der Does, et al., 2019), and this is surprising since absorption costing methods require indirect costs to be allocated.

2.3.7 Analyses enabled by activity-based and time-driven activity-based costing

Several of the ABC and TDABC studies compared costs calculated using traditional accounting costs (Bodar et al., 2020; Fang, Shaker, et al., 2021; Fang et al., 2022), or reimbursement amounts (Fang et al., 2022; Wise et al., 2020), and found that prices do not equal costs. Some carried out quantitative analyses using cost information generated using ABC or TDABC including regression analyses to identify correlations (Fang, Hagar, et al., 2021; Fang, Pagani, et al., 2021; French et al., 2016; Thaker et al., 2021; Wise et al., 2022), compare patient groups (Fang, Hagar, et al., 2021; Fang, Pagani, et al., 2021; Fang et al., 2022), and compare costs and outcomes across a matched patient sample (Thaker et al., 2021).

Two recent studies have conducted patient-level value analyses (PLVAs) (McCreary et al., 2019; Wise et al., 2022), comparing patient-reported outcomes with patient-level TDABC costs. Wise et al. (2022) did so for rotator cuff repair surgery over a period of one year, while McCreary et al. (2019) analyzed ankle fractures. Both studies found costs to be unrelated to patient-reported outcome measures, highlighting the need for further research. This suggests that patient-reported outcome measures are not strongly associated with the costs of the care delivered, and that patient satisfaction may depend on other factors such as their perceived experience with healthcare professionals.

2.3.8 Other absorption costing methods and direct costing

Other absorption costing methods reported in the studies were labelled as micro-costing (n=5), bottom-up clinical costing (Fernando-Canavan et al., 2021), or were described but not labelled (n=6). Most were able to identify cost drivers (n=12, for details see **Table 2.4**) and some compared costs within providers. Notably, Robinson et al. (Robinson et al., 2018) used the cost information to build and evaluate a dashboard that provides real-time feedback to surgeons during operations and monthly summaries and thereby decreases costs significantly. Some studies omitted certain cost categories such as equipment (Danilyants, MacKoul, Baxi, et al., 2019). Direct costing enabled cost drivers to be identified (Chatfield et al., 2019; Featherall et al., 2019; Karns et al., 2018), and in some cases granular cost measurement.

2.3.9 Best practices

Having identified these four facilitators, we compared studies to find common practices. This is particularly useful because costing methods are not labelled consistently. For example, many studies refer to ABC as 'bottom-up costing.' To look beyond labels, we compared the actual methodologies used to measure costs. We found that studies that were able to facilitate VBHC used process mapping (n=33), expert input (n=17), and/or direct observations (n=24) when measuring costs. These practices overlap with TDABC best practices, but are not exclusive to TDABC, as shown in **Table 2.4**.

Studies that made specific care path improvement suggestions used process mapping, and especially those involving multidisciplinary teams reported significant benefits (da Silva Etges et al., 2022; Dziemianowicz et al., 2021; Fang, Shaker, et al., 2021; Ilg et al., 2016). This approach enabled experts (doctors, care professionals, administrators) with the required knowledge and experience to reflect critically on the process (Etges et al., 2022; Dziemianowicz et al., 2021; Fang, Shaker, et al., 2021; Ilg et al., 2016), resulting in actionable suggestions. In comparison, studies that did not use process mapping tended to suggest minimizing high-cost items (e.g., total operating time, nursing costs) but were unable to couple these suggestions to specific activities or to chronological points in the care path. Commenting only on cost items, and not identifying chronological points, limits the ability of cost information to steer management towards where to focus process improvement initiatives.

Expert input while creating process maps or measuring costs was often cited by authors as valuable, especially for estimating preparation time or other behind-the-scenes activities that do not involve the patient but are critical to delivering care. Some studies that could not call on expert input cited this as a limitation. A few cases also evaluated the impact of costing information, for example by involving experts to evaluate a dashboard (Robinson et al., 2018). Finally, some studies involved direct observations, particularly those that calculated process times to the minute or measured the costs of individual patient journeys.

Table 2.4 Costing method implementations, method used, and managerial consequences (ordered by year of publication)

Study Characteristics						Best practices			
Reference	**Medical Specialty**	**Costing method**	**Period**	**Centre**	**Study type**	**PM**	**EI**	**DO**	**CG**
(Alibrahim et al., 2022)	Internal medicine	TDABC	Partial	Single	Retro	Yes	Yes		Items, activities
(Wise et al., 2022)	Surgical, orthopedic, rotator cuff repair	TDABC	Full (FSE)	Single	Retro	Yes		Yes	Items, activities
(Etges et al., 2022)	Cardiology, surgical	TDABC	Full (FSE)	Multi	Retro	Yes	Yes	Yes	Items, activities
(Dziemianowicz et al., 2021)	Oncology	TDABC	Full	Single	Retro	Yes	Yes	Yes	Items, activities
(Fang, Hagar, et al., 2021)	Surgical, orthopedic	TDABC	Full (FSE)	Single	Retro	Yes			Items, activities
(Fang, Shaker, et al., 2021)	Surgical, orthopedic	TDABC	Full (FSE)	Single	Retro	Yes		Yes	Items, activities
(Fang et al., 2022)	Surgical, orthopedic	TDABC	Full (FSE)	Single	Retro	Yes		Yes	Items, activities
(Ganske et al., 2021)	Pediatric, surgical, plastic surgery	TDABC	Full (FSE)	Multi	Pro	Yes		Yes	Items, activities
(McClintock et al., 2021)	Emergency and acute care	TDABC	Full (Multiple)	Multi	Retro	Yes	Yes	Yes	Items, activities
(Sethi et al., 2021)	Surgical, orthopedic	TDABC	Full (FSE)	Single	Retro	Yes		Yes	Items, activities
(Thaker et al., 2021)	Oncology	TDABC	Partial	Single	Pro	Yes	Yes	Yes	Items, activities
(Kukreja et al., 2021)	Oncology (incl. surgery)	TDABC	Full	Single	Retro	Yes		Yes	Items, activities
(Mattar et al., 2021)	Oncology	TDABC	Partial (FSE)	Single	Retro	Yes			Items
(Bueno et al., 2022)	Cardiology	AC (other)	Partial	Multi	Retro				Items
(Casey et al., 2021)	Emergency and acute care	AC (other)	Partial	Single	Retro	Yes			Items
(Cohen et al., 2021)	Surgical, bariatric	AC (other)	Full (FSE)	Single	Retro				Items
(Negrini et al., 2021)	Gynecology and obstetrics	AC (other)	Full	Single	Retro	Yes			Items, activities
(Fernando-Canavan et al., 2021)	Emergency and acute care	AC (other)	Partial	Single	Retro				Items, activities

Value-Based consequences of costing information			
Compare costs across	**ICD**	**MPS**	**Care path adjustment implemented**
	Yes		Suggested
Surgeons, two alternative treatments	Yes	Yes, ± $727 about the mean per patient	Suggested
Hospitals, Procedures	Yes	Yes, estimate 51.0% of Procedure cost	Yes
Treatment care paths	Yes	Yes, $2,302 (25.0%) difference across treatments	Suggested
Patients	Yes		Suggested
Costing methods (TA and TDABC)	Yes		Suggested
Five treatments, cost vs. reimbursement	Yes		
Treatment care paths	Yes	Yes, Up to US$8900, but long-term outcomes yet unknown	Suggested
Eight care paths for acute ureteral stones (patient journeys)	Yes	Yes, $6614 difference across care paths	Suggested
Surgeons	Yes		Suggested
Treatments and individual care paths	Yes	Yes, cost difference of up to 3.33 times, depending on case mix	Suggested
	Yes		Suggested
Pre-implementation and Post-implementation	Yes	Yes, mean cost savings of €309 per patient	Yes
Patient journeys	Yes		Suggested
Surgeons	Yes		
Treatment	Yes		
Procedures	Yes	Yes, $967 per patient	Suggested
	Yes		

Table 2.4 Continued

Study Characteristics						Best practices			
Reference	**Medical Specialty**	**Costing method**	**Period**	**Centre**	**Study type**	**PM**	**EI**	**DO**	**CG**
(Khanijow et al., 2021)	Surgical, colorectal	AC (other)	Partial (FSE)	Single	Retro				Items
(Wise et al., 2020)	Surgical, orthopedics, fracture	ABC	Partial (FSE)	Single	Retro				Items
(Vanni et al., 2020)	Surgical, orthopedic, arthroplasty	ABC	Full (FSE)	Single	both		Yes	Yes	Items, activities
(Jacobs et al., 2020)	Surgical, spine	ABC	Full	Single	Retro	Yes			Items, activities
(Bodar et al., 2020)	Pediatric, surgical	TDABC	Full (FSE)	Single	both	Yes		Yes	Items, activities
(Ning et al., 2020)	Oncology	TDABC	Full (FSE)	Single	Retro	Yes	Yes	Yes	Items, activities
(Ahluwalia et al., 2021)	Surgical, orthopedic	TDABC	Full (FSE)	Single	Pro	Yes	Yes	Yes	Items, activities
(Caloway et al., 2020)	Pediatric, neonatal	TDABC	Partial	Single	Retro	Yes	Yes	Yes	Items, activities
(Burnhope et al., 2022)	Surgical, cardiac/ thoracic	AC (other)	Partial	Multi	Retro	Yes			Items
(Lenfant et al., 2021)	Oncology, surgical	AC (other)	Partial	Single	Retro				Items
(Hernandez et al., 2019)	Multiple	TDABC	Full	Multi, pilot	Retro	Yes	Yes	Yes	Items, activities
(Basto et al., 2019)	Oncology	TDABC	Partial (PSE)	Single	Pro	Yes		Yes	Items, activities
(McCreary et al., 2019)	Surgical, orthopedics fracture	TDABC	Partial (FSE)	Single	both	Yes			Items
(Ahluwalia et al., 2019)	Surgical, foot debridement	TDABC	Partial (FSE)	Single	Retro			Yes	Items
(Kurt et al., 2019)	Ophthalmology	TDABC	Full	Single	Retro	Yes	Yes	Yes	Items, activities
(Danilyants, MacKoul, van der Does, et al., 2019)	Gynecology & obstetrics, surgical	AC (other)	Partial (FSE)	Single	Retro				Items
(Danilyants, MacKoul, Baxi, et al., 2019)	Gynecology & obstetrics, surgical	AC (other)	Partial (FSE)	Single	Retro				Items
(Chatfield et al., 2019)	Multiple	Direct costing	Partial	Single	Retro				Items

Value-Based consequences of costing information			
Compare costs across	**ICD**	**MPS**	**Care path adjustment implemented**
Intervention	Yes	Yes, reduced variable cost, similar total cost	Yes
Patients, patient groups, demographics	Yes		
Treatment care paths	Yes	Yes, estimate €2,054,000 annually	Yes
Patients, patient groups	Yes		Suggested
Costing methods (TA and TDABC)	Yes	Yes, 20.0% and without care path alteration	Suggested
Treatment care paths	Yes	Yes, estimate for each 10.0% decrease in case duration, total costs could decrease by about 8.0%.	Suggested
Treatment care paths	Yes	£2,018 per patient	Suggested
Pre and post intervention	Yes	Yes, 36.0% or $92,000 per tracheostomy care cycle	Yes
Patients, implant devices	Yes		Suggested
	Yes	Yes, Multiple	
Pre and post intervention (IPUs were seen as the intervention)	Yes	Yes, quarterly costs declined	Suggested
Treatment Process within OR (parallel vs. induction design)	Yes	Yes, estimate OR time reduction of 55 min, or US$,2818 missed revenue	Suggested
	yes		Suggested
Pre and post intervention	Yes		Yes
	Yes		Suggested
	Yes		Suggested
	Yes		
	Yes		

2

Table 2.4 Continued

Study Characteristics						**Best practices**			
Reference	**Medical Specialty**	**Costing method**	**Period**	**Centre**	**Study type**	**PM**	**EI**	**DO**	**CG**
(Featherall et al., 2019)	Surgical, orthopedic	Direct costing	Full (FSE)	Multi	Retro				Items
(Martin et al., 2018)	Surgical, carpal tunnel release	TDABC	Partial (FSE)	Multi	Retro	Yes		Yes	Items, activities
(Robinson et al., 2018)	Surgical, appendicitis	AC (other)	Partial (FSE)	Single	Pro		Yes	Yes	Items
(Karns et al., 2018)	Surgical, orthopedic	Direct costing	Partial (FSE)	Single	Retro		Yes		Items
(Isaacson et al., 2017)	Urology	TDABC	Partial	Single	Pro	Yes		Yes	Items, activities
(Yu et al., 2017)	Pediatrics, appendicitis	TDABC	Full (FSE)	Single	Pro	Yes	Yes	Yes	Items, activities
(Parra et al., 2017)	Urology	AC (other)	Partial	Multi	Retro		Yes		Items
(French et al., 2016)	Oncology, surgical	TDABC	Partial (FSEs)	Single	Retro	Yes			Items, activities
(Ilg et al., 2016)	Oncology	TDABC	Full	Single	Retro	Yes	Yes	Yes	Items, activities
(Mattar et al., 2021)	Urology	TDABC	Partial (FSE)	Single	Retro	Yes	Yes		Items, activities
(McLaughlin, Upadhyaya, et al., 2014)	Surgical, neurosurgery	ABC	Partial (FSE)	Single	Retro	Yes			Items, activities
(McLaughlin, Martin, et al., 2014)	Surgical, neurosurgery	ABC	Partial (FSE)	Single	Retro	Yes			Items, activities
(Abbott & Meara, 2011)	Pediatric plastic surgery	ABC	Partial, 1 year	Single	Retro				Items
					Count	33	17	24	

Note: Costing methods are classified based on actual reported costs and methods applied, not necessarily the labels used by authors. ABC, activity-based costing; AC, absorption costing; CG, cost grouping; DO, direct observation; EI, expert input; FSE, full surgical episode; ICD, identify cost drivers; IPU, integrated practice units; MPS, measured provider cost savings; PM, process mapping; Pro, prospective; PSE, partial surgical episode; Retro, retrospective; TDABC, time-driven activity-based costing.

2

Value-Based consequences of costing information			
Compare costs across	**ICD**	**MPS**	**Care path adjustment implemented**
Pre and post intervention		Yes, £255 per patient	Yes
Multiple treatment care paths	Yes	Yes, 70.9% (US$27,103) and 31.6% (US$178)	Yes
Pre and post intervention (dashboard was seen as the intervention)	Yes	Yes, decreased by US$496 per operation	Yes
Intervention	Yes		
	Yes	Yes, estimate two hours per cycle	Suggested
Pre and post intervention (treatment care path comparison)	Yes	11.0% cost reduction, and 51.0% hospitalization time reduction	Yes, several
Potential staffing ratios for 11 types of surgery	Yes	Estimate 13.0-28.0% per surgery type	Modelled and Suggested
Treatments (high-dose vs. low-dose brachytherapy)	Yes	US$2,668 difference across treatments	Yes
Five treatment care paths	Yes	Yes, 400.0% increase from least to most expensive pathways	Suggested
Patients	Yes	Yes, 25.0%	Yes, several
Patients	Yes		Suggested
Patients	Yes		Suggested
38	47	26	39

2.4 Discussion

This review focused on VBHC studies that have measured or estimated costs, and on identifying which costing methods can facilitate VBHC. By assessing the consequences of the costing methods used, we were able to identify characteristics of costing methods that do facilitate VBHC.

Previous research found that TDABC can facilitate VBHC through cost containment and process improvements (Etges et al., 2020; Zanotto et al., 2021). We built on these assertions by comparing the benefits or consequences of using particular cost measurement methods. While the field is young and alternatives seem limited, we have found considerable evidence that TDABC and ABC can facilitate VBHC. As previously noted, TDABC is considerably easier to implement than ABC, which leads us to recommend it over ABC. We found no well-documented alternatives to TDABC or ABC in our review. However, not all the TDABC studies delivered the facilitating factors we have identified. We therefore emphasize the need to follow TDABC guidelines carefully and to explicitly document methods used. Several of the studies in this review simply stated that TDABC was applied, outsourced, used with incomplete costs, or used without listing exact cost rates – such practices may limit its organizational impact, and organizational efforts to maintain systems.

The start and end points of care paths tend to be well documented by authors but are inconsistent. To view costs in relation to outcomes, as suggested by Porter (Porter, 2010), the total costs from start to finish of a trajectory should be included (Steinmann et al., 2021). In many studies, the start and end points of cost measurement windows seem somewhat arbitrary but are still labelled as full care paths. Consequently, this results in inconsistencies across studies, hindering comparisons. Encouragingly, some of the more recent studies have measured costs across a genuine full care path and future research should do the same, explicitly defining start and end points. This would enable consistent comparisons across providers. As with the ICHOM standard outcome sets produced by the International Consortium for Health Outcomes Measurement, costs could be catalogued and compared over full care paths. Indeed, in a recent expert consensus study, experts agreed on the need to focus on full care paths (Steinmann et al., 2021).

Furthermore, we can see a trade-off in the specificity and length of the care path costed. Studies that measure costs for elements of a care path (such as a surgical operation) can provide detailed costs for that portion of the care path, but not total care costs for a patient because the remainder of the care path is excluded. Some surgical studies measured costs for partial care paths, and often concluded that operating theatre time should be minimized due to high surgeon and operating theatre costs. However, this conclusion has limited relevance for the value equation or managers (Porter & Teisberg, 2006) because it does not provide cost information for an entire care path, or advice on how to e.g., circumvent surgery or minimize the chance of needing one.

Studies that cost complete care paths appear to use less detailed costing methods (due to the sheer length of the care path) but can compute total costs of a patient's care. This enabled benchmarking across providers, as well as cost comparisons of new vs. standard care, or of treatment alternatives. According to the included studies, this allowed providers to steer towards value by for instance improving processes without negatively impacting outcomes. Future research should focus on measuring costs for full care paths, and on comparing costs to outcomes as demonstrated in some of the more recently published studies reviewed (McCreary et al., 2019; Thaker et al., 2021; Wise et al., 2022).

Our review highlights the need to involve medical professionals in this process, both when implementing costing methods as well as when evaluating the results. Future cost measurement studies, and hospitals looking to implement TDABC, should involve multidisciplinary teams. Studies that have involved medical professionals in the process of measuring costs and then using the findings were able to improve care paths through improvement initiatives and/or dashboards. This suggests that generating and using costing information should be viewed as a process, throughout which users can learn how and where costs are incurred or could be reduced. Future qualitative research should follow this process to better understand the mechanisms through which cost information impacts decision making, and the impact that staff involvement has on cost containment. Previous research suggests that staff involvement is critical as it builds trust in the accuracy of the data (Hoozée & Bruggeman, 2010).

2.4.1 Limitations and future research

We acknowledge several limitations related to the scope, breadth, and quality of the included studies. First, our search strategy will have missed studies that measure costs but do not label the study as VBHC-oriented. Not all TDABC studies make value-based claims or contributions and are thus excluded from our review. Additionally, not all studies explicitly discuss the managerial impact or organizational consequences of the costing method applied, which may impact our findings. Future qualitative research could investigate TDABC implementations and evaluate how, when, or why the benefits found in this review are achieved in practice. Second, sophisticated methods such as TDABC are currently only used with predictable and/or short care paths such as orthopedic surgery. Further research testing the feasibility and practicality of TDABC in different settings, such as emergency on-call care, or longer care paths such as fertility treatment, is warranted given that care is increasingly personalized to patients. Further, our findings may have limited generalizability across medical specialties as indicated in **Table 2.1,** as prior research focused on surgical interventions. Finally, we have relied on the reporting of authors, whose style and language differs across disciplines and journals. We circumvented this limitation by looking beyond the labels used by authors, by extracting the costs included and methods used, and then categorizing them using established accounting definitions. However, we cannot exclude the possibility of errors due to a lack of explicit reporting in some of the studies reviewed.

2.5 Conclusions

This systematic review reveals that cost information, at the treatment or patient level, for complete care paths enables value-based decision making through several mechanisms. Such cost information can direct quality and process improvement initiatives, alongside informing appropriate reimbursement levels. In the pursuit of VBHC, practitioners and academics are advised to apply ABC or TDABC to estimate costs, using process mapping, expert input, and observations, rather than relying on pricing information.

Chapter 3

Valuing care at the intersection of accounting and medical practices

Based on: Leusder, M., van Elten, HJ, De Loo, I. *(under review, revisions)* Valuing care at the intersection of accounting and medical practices. *Accounting, Auditing & Accountability Journal.*

This article has benefitted from helpful comments provided by Dominic Detzen, research seminar participants at the University of Innsbruck (Accounting Research Seminar, 2025) as part of my research visit, University of Groningen (Accounting Research Seminar, 2024), Nyenrode Business University (2023), session participants at the Interdisciplinary Perspectives on Accounting doctoral colloquium (IPA, 2024), and two anonymous reviewers. We would like to acknowledge the cooperative participation of the clinic and a supporting grant from DSW health insurer. The study was approved by the ethics committee of the Erasmus School of Health Policy & Management (ETH122-0355) and the participating hospital.

Part 2: Shifting practices

Chapter 4

A novel method for patient-level cost management

Published in BMJ Open (2023)

Abstract

Introduction Value-based healthcare suggests that care outcomes should be evaluated in relation to the costs of delivering that care from the perspective of the provider. However, few providers achieve this because measuring costs is considered complex and elaborate and, further, studies routinely omit cost estimates from 'value' assessments due to lacking data. Consequently, providers are currently unable to steer towards increased value despite financial and performance pressures. This protocol describes the design, methodology and data collection process of a value measurement and process improvement study in fertility care featuring complex care paths with both long and non-linear patient journeys.

Methods and analysis We employ a sequential study design to calculate total costs of care for patients undergoing non-surgical fertility care treatments. In doing so, we identify process improvement opportunities and cost predictors, and will reflect on the benefits of the information generated for medical leaders. Time-to-pregnancy will be viewed in relation to total costs to determine value. By combining time-driven, activity-based costing (TDABC) with observations and process mining, we trial a method for measuring care costs for large cohorts using electronic health record (EHR) data. To support this method, we create activity and process maps for all relevant treatments: ovulation induction (OI), intra-uterine insemination, in-vitro fertilization (IVF), in-vitro fertilization with intracytoplasmic sperm injection (ICSI) and frozen embryo transfer after IVF. Our study design, by showing how different sources of data can be combined to enable cost and outcome measurements, can be of value to researchers and practitioners looking to measure costs for care paths or entire patient journeys in complex care settings.

Ethics and dissemination This study was approved by the ESHPM Research Ethics Review Committee (ETH122-0355) and the Reinier de Graaf Hospital (2022-032). Results will be disseminated through seminars, conferences, and peer-reviewed publications.

4.1 Introduction

The healthcare services, policy and management literature emphasizes the need to strive for 'value' in healthcare by considering both costs and outcomes at the patient level (Cossio-Gil et al., 2022; Porter, 2010). To improve value, providers must either deliver better outcomes, or the same outcomes more efficiently, and this requires an ability to measure costs per outcome over time (Feeley et al., 2020). Cost measurement at the patient level provides insight into the sources of costs, guidance for process improvement initiatives and can inform payment policies such as bundled payment initiatives (Etges et al., 2020; Porter & Teisberg, 2006). Such information would be particularly useful to medical leaders who face complex decisions and trade-offs in a world of financial pressures. In a recent consensus report of European university hospitals, 'routinely measuring costs at the patient level' was not achieved by any of the frontrunner hospitals studied (Cossio-Gil et al., 2022). Experts have stressed the need to measure costs and outcomes across full treatment cycles, and to learn how to optimize health outcomes relative to costs (Steinmann et al., 2021), but indicate they are currently unable to do so (Cossio-Gil et al., 2022; Jacobs et al., 2004).

This difficulty is reflected in the fact that most value-based healthcare (VBHC) studies focus on reimbursement amounts as a proxy for provider costs rather than the actual costs itself, even though reimbursements have been shown to be unrelated to actual costs incurred by the care provider (Leusder et al., 2022; Wise et al., 2022). Reimbursements paid by insurers or patients assume global averages and do not reflect the actual costs incurred by care providers, and hide the variability in costs across patient groups (Fang et al., 2022). As such, they do not inform clinics, hospitals, or healthcare providers on their own, local cost variability, or where to target process quality initiatives to improve value (Ederhof & Ginsburg, 2019; Leusder et al., 2022; Wise et al., 2022). Therefore, they should not be used for value assessments or managerial decision making.

However, some recent studies have assessed the so-called 'true costs' of care which they define as total organizational costs incurred by care providers in delivering care, per patient (Fang, Shaker, et al., 2021; Wise et al., 2022). To date, cost estimations have predominantly been successful in enabling process improvements in surgical and to an extent in orthopedic care paths (Etges et al., 2020; Wise et al., 2022). These healthcare areas or medical specialties characterized by relatively short and linear cycles of care, without long patient journeys involving chronic or multiple conditions or requiring additional care such as mental health support (Berthelot et al., 2021). The reality is that little is known about whether benefits can be realized from cost measurement in complex care, or medical specialties that feature long care paths with many decision points, alternative treatment options, and extensive time horizons (Keel et al., 2020). In such cases, there is little attempt to measure costs and outcomes from the initial consultation or diagnosis through the entire care path (Campanale et al., 2014; Eldenburg et al., 2010; Keel et al., 2020, 2017; Leusder et al., 2022). Instead, costs are typically estimated by using charges filed by the hospital, diagnosis-related group prices (DRGs) or length of stay as a proxy of costs (Jain, Phillips, et al., 2018; Keel et al., 2017; Špacírová et al., 2022; Tanet al., 2011). In this case, length of stay refers to the duration for which patients were admitted to a ward or department with overnight stays. However, these are uninformative about the actual costs paid by the care provider (e.g. a clinic, hospital) and these proxies hide within-treatment variability. Furthermore, proxies such as length of stay are irrelevant for treatments without hospital stays (i.e., outpatient treatments). As a result, proxies used in earlier studies are too aggregated for managerial decision-making (Eldenburg et al., 2010; Keel et al., 2017).

Fertility care offers a relevant opportunity to investigate the applicability and merits of cost measurement for value-based processes and quality improvements in complex care. Current knowledge is limited to reimbursement totals or hospital prices, which range from $412-$50,233 (≈ €400-€50,000) per month across treatments, countries and patient characteristics (Bahadur et al., 2020; Chambers et al., 2013; Connolly, Hoorens, et al., 2010; Katz et al., 2011; Lipton et al., 2020). The costs of assistive reproductive technologies (ARTs) are largely unknown, and clinics stand to gain valuable managerial and organizational information that would be relevant for internal decision-making (Keel et al., 2020; Leusder et al., 2022), for reimbursement negotiations with insurers (Porter & Teisberg, 2006), and for long-term planning (Ederhof & Ginsburg, 2019; Kaplan & Anderson, 2007).

This research protocol describes the study design and methods to be applied in a sequential multi-phase project in which we will measure the costs of delivering fertility care, identify potential process improvement opportunities and evaluate the value of such cost information to medical leaders when making value-based decisions. By describing the study design, analyses, and data collection in detail we hope to aid researchers and practitioners in responding to the call for sounder cost estimates to enable VBHC.

4.2 Aims, context and research questions

The broad purpose of this research project is to further the value-based care research agenda through the application of TDABC and process mining in a complex, long and non-linear care path setting. Our research specifically assists the development of better fertility care paths by enabling clinics to measure and strive for high value care, defined by a short time-to-pregnancy relative to costs. A recent patient-centered fertility care survey confirmed previous research that the biggest contributor to patient satisfaction is time-to-pregnancy (Shandley et al., 2020), which can range from months to years in some cases.

4.2.1 The context of fertility care and ART care pathways

After being referred by their general practitioner, couples or individuals enter a fertility clinic wishing for a healthy pregnancy and birth. During an initial fertility assessment (IFA), diagnostic testing is conducted over a period of four to six weeks after which the clinic provides an assessment, diagnosis, and prognosis. Treatment is cyclical in nature because each treatment cycle must be timed to match the female patient's monthly menstrual cycle. Patients can be switched from one treatment to a more invasive alternative throughout the trajectory, making fertility care an example of complex care. Current guidelines suggest starting with the least invasive treatment option available for a patient's characteristics and indications, which is why it is common for patients to try ovulation induction (OI) or intra-uterine insemination (IUI) before moving on to in-vitro fertilization (IVF) or IVF with intracytoplasmic sperm injection (IVF-ICSI). It is not unusual for a patient to try IUI for six monthly cycles before switching to IVF. Indications favoring one treatment over another can change as the patient progresses through treatment cycles because each treatment cycle provides additional information to gynecologists and physicians. This is why per-cycle care costs are considered one of the four key factors in evaluating value in ARTs (Fauser, 2019).

Current treatment protocols for fertility care in the Netherlands are defined by the WHO, the Dutch Association for Obstetrics & Gynecology (In Dutch: Nederlandse Vereniging voor Obstetrie en Gynaecologie [NVOG]), and the European Society of Human Reproduction and Embryology (ESHRE). As such, the baseline costs we will calculate will be relevant to clinics adhering to similar guidelines. We summarise treatment options and their abbreviations used in this protocol in **Figure 4.1.**

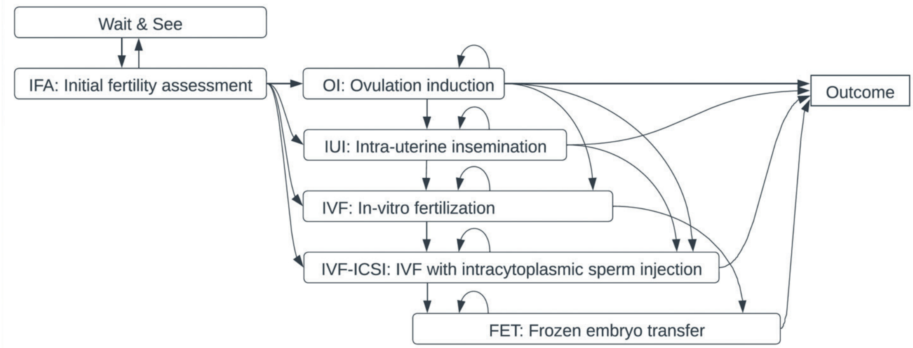

Figure 4.1 Non-surgical treatment options and treatment transfer possibilities for patients diagnosed with subfertility

4.2.2 RQ1: What are the costs of delivering subfertility treatments, and where are the opportunities for improved value?

In 2020, the WHO called for safe, effective and affordable fertility treatment worldwide (WHO, 2021). In the past, live birth rate (LBR) has been the key outcome reported in the literature and by clinics. Recent studies urge looking beyond only the LBR when assessing the outcomes of fertility treatments. Instead, four broad factors should be considered (Nagarund & Fauser, 2020; Geeta Nargund & Datta, 2022): live birth rate; total costs per treatment cycle; incidences of complications in mother or baby as indicators of value; and patient-reported outcome and experience measures.

Per-cycle cost measurement

In seeking to answer this research question, we will conduct a TDABC analysis in line with Kaplan and Anderson (2007) as the viability of this approach has been demonstrated in other medical specialties that include chronic conditions (Keel et al., 2020). In this approach, the costs of care are calculated using the minutes worked by care professionals as a key factor in distributing the organizational care costs incurred by the care provider across a care path. Organizational costs include salaries paid to staff, rent, infrastructure, disposable materials consumed, medications used or prescribed, and equipment used. The analysis also identifies 'cost predictors', which are variables associated with longer treatment durations and/or higher costs. Identifying cost predictors, or phases during the care path that are particularly costly, helps identify opportunities for cost reduction or quality improvement through care path redesign. Care path redesign involves shifting activities or entire processes to a more effective order, technology, or ways of working (Leusder et al., 2022).

Relevance

Clinics can benefit from cost and cost predictor information because it would enable them to pursue value-based care by informing quality and process improvement initiatives and by aiding managerial decision-making (Kaplan & Anderson, 2007; Keel et al., 2020). From a theoretical perspective, cost awareness is likely to impact the decisions that medical leaders make because such information moderates the relationship between intent and behavior (Hagger et al., 2022). Cost information provided by methods such as TDABC can be expected to aid medical professionals and leaders in their decision-making (Ahumada-Canale et al., 2023; Kaplan & Anderson, 2007). For example, revealing that a technological investment could benefit a clinic financially in the long term by reducing per-cycle care costs may increase the likelihood of medical leaders taking value-based decisions.

In addition, reliable per-cycle cost information can be used to improve reimbursement policies for infertility treatments. This is important for three reasons. First, disproportionate reimbursements create inappropriate financial incentives. For example, IUI is currently considered a 'high earning' fertility treatment in Europe because it typically requires only a few physician hours or resources relative to the reimbursement amount. In other words, IUI treatments tend to have a positive impact on a clinic's bottom line. Conversely, IVF with ICSI is considered a 'bleeder' meaning that ICSI reimbursements are very low relative to the hours and resources involved. In some cases, clinics incur losses on ICSI treatments which are compensated for by the positive margins on IUI or OI treatments. As a consequence, under the current fee-for-service payment model used in the Netherlands, clinics or hospitals benefit from offering additional IUI or OI treatments, and even depend on these for financial stability. However, delivering additional cycles of OI or IUI treatment without achieving a pregnancy would be rated poorly in the context of VBHC. To incentivize value-based decision-making in fertility care, reimbursement amounts need to be adjusted such that the prices paid by insurers match the relative resources and hours involved. Our approach, by providing this information and making the burden on the clinics more transparent, will we hope stimulate payment renegotiations. This is particularly relevant for the future because the population's health is shifting, and the demand for IVF and IVF-ICSI treatment may increase relative to OI and IUI in Europe (Ferraretti et al., 2017) and globally (Boivin et al., 2007).

4.2.3 RQ2: What costs are associated with the most common patient journeys in Dutch fertility treatments?

Building on Research Question 1, we aim to devise an approach that can calculate the total cost of care across entire patient journeys taking into account the reality that patients can switch between treatment options. The cost analysis proposed under RQ1 will result in total costs of care per treatment cycle of each treatment type. RQ2 builds on this by setting out to determine the value of the care by considering outcomes in relation to costs. A short time-to-pregnancy is considered the key outcome as emphasized by patients (Shandley et al., 2020), alongside process and experience measures (Cornelisse et al., 2022; Shandley et al., 2020). To determine 'value', we will consider total costs across the patient journey in relation to the time-to-pregnancy.

Patient journeys and associated costs

The costs per patient journey will be estimated using the time equations developed through TDABC with data extracted from the electronic health record (EHR). How we intend to combine the different sources of data is described under the heading 'study design'. Through process mining we expect to refine a model that is similar to **Figure 4.1** but disaggregated into treatment phases. Process mining will reveal how often patients repeat certain treatments, how often patients switch between treatments, and the individual and average durations of each process. This will reveal the most common patient journeys, the costs associated with each path towards its outcome, and the time-to-pregnancy per path.

4.2.4 Setting

This research project is being carried out in conjunction with a Dutch fertility clinic. The Netherlands has mandatory basic health insurance that covers GP services, mental healthcare and specialist care. Basic health insurance covers an unlimited number of cycles of OI or IUI plus three cycles of IVF, with an unlimited number of related frozen embryo transfers (FET). To illustrate, IVF-ICSI is set at €2675 (2022 prices, one round) (NZa, 2022).

4.2.5 Study design and methods

We have determined a sequential study design with four phases as shown in **Figure 4.2.** The first three phases involve TDABC with multiple data collection methods. In phase 4, we will apply process mining to address the second research question. This study has been approved by the ESHPM Research Ethics Review Committee (ETH122-0355) and the Reinier de Graaf Hospital (2022-032). To limit the research burden associated with the manual collection of activity durations using a stopwatch in phase 2, we focus on patients receiving non-surgical treatment options, as also shown in **Figure 4.1**.

	Phase 1	Phase 2	Phase 3	Phase 4
Data collection and/or analysis	Document analysis (protocols)	Document analysis (financial), observations with time measures, build model	Cost calculation and internal communication of results, informal interviews	Process mining of EHR data, and modelling costs using cohort
Method	TDABC	TDABC	TDABC	Process mining
Deliverables	Medical metro line and process maps for OI, IUI, IVF, IVF-ICSI, FET and IFA	Time equations, and determination of EHR data requirements	Per-cycle costs for OI, IUI, IVF, FET, and IFA	Patient journey outcomes and costs from initial consultation to pregnancy

Figure 4.2 Sequential phases of data collection and analysis for TDABC-PM.

Note: OI: Ovulation induction, IUI: Intra-uterine insemination, IVF: In-vitro fertilization, IVF-ICSI: IVF with intracytoplasmic sperm injection, FET: Frozen embryo transfer, IFA: Initial fertility assessment, TDABC: Time-driven activity-based costing

4.2.6 TDABC with observations and medical metro lines (phases 1-3)

The TDABC begins in phase 1 with a seven-step process (Keel et al., 2020). This starts by identifying the care paths followed by patients with subfertility at the focal clinic (step 1). Care paths are defined with clear start and end points, and are further broken down into individual activities and processes (step 2). An activity is a single step in delivering care, and processes consist of several activities. These care paths will be visualized using the medical metro line visualization tool created by *Panton designers for healthcare* for use with MS Visio. This template was created by Panton with service design experts to aid care path visualization and shared decision-making. An important element of this mapping process is that it is iterative: as new information is shared by experts (e.g. gynecologists, physicians, lab analysts), the activity maps will be amended until they are complete. The activity and process maps will cover all treatments offered by the clinic for patients with subfertility diagnoses: OI, IUI, IVF, IVF-ICSI, FET and the IFA prior to treatment. To test the feasibility and validate this approach, we initially created one metro line using this method (**Figure 4.3**).

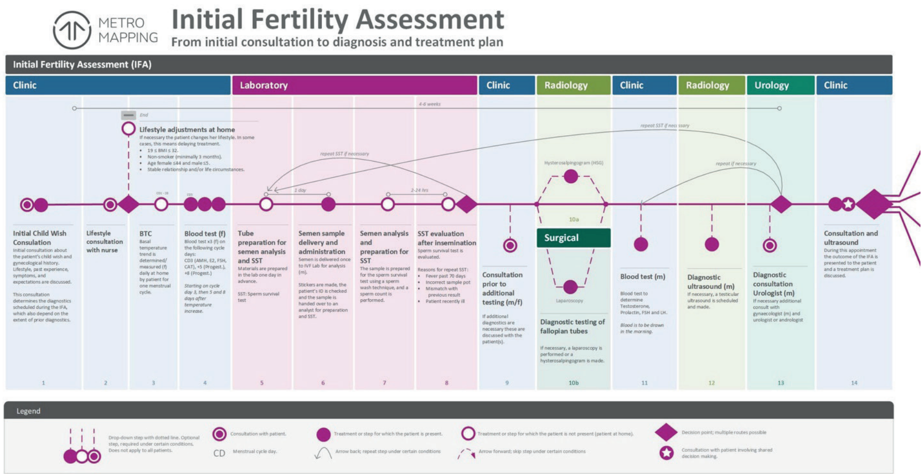

Figure 4.3 Medical metro line of the initial fertility assessment prior to treatment.

Note: Patients move from left to right along the solid line. Solid circles: activities for which the patient is present, white and outlined circles: activities for which the patient is not present, circles with smaller circle in center: consultations with patient, diamonds: decision points, dotted line: activities that may be necessary but do not apply to all patients, SST: Sperm survival test, FSH: Follicle stimulating hormone, AMH: Anti mullerian hormone, BMI: body mass index.

In phase 2 we will determine the time required per activity and process identified in phase 1. In applying TDABC, one must estimate the time (in minutes) for each activity. This involves using protocols, expert input and observations in a similar approach to Keel et al. (2020). For each metro line created in phase 1, a time equation is constructed that calculates the total process time and incorporates relevant variables that increase or decrease the time required (step 4). For activities for which treatment protocols and scheduling systems do not specify a set time, or for which care professionals cannot estimate an accurate time because the time can vary, we intend to time activities with repeated observations to determine a realistic estimate. Activities that exhibit considerable variation in duration will be observed more frequently to identify variables associated with this variation (to establish cost predictors to be incorporated in the time equations). During the observations, the researcher (ML) will ask staff involved open-ended questions about the sources of variations, possible cost predictors and any suggestions for improvements. Personnel involved will be asked informed consent and all observational data will be pseudonymized.

Costs will be obtained from the clinic in the form of the clinic's total annual cost data for 2021 (step 5). Per-minute cost rates (CCRs) are calculated by pooling cost data per process, and by dividing the pooled costs by the practical capacity of the medical professional providing the care (step 6). One can anticipate more than one CCR because care paths have very different resource requirements, thus requiring separate combinations of resource costs (Kaplan & Anderson, 2007). For example, OI does not involve the lab in any way, whereas a significant portion of the care in the IVF-ICSI care path is completed inside the lab.

In phase 3 we will calculate the costs per cycle of care. We expect to identify between 15 and 50 activities and 1 to 10 processes for each of the six care paths identified. To complete the cost calculations for such a large number of activities and processes, we have programmed a formulaic model in MS Excel using the structure outlined in **Table 4.1.**

Table 4.1 Structure of the TDABC-PM calculation model.

Process (P)	**Activity (A)**	**CCR1 (C1)**	**CCR2 (C2)**	**CCR*n* (C*n*)**	**Direct fixed costs (d)**	**Costs**
1	1	minutes	minutes	minutes	€d	$\text{Costs}_{A1} = \text{minutes}_{A1,C1}$ x C1+…+$\text{minutes}_{An,Cn}$ x $Cn + d$
	2	minutes	minutes	minutes	€d	$\text{Costs}_{A2} = \text{minutes}_{A2,C1}$ x C1+…+$\text{minutes}_{An,Cn}$ x $Cn + d$
	n	minutes	minutes	minutes	€d	$\text{Costs}_{An} = \text{minutes}_{An,C1}$ x C1+…+$\text{minutes}_{An,Cn}$ x $Cn + d$
						Total costs per process: $\mathit{Costs}_{P1} = \mathit{Costs}_{A1} + \ldots + \mathit{Costs}_{An}$
n	*n*			$\text{minutes}_{An,Pn,Cn}$	$€d_{An,Pn}$	*Total costs per care path:* $\mathit{Costs}_{P1} + \ldots + \mathit{Costs}_{Pn}$

Note: Each row is one activity, and a process is made up of n activities. Each CCR identified fills one column. The number of minutes an activity takes is placed in the appropriate cell. The formula in the 'costs' column multiplies the minutes by the given CCR to give the costs per activity. CCR: Cost capacity rate

In the cost column, the total costs per process are calculated by multiplying the minutes needed for an activity within the process by the relevant CCR and totaling these across activities. Direct fixed costs such as disposable items are allocated directly to a process if they do not vary with time (*+d*). For example, a single catheter is used with each IUI insemination: even if this procedure takes longer than usual, still only a single catheter is used. Total costs of care for a care path can then be calculated by totalling the costs per process as shown in the rightmost column (step 7).

4.2.7 Process mining (phase 4)

In phase 4, process mining will be used to analyse a retrospective cohort of patients' electronic health records (EHRs) to reveal real patient pathways. These will be identified by extracting the relevant process start and end points and cost predictor values from the EHRs alongside patient characteristics relevant to fertility care (BMI category, age category, primary vs. secondary infertility) (Maheshwari et al., 2022). For example, we define the IFA to start on the date of the first onsite consultation with a gynaecologist and the end point as the date of the final IFA consultation during which the assessment results are communicated and a treatment plan discussed with the patient. The process duration is the time elapsed between these two dates. By using process mining in combination with the time equations established earlier, we can see how patients travel through the process map created in phase 1 step 2. The process mining will be conducted in line with previous research in Fluxicon Disco® and R using the fuzzy miner algorithm (Saint et al., 2021). To ensure the data are unidentifiable, they will be extracted by a data scientist and supplied to us without identifiers. Additionally, data will be categorical where possible. A detailed template of the data required will be supplied after completing phase 3 (see section 'Data' below). To validate the data gathered, and the results gained, feedback from medical professionals will be sought during each phase.

4.2.8 Data

Figure 4.4 summarizes the study design in terms of the flow of raw data through to the research results.

The treatment protocols form the basis of the medical metro lines (A). The medical metro lines will be established iteratively, with rounds of feedback from experts (B) and adjustments. The metro lines should reflect the activities and processes involved in delivering care (C). Both the metro lines and the lists of activities and processes will be validated through observations (E&F) although an initial list of anticipated activities has been prepared to enable observations to be planned (G) since these involve the timing of activities defined for the TDABC (H).

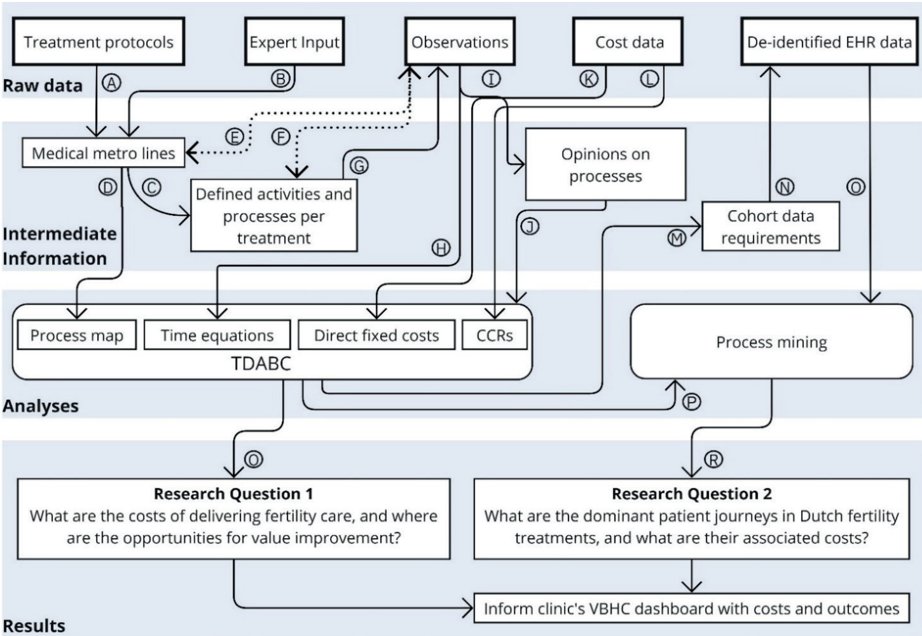

Figure 4.4 Flow of data during all four phases of TDABC-PM at the studied clinic.

Note: Labelled arrows are referred to in the text. Bold outlined rectangle: data source, rounded rectangles: analyses performed on data, solid arrows: data flow, dotted arrows: data validation, CCR; Cost capacity rate, EHR: Electronic Health Record, OI: Ovulation induction, IUI: Intra-uterine insemination, IVF: In-vitro fertilisation, IVF-ICSI: IVF with intracytoplasmic sperm injection, FET: Frozen embryo transfer, IFA: Initial fertility assessment, TDABC: Time-driven activity-based costing, VBHC: Value-based healthcare.

The observations will also be used to elicit staff members' opinions on processes (I&J). To complete the TDABC, cost data will be combined with the observational data and the medical metro lines. The cost data are used to calculate CCRs (L) and non-variable direct materials costs (K). Through the TDABC analysis, cost predictors will be established for each care path once the time equations are specified. The time equations identify the total minutes required for a process and will include variables that impact the time required in the form of multipliers or if-then statements (Kaplan & Anderson, 2007). This will inform the data requirements for the process mining analysis (M&N). The EHR data retrieved will consist of time stamps of key activities that define the start and end points of processes in each of the care paths identified in the medical metro lines (C), as well as the variables identified in the TDABC analysis (P). The process mining will enable the time equations to be completed through the EHR inputs on patient journeys (O).

Research Question 1 will be answered by the TDABC analysis (Q), and Research Question 2 through the process mining analysis (R) which is dependent on the TDABC analysis. An additional outcome is that the cost and outcome data will be used at the focal clinic in a VBHC dashboard. The study project, including design and coordination, is scheduled to run from 01/01/2021 to 01/06/2025. Data collection is ongoing and planned to be completed by 01/01/2024 including potential data cleaning in preparation for the process mining analysis.

4.2.9 Patient and public involvement

There is no *direct* patient or public involvement in this study. The research questions and some of the outcome measures have been informed by patient preferences reported in recent publications. The clinic's staff will be involved in the study through the observations and providing expert input. The results of the research will be disseminated to the clinic's staff throughout the research phases, and to the public through conference presentations and publications. The data gathered and the medical metro lines created will inform the clinic's VBHC dashboard. Once published, the results will be used in the education programs of bachelor and master students.

4.3 Discussion

Our aim is to contribute the VBHC literature by demonstrating how TDABC and process mining can be combined to enable realistic cost measurement on a large scale, an aspect which practitioners currently consider both urgent and a major challenge (Cossio-Gil et al., 2022). Further, by trialing this method in a complex care context we will contribute to the currently sparse literature on cost measurement and process improvements in complex care with long time horizons and non-linear care paths (Keel et al., 2020).

We further aim to contribute to the patient-centered fertility care literature by introducing TDABC to the field (Cornelisse et al., 2022; Shandley et al., 2020; Zaat et al., 2020), and by reporting real patient journey costs and outcomes (in a baseline value assessment) that can serve as a benchmark for other clinics. Other clinics will be able to input their annual costs into the model while assuming the same time-based equations. The time equations can also be adjusted as technologies change or processes modified, for example by introducing AI embryo selection or vitrification (Berntsen et al., 2022; Rienzi & Fauser, 2021). Through this research, we hope to enable internal, longitudinal benchmarking as well as across-clinic benchmarking. In addition, we believe that the outcomes of this research could aid clinics in predicting future costs as populations age and change, and in their organizational decision-making (Keel et al., 2020). This approach could contribute to improve quality and efficacy to keep healthcare affordable in the future decades.

Patients have repeatedly indicated that expectation management and information sharing are important aspects of patient satisfaction (Abdulrahim et al., 2021; Cornelisse et al., 2022; Dancet et al., 2010; Shandley et al., 2020). By incorporating patient journey information in a value-based dashboard, we aim to provide gynecologists with the tools to better discuss likelihoods and time-to-pregnancy with patients, and consider costs as one of multiple, pluralistic performance measures. We see the medical metro lines created in this project as a tool with which clinics can visually communicate and redesign care paths.

This research has several methodological limitations. First, the single-center focus of this study will potentially limit the generalizability of the results because all the data are gathered from one clinic. Nevertheless, we consider this single-center design realistic since we are covering several care paths and anticipate a high volume of manual data collection (observations). To partially mitigate this shortcoming, we have chosen a focal clinic that adheres to European guidelines, meaning that the standard operating procedures and ways of working are comparable to other European clinics governed by the NVOG (NVOG, 2017a, 2017b) and ESHRE. These treatment protocols are publicly available for comparison purposes (ESHRE, 2023a). The treatment modalities we cover in this research project are described in detail in prior consensus statements issued by ESHRE (ESHRE Guideline Group on Good Practice in IVF Labs et al., 2016; ESHRE Working group on Time-lapse technology et al., 2020; ESHRE Working Group on Ultrasound in ART et al., 2019; Grimbizis et al., 2016; ESHRE Guideline Group On Ovarian Stimulation, et al., 2020). Furthermore, our findings are likely to be applicable in clinics that work according to WHO standards. To further improve the generalizability and benchmarking potential, we aim to measure the duration of activities that involve alternative technologies or ways of working. For example, multiple methods for freezing and thawing embryos will be observed and measured (vitrification and cryopreservation).

Second, the process mining will have limitations related to incomplete cases (Litchfield et al., 2018). For patients that have started but not yet finished treatment, an outcome state cannot be defined. We will address this limitation by restricting the sample to cases with known outcome states in robustness checks, which limits the size of the cohort. An associated issue is that, by using retrospective data (especially if only completed cases), the study will be impacted by technological advancements in fertility care, with earlier cohorts treated under different technological conditions than those observed during our observations.

Third, TDABC studies can suffer from subjectivity because the cost calculations are heavily dependent on the time measures used, and these are typically estimated based on expert interviews. To address this limitation and improve the generalizability of our results given different staff experience levels, daily circumstances and patient characteristics, we will use time measurements during repeated observations to reach an average time per activity and process. This will also enable us to identify cost predictors associated with activities with variable durations as described previously.

Chapter 5

Improving patient-level costs and value

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This article has benefited from valuable feedback provided by participants at the Time-Driven Activity-Based Costing (TDABC) conference in Lisbon (2022), the ISPOR conference in Boston (2023), and the INFORMS Healthcare conference in Toronto (2023). Additional suggestions were gratefully received during my invited research seminar at the University of Melbourne, hosted by the Cancer Health Services Research Unit within the School of Global Population Health, as well as during two internal research seminars at Erasmus University Rotterdam, Department of Health Services Management & Organization.

Abstract

Background Health economic evaluations require cost data as a key input, and reimbursement policies and systems should incentivize valuable care. Subfertility is a growing global phenomenon, and Dutch per-treatment DRGs alone do not support value-based decision-making because they don't reflect patient-level variation or the impact of technologies on costs across entire patient pathways.

Methods We present a real-world micro-costing analysis of subfertility patient pathways (n=4190) using time-driven activity-based costing (TDABC) and process mining in the Dutch healthcare system, and built a scalable and granular costing model.

Results We find that pathways (13 203 treatments, 4 190 patient pathways, 10 years) from referral to pregnancy and birth vary greatly in costs (mean €6329, maximum €36 976) and duration (mean 25,5 months, maximum 8,59 years), with structural variation within treatments (and DRGs) of up to 65%. Patient-level variation is highest in laboratory phases, and causally related to patients' cycle volume, type, and treatment methods. Large IVF or IVF-ICSI cycles are most common, and most valuable to patients and the healthcare system, but exceed their DRGs significantly (33%). We provide recommendations that reduce costs across patient pathways by €1,3m in the Netherlands, to support value-based personalized care strategies. These findings are relevant to clinics following European protocols.

Conclusions Fertility treatments like IVF feature significant cost variation due to the personalization of treatments, and rapidly evolving laboratory technologies. Incorporating cost granularity at the patient and treatment level (cycle volume, type, method) is critical for decision-making, economic analyses, and policy as subfertility rates and treatment demand are both rising.

5.1 Introduction

Healthcare providers are highly complex organizations that deliver increasingly tailor-made procedures, treatments, and services. In the case of complex care like fertility care, such treatments draw on a variety of costly medical specialties, and use expensive equipment and materials to different degrees per patient (Keller & Chambers, 2022). Accordingly, "managing and financing healthcare services requires a detailed understanding of how resources are used" (Špacírová et al., 2022), for which European countries use Diagnosis-Related Group (DRG) prices as unit cost estimates (Busse et al., 2011; Pöhlmann et al., 2020), input for reimbursement negotiations (e.g. The Netherlands, Germany, France), or as descriptive instruments to inform policy or budgets (e.g. Nordics).

However, in complex care settings such as fertility care, DRGs may offer insufficient granularity to support comparisons or decision-making within treatment categories (Bahadur et al., 2020; Chambers et al., 2013; Connolly, Hoorens, et al., 2010; Katz et al., 2011). This does not present an issue to reimbursements, if the DRG covers the average costs of care, but DRGs alone may be insufficient to pursue value-based care strategies and/or discover process (in)efficiencies or cost differences between different patient groups or technologies within treatments (Lindgren & Althin, 2021; Llewellyn & Northcott, 2005; Špacírová et al., 2022). For example, the current Dutch DRG for one in-vitro fertilization (IVF) with intra-cytoplasmic sperm injection (ICSI) treatment is €3064 (14B168), even though European clinics offer varieties within this treatment type, which require different resources, and which clinics are unaware of due to lacking cost estimation infrastructure (Cossio-Gil et al., 2022). In this study, we find this treatment to vary significantly in clinician time spent and costs (by 65%; €2479 to €4089), and these differences structurally relate to patient-level characteristics, such as the number of embryos cultured, and the number of consultations required. Additionally, the construction of DRGs has featured significant variation in how indirect costs are allocated to treatment categories (Lindgren & Althin, 2021; Preston, 1992; Špacírová et al., 2022; Tanet al., 2011), which is challenging in complex care settings like fertility care which utilize expensive specialized laboratories worth upwards of €1m and thus feature significant indirect costs - excluding or underrepresenting indirect costs distorts economic analyses and decision-making (Ederhof & Ginsburg, 2017, 2019; Špacírová et al., 2022). Due to lacking cost estimation in hospitals (Cossio-Gil et al., 2022), and due to the aggregate nature of Dutch DRGs in fertility care specifically (Leusder et al., 2023, chapter 4), there is a general lack of understanding of how resource use varies across treatment types (Bouwmans et al., 2008). This currently poses a barrier to medical managers and policymakers that wish to assess medical technological advancements that improve the costs and outcomes *within* treatment types (Leusder et al., 2023; Tanet al., 2011), or *across* entire patient trajectories (Leusder et al., 2022), as current DRGs cannot provide such opportunity cost information (Chambers et al., 2013; Connolly, Hoorens, et al., 2010; Keller & Chambers, 2022; Špacírová et al., 2022). Further, high profit margins and the use of lucrative 'add-ons' to attract vulnerable patients distort prices in countries like the US .

Subfertility is an escalating global epidemic; its global economic burden is predicted to reach 2 million treatment cycles per annum (Chambers et al., 2021) at US$27 bn by 2026 (Keller & Chambers, 2022; Sumant & Joshi, 2019). Subfertility impacts one in six individuals (WHO, 2023), so approximately 48 million couples and 186 million individuals worldwide (WHO, 2021), or 11% and 15% of US and EU residents respectively (ASRM, 2017; ESHRE, 2021; Keller & Chambers, 2022). Consequently, identifying cost variation and savings across the patient pathway, and within broad treatment categories like IVF, is considered imperative to make treatments accessible to all (Gerris & Fauser, 2020; Rienzi & Fauser, 2021; WHO, 2023), and to enable systematic cost reductions through process improvements (Gerris & Fauser, 2020). This paper reports the implementation and findings of a comprehensive micro-costing project in the Dutch healthcare system. The aim of this study is to develop fine-grained cost insights in fertility care, to measure and improve costs and duration (time-to-pregnancy), by informing comparisons between technologies and treatment protocols *within* treatment types/DRGs, and *across* entire patient pathways from initial consultation to pregnancy.

The costing infrastructure developed in this project, informed by our protocol (Leusder et al., 2023), is included as supplementary material for modification or use in other clinics or settings. We discuss what our findings may mean for the use of DRGs in complex care settings, and how fertility treatments can be made more valuable to patients, clinics, and the healthcare system. For instance, our analysis indicates that employing vitrification techniques results in savings of up to €1998 per pregnancy trajectory (across repeated treatments) and €1 311 396 in Dutch clinics, which may also be relevant to other European clinics following the same protocols. These savings stem from the high frequency of repeated treatments per patient, and the reduction in workload associated with clinical decisions made in one treatment during later treatments.

5.2 Setting, method, and data

5.2.1 Setting

Patients diagnosed with subfertility need medical assistance to conceive and have children; various treatment options are available, and most patients undergo multiple cycles of month-long treatments on their journey from desiring a child to achieving pregnancy (Bahadur et al., 2020). In Europe, all clinics or hospitals offering fertility treatments follow treatment protocols published by the European Society of Human Reproduction and Embryology (ESHRE). The Netherlands features mandatory basic health insurance that covers unlimited cycles of two kinds of subfertility treatment, namely ovulation induction (OI) and intra-uterine insemination (IUI), three cycles of in-vitro fertilization (IVF) or IVF-ICSI per live born child, and an unlimited number of frozen embryo transfers (FETs). If a couple wishes to pay for IVF or IVF-ICSI out of pocket (e.g., a fourth cycle, not covered by health insurance), this costs the DRG amount, namely €2955 (14B168) or €3064 (14B168) respectively, as per 2023. IUI treatments are reimbursed €737 (14B191) per cycle, and OI treatments are reimbursed €845 (14B192) regardless of type. FET, which are only possible after IVF treatments if embryos are cultured and frozen for future use, are reimbursed €817 (14D226) (NZa, 2022). Within IVF treatments, FET cycles are most common, as shown in **Table 1** depicting the most recently available statistics of Dutch and European treatment cycle types (ESHRE, 2023b; NVOG, 2022). In the Dutch setting, expenditures have risen significantly in recent years, and governmental agencies are attempting to reduce annual expenditure growth (Gajadien et al., 2023).

5

Table 5.1 Dutch (NVOG, 2022) and European (ESHRE, 2023b) statistics of IVF treatment types and their frequency from the past five available years.

	IVF cycles		IVF-ICSI cycles		FET cycles		Total IVF, IVF-ICSI and FETcycles
Netherlands, 2020	5590	23%	5468	23%	13141	54%	24 199
Netherlands, 2019	6240	23%	7101	26%	14257	52%	27 598
Netherlands, 2018	6524	24%	7199	26%	13496	50%	27 219
Netherlands, 2017	6417	23%	7574	28%	13469	49%	27 460
Netherlands, 2016	6781	25%	7803	29%	12545	46%	27 129
Netherlands, Average 2016-2020:	6310	24%	7029	26%	13382	50%	26 721
Europe, 2019:	160 782	17%	427 980	46%	335 744	36%	924 506

5.2.2 Study design

We apply a unique methodology described in the study protocol (Leusder et al., 2023), which combines time-driven activity-based costing (TDABC) with process mining using data from one representative clinic which follows European protocols, to generate unique cost estimates per patient based on actual resource consumption, from initial consultation to pregnancy. TDABC uses the time spent by clinicians to allocate direct and indirect organizational costs such as equipment used, or salaries paid, first to treatment types and then to patient journeys by generating cost estimates that reflect individual patient-level variability through cost equations (Kaplan & Anderson, 2007; Leusder et al., 2023). The amount of time required can depend on cost predictors (e.g. number of ultrasounds), which results in per-patient variation in costs. In this way, TDABC uncovers the sources of cost variation, and allocates all yearly costs of running an organization such as a fertility clinic to treatment pathways by treating them as cost dynamic objects (Berthelot et al., 2022; Kaplan & Anderson, 2007; Keel et al., 2020). We first determine activity and process durations per treatment type, before simulating the estimation using longitudinal data through process mining. Per-patient costs are calculated by multiplying resource-specific capacity cost rates (CCRs) with durations, per cycle of care delivered, thereby incorporating patient-level variation in both direct and indirect cost allocation. The construction of these systems is subject to user design, i.e., the process of conducting TDABC cannot be standardized (Clark, 1923; Malmmose & Lydersen, 2021; Tan et al., 2011; Tan et al., 2012, 2014), as the system can be made as fine-grained or broad as desired. This choice is reflected in the number of cost equations constructed, the number of patient parameters included, and the granularity of the CCRs. For example, some studies generate only a single CCR for an entire department (Demeere et al., 2009), whereas others acknowledge different utilization rates within departments (Keel et al., 2020), and some include indirect costs whereas others exclude these (Leusder et al., 2022). For these reasons, such studies must be reported transparently, by reporting the CCRs generated, and the activities included and costed in each cost equation (Clark, 1923; Špacírová et al., 2020).

To generate fine-grained cost estimates that are both accurate and generalizable, we used a detailed approach based on measured variation through participant observations during which the researcher shadowed clinicians and timed their work durations (Špacírová et al., 2020). In doing so, we constructed cost equations that distinguish variation within treatment (and thus DRG) categories, by differentiating between different ways of working, and patient-level variation, within treatment categories.

5.2.3 Method and data

To estimate the costs of treatment cycles we measured the time required to deliver care, per staff function, per activity, for each treatment option. To ensure accuracy (Špacírová et al., 2020), we documented care activities in chronological order using the Panton Metro Line tool (Panton, 2022), to establish transparency regarding which activities are costed. Each activity (e.g., a consultation, a diagnostic test, a procedure) is shown on the metro line, which forms a long chain of activities, and corresponds to an activity in the costing tool built in this project. These activity maps are based on treatment protocols, EHR data of all patients ever treated in the clinic since 2014 (n=6 822), and healthcare professionals (HCP) input provided iteratively over one year. Due to the high data requirements of this method, and the high research burden of conducting observations and developing the medical metro line, we conducted the analysis at one Dutch clinic following ESHRE standards. To ensure generalizability, we chose a Dutch clinic that offers each treatment option, follows strict European protocols defined by ESHRE and NVOG (ESHRE, 2023a; Leusder et al., 2023), and that operates as a financially and physically separate entity from a hospital. This allowed us to incorporate all variable overheads (Špacírová et al., 2020). Further, the results were presented to five other Dutch fertility clinics for validation. To enable generalizability over time as embryology develops, we include the entire medical metro line and the editable costing tool in the supplementary appendix.

Next, we used participant observations over the space of one year to measure activity durations and identify sources of variation to determine cost predictors (Keel et al., 2020). All participants observed and timed were asked for informed consent, following the study protocol (Leusder et al., 2023). To limit research burden, we used direct observations only in cases where activity durations could not be reliably estimated from scheduling data. For example, consultations always required 30 min of gynecologists' or clinicians' time and were therefore costed at a median of 30 minutes. Consultations occurring outside the clinic in another specialty, e.g., urology, were also observed, and activities exhibiting a large degree of variation in duration were observed more frequently (details are provided in the supplementary appendix).

Subsequently, cost data such as variable overheads (Špacírová et al., 2020), equipment purchase prices and disposables were inventoried and allocated to care paths using CCRs following TDABC guidelines as follows (Kaplan & Anderson, 2007):

$$Capacity\ cost\ rate = \frac{Cost\ of\ capacity\ supplied}{Practical\ capacity\ of\ resources\ supplied}$$

$$Cost\ per\ activity = capacity\ cost\ rate \times time\ required\ to\ perform\ activity$$

To account for the sub-departments mentioned previously, we expand this formula to recognize different resource needs within a single activity as follows:

$$\begin{aligned} &\mathit{Cost\ per\ activity} \\ &\quad = CCR_1 \times \mathit{time\ required\ by\ resource}_1\ \mathit{to\ perform\ activity} \times k \\ &\quad + CCR_2 \times \mathit{time\ required\ by\ resource}_2\ \mathit{to\ perform\ activity} \times k \\ &\quad + CCR_n \times \mathit{time\ required\ by\ resource}_n\ \mathit{to\ perform\ activity} \times k \end{aligned}$$

Where CCR_n is the capacity cost rate of resource pool *n*, and where time required can be unique to a resource, and can depend on a cost predictor *k*. A care path consists of multiple such activities or processes. Cost predictors can equal 1 in case no predictor is present and variation is negligible. The resulting CCRs, and their components, are provided in **appendix I**. The resulting model was programmed into an interactive tool in Microsoft ® Office Excel ® due to its universal availability in clinical settings, and with data safety in mind, as the tool does not require an internet connection or data transfer. The model is provided in **appendix J**.

Finally, we applied process mining using Fluxicon Disco to discover patient trajectories in 10 years of clinical data from this clinic (De Roock & Martin, 2022; Rismanchian et al., 2023), based on the treatment categories identified in the TDABC analysis (i.e., treatment types within DRGs that features significantly different costs, such as sub-categories of IVF). For example, within IVF-ICSI treatments, a small IVF-ICSI treatment consumes significantly fewer resources than a large combination cycle (IVF-Combi). These categories were thus incorporated in the process mining analysis, rather than relying on aggregate treatment labels alone. The full patient sample (n=6 822 patients) was restricted to cases that started and ended their treatment journey between 1/1/2014 and 1/1/2023 and that completed at least one cycle of care (to exclude patients only seeking a second opinion, or those still undergoing care today), resulting in a consolidated sample of 3 335 female patients covering 13 203 treatment cycles relating to 4 190 pregnancy trajectories, and data on their partners (or donors). This methodological approach is summarized in **Figure 5.1.**

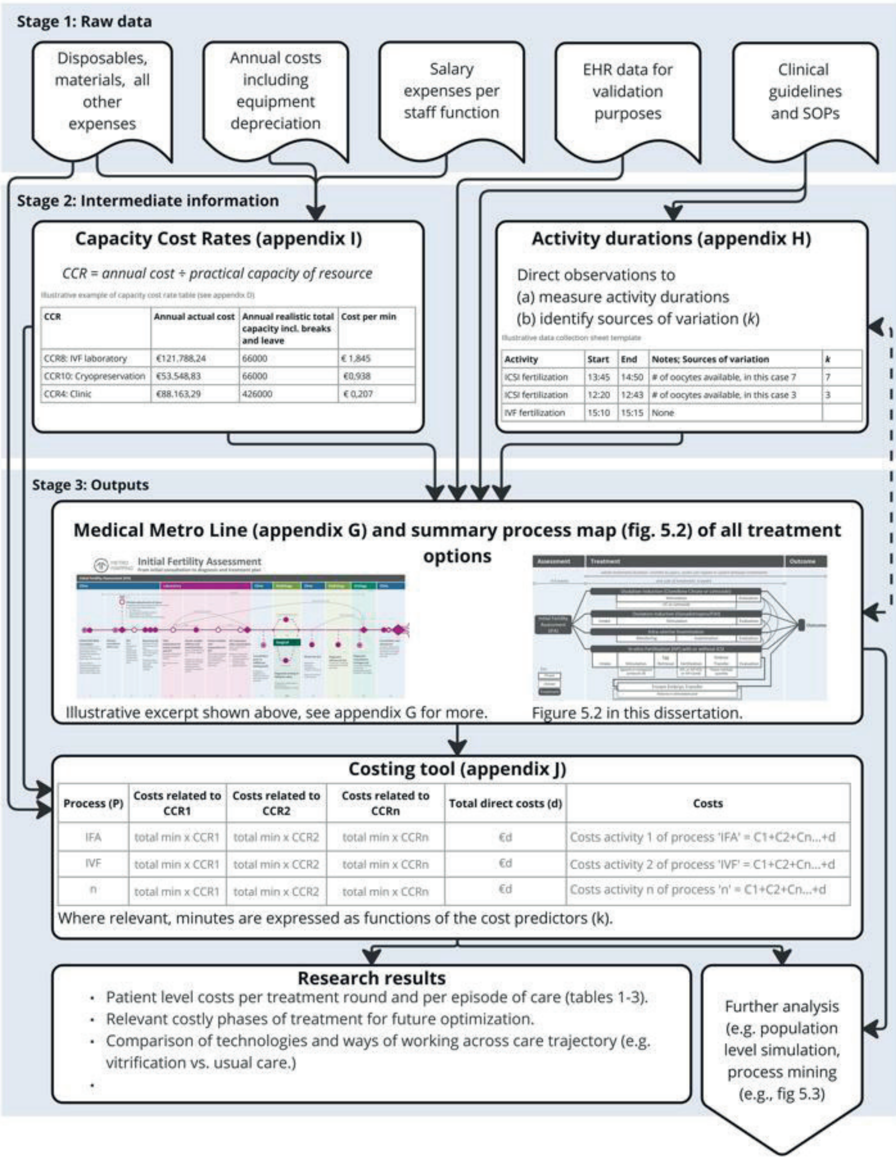


Figure 5.1 Summary of data collection and analysis, with reference to appendices.

Note that the appendix numbering in this figure differs from the figure in the appendix of the published manuscript, to keep the numbering consistent in this dissertation. In the published article, this figure is only included in the appendix.

5.3 Results

The treatment options available are summarized in the process map in **Figure 5.2.** Patients can repeatedly cycle through, and switch between, four alternative treatment options as reflected in the DRGs described in **Section 5.2.1**. These include two kinds of ovulation induction (OI), in-vitro fertilization (IVF), or intra-uterine insemination (IUI). In-vitro fertilization (IVF) involves four distinct phases: stimulation, follicle aspiration, fertilization, and embryo transfer. These generate frozen embryos, which are used in subsequent frozen embryo transfer (FET) cycles during which a frozen embryo is thawed and placed into the uterus. Decisions made during IVF impact the processes used during FET cycles; for example, if embryos are frozen using cryopreservation m methods, they must be thawed using the same medical protocol. One cycle of IVF can involve many FET attempts, each lasting one month, depending on the number of embryos generated and frozen. Patients can repeat treatments or switch to different treatments after each monthly cycle. The distinction between IVF and ICSI comes from the technology used to complete the fertilization phase of IVF. An IVF cycle thus has four options that differ in resource consumption: IVF, IVF-ICSI, IVF-Combi. IVF-Combi can be disaggregated down further into intentional IVF-Combi cycles and rescue-ICSI cycles. In an IVF-Combi cycle half of all oocytes are fertilized with IVF, and half with ICSI. In case of a rescue-ICSI cycle, oocytes are fertilized with the ICSI technology if no oocytes are fertilized through IVF earlier that same day. This means that they require significantly more resources, but are highly valuable, as patients would otherwise have been guaranteed a poor outcome (no chance of pregnancy) and subsequent IVF or ICSI treatments. We provide a summary of the relevant European clinical guidelines in **Appendix F.** The medical metro line, which depicts all individual activities costed per treatment type, is provided in **Appendix G.** This appendix covers all processes shown in **Figure 5.2,** and an example is provided later in **Figure 5.5.**

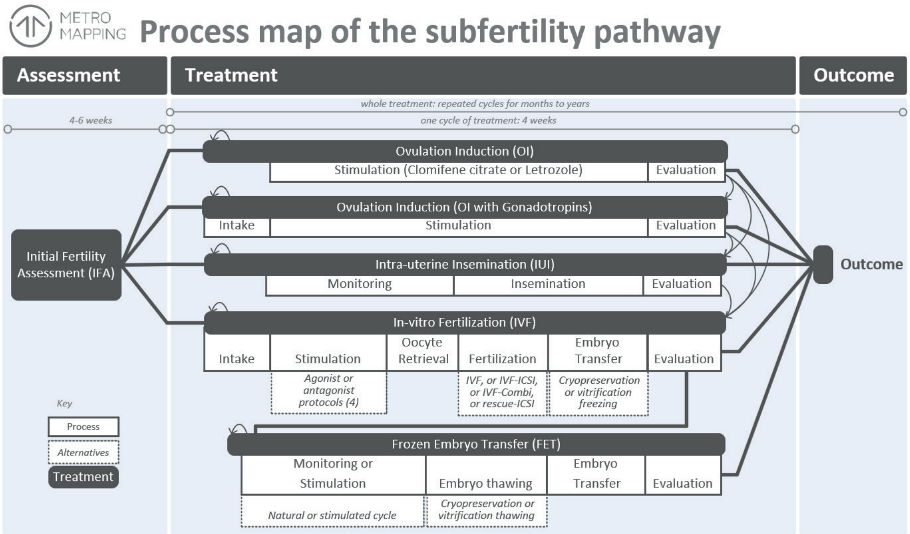


Figure 5.2 Macro and meso-level process map depicting the four possible treatment types.

Note: ICSI, intracytoplasmic sperm injection. Filled long rectangles indicate processes, which are split into sub-processes. A failed cycle can be followed by another cycle (of the same or a different treatment). If embryos are frozen during IVF, thawing can be planned and initiated the following cycle or later (FET). Frozen embryo transfer is recognized as a sub-process of IVF but involves a new cycle during which the patient is prepared for the embryo transfer, like in IVF but using thawed embryos. Note that the activity level flowcharts of each process are provided in **appendix G.**

5.3.1 Observations, cost predictors (k) and capacity cost rates (CCRs)

Observations related to the IVF pathway exhibited the longest durations and greatest variation; whilst an average IVF cycle required 313 minutes of lab staff time, ICSI and IVF-ICSI required 386 and 445 minutes, respectively. We identified six core cost predictors, chosen by clinicians during meetings as the analysis and intervention proceeded. These are clinical decisions or patient-level factors that lead to higher resource utilization per patient in this clinic:

1) the type of semen wash technique required and used,
2) the number of predicted oocytes based on ultrasounds,
3) the realized number of oocytes retrieved after a follicular aspiration,
4) the number of consultations and ultrasounds required during one treatment cycle,
5) the number of embryos fertilized using IVF, IVF-ICSI, rescue-ICSI, or ICSI, and
6) the type of technique used to freeze (during IVF) and thaw (during FET) embryos.

5

In total, 13 CCRs were determined to allocate costs, and these reflect the unique resource requirements of all care delivered (e.g., laboratory staff, laboratory equipment specific to IVF, ICSI, etc.). These 13 CCRs are minimally necessary to respect TDABC's principle of homogeneity (Kaplan & Anderson, 2007, p. 49), which specifies that CCRs must be constructed such that no costs are allocated to objects that do not consume them, and that departmental CCRs are only applicable if each service delivered by the department uses the same mix of resources. However, as each treatment delivered by the fertility clinic uses a different mix of resources (e.g., ICSI treatments use different resources than IVF, and OI treatments use no laboratory resources at all, and IUI treatments use a different sub-department of the laboratory than IVF and ICSI) a single CCR is inadequate, and both the laboratory and clinical areas of the clinic needed to be split into separate cost rates i.e. sub-departments. The durations and cost predictors determined using observations are available in **Appendix H**. The cost equations, which multiply the CCRs with the duration of care processes, are provided in **Appendix J,** in the form of an interactive tool which can either be used verbatim or interpreted as a template (by entering appropriate direct and indirect costs of the organization). Patient-level variation is incorporated through cost predictors; by entering the parameters of the cost predictors identified above, the equations produce cost estimates that reflect them, rather than assuming static cost objects per treatment type like DRGs can do (Llewellyn et al., 2016). In this way, patients that require more materials and HCP's time, due to e.g. a large cycle size, are allocated more costs than those requiring fewer materials and/or time.

5.3.2 Average total costs of care per treatment cycle (within DRGs)

Table 5.2 displays the total costs per treatment type determined using TDABC, and a percentage breakdown of the cost sources per resource (CCR). We find that an average initial fertility assessment (IFA), excluding extensive diagnostics such as an operation, costs €504 to deliver in total. An average natural, unstimulated cycle of IUI costs €518, and a stimulated cycle €845. One cycle of OI using Clomid CC or Letrozole as a stimulation agent costs €221, consisting primarily of consultations. Using FSH stimulation raises that amount to a total of €963 due to the additional monitoring appointments and medications required. One average cycle of IVF costs a total of €2610 to deliver, with IVF lab staff (25%) and lab material and equipment (15%) representing the greatest source of costs after medications. An average ICSI cycle costs €3005, and a combination cycle €3193. Offering both types of fertilization in one combination cycle (IVF-Combi) requires separate preparation for and administration of each half of the oocytes retrieved, resulting in the highest workload in the lab, generating higher costs. Further, this is only offered to patients with more than 10 oocytes in a cycle, resulting in a higher-than-average volume of patient material to manage in the lab for these specific cycles. A FET costs between €922 and €1036 per cycle.

The analysis underscores a tradeoff: higher costs are incurred with increased volumes of patient materials processed in the laboratory during IVF cycles. However, this added workload is exceptionally valuable to patients and the healthcare system as it raises the likelihood of reaching pregnancy, reducing the necessity for additional cycles of care later (Bahadur et al., 2023; Keller & Chambers, 2022), raising the likelihood of timely pregnancies. This is because, following IVF or ICSI, patients can undergo FET treatments which are less invasive and much lower in costs. So, delivering costly high-volume IVF-cycles is valuable overall, both to patients and the healthcare system, but is currently very costly to clinics. **Table 5.3** illustrates the impact of cycle size on costs incurred, and how frequently each type occurs in our sample as percentages.

Table 5.2 Average costs of care per treatment type

	Diagnostic	IUI cycles	
	IFA	**Natural**	**Stimulated**
Costs per phase of treatment:			
Intake/diagnostics	436.66 1979.26*	14.18	14.18
Stimulation/monitoring		94.13	430.43
Egg retrieval			
Insemination/fertilization		234.85	234.85
Embryo Transfer			
Freezing or thawing			
Evaluation	67.02	174.84	174.84
Cost sources as relative % of total cost per treatment type:			
Significant disposables and blood tests	22%	9%	24%
Direct medication costs			3%
CCR 0 Overheads	4%	7%	7%
CCR 1 Gynecologist	27%	11%	7%
CCR 2 Physicians		24%	20%
CCR 3 Nurses	10%	19%	18%
CCR 4 Clinic	3%	6%	7%
CCR 5 Urology			
CCR 6 Laboratory staff	28%	21%	13%
CCR 7 Laboratory – general	6%	4%	3%
CCR 8 Laboratory- IVF			
CCR 9 Laboratory – ICSI			
CCR 10 Laboratory – Freezing and thawing			
CCR 11 Radiology staff			
CCR 12 OR staff			
Total costs (average case)	**€504**	**€518**	**€845**

Note: Costs of 'usual care' per treatment cycle using mean time and cost predictor observations. Absolute costs are first broken down by phase, then summed in the bottom row. The resource utilization is shown in italics as a relative percentage of the total costs per treatment type. *In some cases, a diagnostic laparoscopy or hysterosalpingography (HSG) are required, or a urology consult, which raises costs. These are excluded in the relative percentages shown.

OI cycles		IVF cycles					
Clomid or Letrozole	**FSH**	**IVF intake**	**IVF- only**	**IVF-ICSI Combi**	**IVF-ICSI**	**FET**	**FET with stimulation**
	78.12	356.62 895.66*				47.12	47.12
55.91	612.38		853.93	858.65	853.93	113.48	209.56
			637.66	1025.97	995.38		
			441.75	632.07	479.19		
			293.99	293.99	293.99	293.99	293.99
			207.55	207.55	207.55	301.11	301.11
165.51	272.87		174.84	174.84	174.84	184.18	184.18
24%	12%	20%	7%	5%	8%	8%	7%
2%	19%		20%	16%	18%	2%	5%
4%	7%	3%	4%	4%	4%	5%	5%
65%	6%	22%	2%	2%	2%		
	27%		8%	6%	7%	14%	16%
	21%		11%	9%	10%	16%	17%
6%	8%	2%	3%	3%	3%	6%	5%
		44%	25%	29%	27%	25%	22%
		9%	3%	5%	4%		
			15%	13%	10%	19%	17%
				6%	7%		
			2%	1%	1%	6%	5%
€221	**€963**	**€357**	**€2610**	**€3193**	**€3005**	**€940**	**€1036**

Table 5.3 Cost variation across different IVF cycle sizes

IVF treatment type	**IVF cycles1030 cycles**			**IVF-ICSI cycles1571 cycles**			**IVF-ICSI Combi cycles308 cycles**		
	small	**medium**	**large**	**small**	**medium**	**large**	**small***	**medium**	**large**
	32.2 %	**35.6 %**	**32.1 %**	**21.5 %**	**36.7%**	**41.8%**	**0.3%**	**34.7%**	**64.9%**
Phase of treatment:									
Stimulation and/or monitoring	853.93	853.93	853.93	853.93	853.93	853.93	858.65	858.65	858.65
Oocyte retrieval	637.66	637.66	637.66	848.24	1152.40	1456.55	775.51	1019.71	1263.91
Insemination, fertilization, and cultivation	311.41	426.69	657.24	361.69	608.61	1102.46	274.46	455.55	817.75
Embryo Transfer	293.99	293.99	293.99	293.99	293.99	293.99	293.99	293.99	293.99
Freezing or thawing	207.55	207.55	207.55	207.55	207.55	207.55	207.55	207.55	207.55
Evaluation	174.84	174.84	174.84	174.84	174.84	174.84	174.84	174.84	174.84
Total	**€2479**	**€2595**	**€2825**	**€2740**	**€3291**	**€4089**	**€2585**	**€3010**	**€3617**

Note: Cost comparison of different in-vitro fertilization cycles based on volume. A small cycle is defined as 10 predicted oocytes, 5 realized oocytes, and 3 embryos. A medium cycle is defined as: 20 predicted oocytes, 10 realized oocytes, and 6 embryos. A large cycle is defined as 30 predicted oocytes, 20 realized oocytes, and 12 embryos. The sample data was categorized based on the number of predicted oocytes, as most of the preparatory laboratory work is based on these predictions. *Small IVF-ICSI cycles are technically possible, but not offered by clinics, which is why the category "small" only represents 0.3% of the sample.

More ICSI and combination cycles are administered compared to IVF-only cycles, and these cycles tend to be of medium or large size. While the cost of IVF-only cycles ranges from €2479 (32%) to €2825 (32%), ICSI cycles range from €2740 (22%) to €4089 (42%), and combination cycles range from €3010 (35%) to €3617 (65%). However, under the current DRG as per 2023, all cycles are reimbursed at a fixed rate of €2955 for IVF and €3064 for ICSI and combination cycles, regardless of their size (NZa, 2022). This reimbursement amount falls short of the estimated costs presented here, which generates losses for clinics for high-volume cases (which are most common). For example, 42% of ICSI cases were large, costing €4089 to deliver yet generating DRGs of €3064 (or less in prior years), which is a discrepancy of €1025 or a shortcoming of 33%. These cost estimates are conservative, under ideal conditions, and only incorporate resources used; they exclude e.g., spare equipment like spare microscopes maintained purely to ensure services levels, and they exclude repeated activities e.g., repeated embryo thaws (which are common in practice).

5.3.1 Total costs of care per pregnancy outcome (across DRGs)

As patient journeys consist of many rounds of care, understanding patient-level costs and the impact of treatment choices requires an analysis of total patient trajectories. Using the costing model developed, costs can be estimated using sample averages (as shown in **Table 5.1 and Table 5.2**), or alternatively at the patient level using individual input parameters per patient per round. We constructed an event log of the patient sample, with each event corresponding to one process costed with TDABC and simulated the total costs of care per patient and pregnancy pathway for the entire sample. The patient sample is summarized in **Table 5.4.**

Table 5.4 Summary statistics of patient sample. Note that not all activities are treatment cycles.

	n	%
Pregnancy trajectories (first consult to pregnancy or end of treatment)	4190	
Pregnancies	2106	50,3%
Birth trajectories (first consult to birth or end of treatment)	3830	
Live births	1411	36,8%
Patients	3335	
Starting year of treatment		
2014		20,60%
2015		18,02%
2016		14,66%
2017		12,53%
2018		9,84%
2019		10,07%
2020		7,32%
2021		5,43%
2022		1,53%
Treatment cycles		
Total treatment cycles* in sample	13 203	
Intra-uterine insemination	5211	
with stimulation		52,4%
without stimulation		47,6%
Ovulation induction	1127	
with Clomid or Letrozole		16,0%
with Gonadotropins/FSH		84,0%
In-vitro fertilization (IVF)		
IVF only	1030	
small		32,2%
medium		35,6%
large		32,1%
IVF-ICSI only	1571	
small		21,5%
medium		36,7%
large		41,8%

Table 5.4 Continued

	n	%
IVF-ICSI Combi	308	
small		0,3%
medium		34,7%
large		64,9%
FET	3146	
with stimulation		15,4%
without stimulation		84,6%
Expectative	810	
Planned		50,6%
Unplanned (failed treatment cycle)		49,4%

Note: Summary statistics of patient sample and treatments. Note that couples or patients can have multiple diagnoses, which is why the diagnosis percentages add up to more than 100%. Pregnancies are defined as a positive pregnancy test and/or ultrasound at 12 weeks.

On average, pathways from first consult to end (pregnancy, birth, or end of treatment) took 25,5 months at mean cost of €6329. This includes cases of multiple pregnancies, with or without births, and cases that never once reach pregnancy (shown in **figure 5.3** and **table 5.4**). Consequently, the costs of these pathways ranged significantly, from €221 to €36 976, and their duration varied from 30 days to 8,59 years.

Alternatively, when considering each pregnancy achieved or strived for as a separate pathway, and thus subsequent attempts at pregnancy by the same patient or couple as a separate trajectory, mean costs were €5037 with a mean duration of 20,3 months, and with costs ranging from €162 to €30 074. Of these 4 190 trajectories relating to the 3 335 patients, 1411 resulted in live births (36,8%), which is above average (Bahadur et al., 2020). Notably, high resource utilization was most common among those patients who never reached a single pregnancy, whilst patients who gave birth twice or more required significantly fewer resources and fewer cycles of care in total, shown in **figure 5.3**.

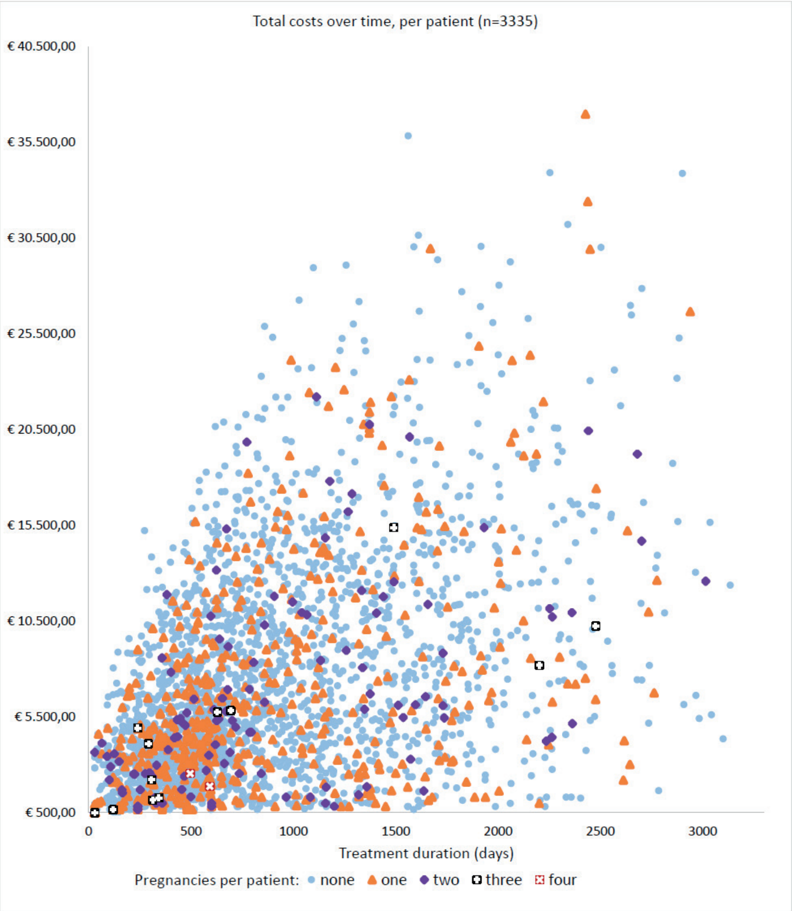


Figure 5.3 Scatterplot of total patient costs in relation to treatment duration (n=3335 female patients).

We present the most prevalent patient pathways for the entire sample, per trajectory, in **Figure 5.4**. Each treatment box contains the total frequency per treatment, and the maximum number of repetitions per case in brackets. The most common treatment type is IUI, followed by FET cycles after IVF, which both feature many repetitions. Given the prior cost results and given that patients frequently repeat IVF and FET cycles, it can be concluded that significant cost reductions can be gained from avoiding failed cycles of IVF, IVF-ICSI, or combination cycles, and from reducing the per-cycle costs of each individual IVF and FET, as these are frequently repeated (up to 17 times by a single patient in case of FET). Choices made, and outcomes achieved, during IVF treatments causally determine costs incurred during FET cycles; for instance, how many embryos are generated and frozen, and how they are frozen, determines the number of FET cycles that are possible and their costs.

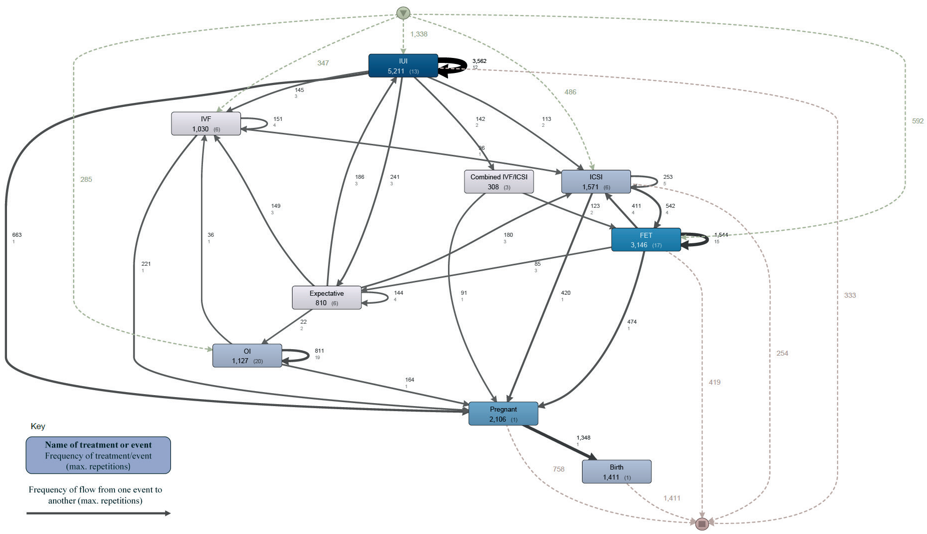


Figure 5.4 Overview of pathways after diagnostics (4190 trajectories from first consultation to pregnancy).
Note: FET, Frozen embryo transfer; ICSI: intracytoplasmic sperm injection; IUI: intra-uterine insemination; IVF: in-vitro fertilization; Expectative: skipped or cancelled cycle due to e.g. cycle failure. Each rectangle contains the total frequency of treatment rounds, and the maximum repetitions per patient per treatment type in brackets. Arrows depict the most dominant patient flows, including frequency. Max. repetitions are given in brackets.

5.3.2 Cost variation and savings within DRGs, and across patient pathways

Given the findings presented in the prior sections, we evaluate two methods that reduce burden on the laboratory phases of IVF: (1) vitrification, which is a new means of embryo freezing and thawing (refer to **Figure 5.2,** FET), and (2) artificial embryo selection using time-lapse imaging during the fertilization phase (refer to **Figure 5.2,** IVF). These methods reduce costs *within* treatment/DRG categories and have significant economic impact *across* patient trajectories from initial consultation to pregnancy; such dependencies between treatments must be accounted for when calculating opportunity costs for economic analyses (Katz et al., 2011; Pöhlmann et al., 2020; Špacírová et al., 2022; Tan et al., 2014), but our results indicate that they are not currently reflected in DRGs, which may misalign incentives (Gajadien et al., 2023).

First, our results show that quick freeze vitrification during IVF reduces the costs of that IVF cycle (Stehlik et al., 2005), and costs of all subsequent FET cycles, and positively impacts the chance of pregnancy. The difference stems from the fact that vitrification is quicker to perform, both whilst freezing (during IVF cycle) and thawing (during FET cycle) as shown in **Appendix H**. Because thawing after quick freeze vitrification significantly reduces the workload for clinicians (26 vs. 50 minutes), more embryos can be thawed on the day of the procedure, and these embryos are less likely to degenerate. This is extremely valuable, as the embryo transfer must be cancelled if no viable embryo is available at the time of the procedure (this implies the entire month-long treatment must be repeated). Further, embryos thawed with vitrification can be evaluated more quickly, which has significantly reduced cancellation rates in comparison to cryopreservation methods. This makes it a significant and value-adding clinical choice, as it improves both costs and success chances during subsequent treatments. On the other hand, embryos thawed with cryopreservation need continued monitoring over 30 min-3 hours to determine if they are viable or not, which significantly increases work; prior to this assessment, no further embryos can be thawed. This evaluation delay can cause a treatment cycle failure if the thawed embryo is evaluated to be unusable, but insufficient time is left to thaw and evaluate another one. These dependencies, and the critical role of embryo availability, are depicted in **Figure 5.5** column 9-10. Cycles that fail towards the end of the cycle, on the day of the embryo transfer due to embryo unavailability, are extremely costly to deliver and hold no patient value; without an embryo transfer there is zero chance of a positive outcome (pregnancy), and all of the resources and costs relating to columns 1-11 in **Figure 5.5** have already been incurred. These represent 80% of total treatment delivery costs shown in **Table 5.2**.

Whilst freezing with vitrification only minorly impacts the costs *within* the IVF cycle (€13 savings), it significantly reduces costs of subsequent FET cycles due to more efficient processing (€98 savings per vitrification thaw, due to quicker processing time). Thus, if a patient's embryos are frozen using vitrification during IVF, this benefits all subsequent FET cycles and relieves overall workload in the laboratory, which is preferable to embryologists and laboratory technicians. In our sample, patients that underwent IVF required up to 8 rounds of IVF (IVF, IVF-ICSI, or IVF-Combi), and up to 17 rounds of FET (**Figure 5.4**). In an average case, vitrification vs. usual care thus saves €322 per patient pathway across all FETs, and in extreme cases (17 repetitions) up to €1 998 per patient pathway, at superior medical performance (Stehlik et al., 2005). This superior performance further reduces embryo degeneration chances within the IVF treatment cycle (Stehlik et al., 2005), which avoids additional treatment rounds (€940 - €4 089 savings per additional FET or IVF avoided, see **Table 5.2** and **Table 5.3**). Improving time-to-pregnancy by reducing the number of treatments required is highly valuable to patients, as treatments are painful and invasive. It is also valuable to the healthcare system, as it would reduce waiting times, which in turn benefits other patients because success chances decrease with patient age. As about 50% of all Dutch cycles are FET cycles (**Table 5.1**), the annual savings of using vitrification instead of cryopreservation amount to €1 311 396 (€98 x 13 382 average annual FET treatments), whilst improving laboratory workflow, workload, and value to patients by reducing the chances of treatment failures. Given that 335 744 FET cycles are delivered on average in Europe per 2019, choosing vitrification may also reduce workload or costs across Europe.

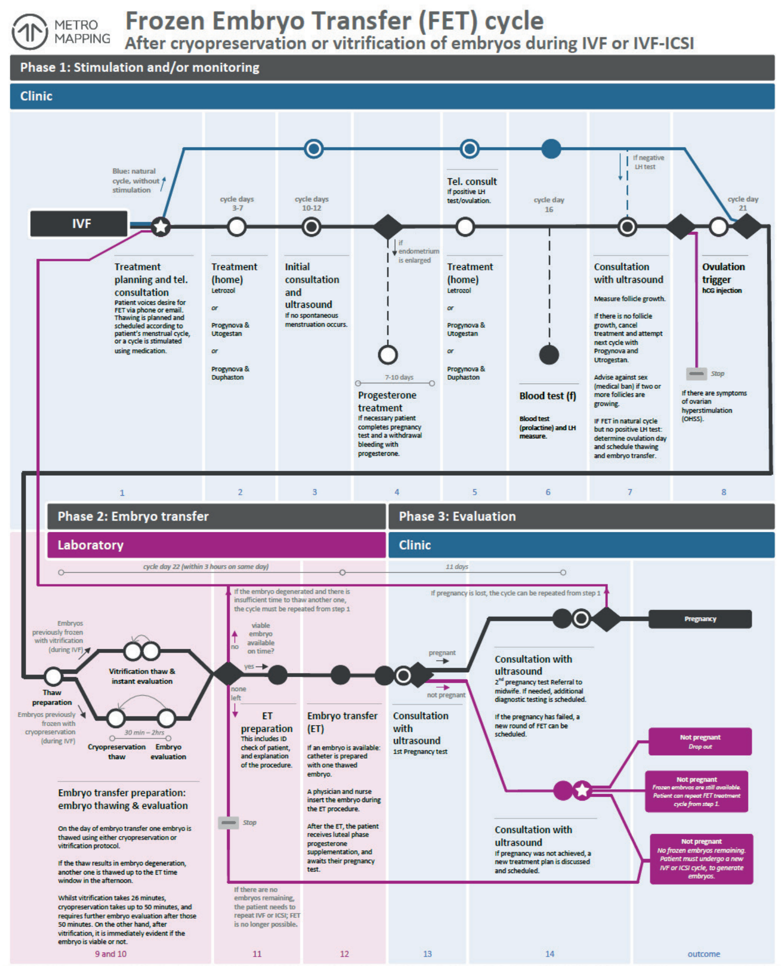


Figure 5.5 Medical Metro Line of FET delivery, expanded from appendix G.

Note: Metro line showing all steps for FET delivery, based on observations and real-world data according to European standards. Red paths signify poor outcomes (e.g., repeated cycles, no pregnancy). Circles represent activities; stars denote shared decision-making points, diamonds indicate alternative routes, white circles denote tasks performed by healthcare providers without patient presence, and filled circles represent activities with patient involvement.

Secondly, algorithmic embryo evaluation reduces time spent by HCPs and improves medical performance (Berntsen et al., 2022; Cimadomo et al., 2022; Fishel et al., 2020), which is consistent with our observations (**Appendix H**). High utilizers of care are those patients that undergo multiple large cycles of IVF (either IVF, IVF-ICSI, IVF-Combi) and subsequent FETs, which can be repeated until no embryos remain. Avoiding just one additional cycle thus saves between €940 and €4089 in costs. These efforts are being combined with training in a so-called 'rescue-ICSI' wherein oocytes not fertilized with IVF are treated with ICSI within 24 hours of failed fertilization (Paffoni et al., 2021), to attempt to avoid a failed cycle by fertilizing the oocytes manually through injection using ICSI techniques. This provides patients, who would have ordinarily had a failed cycle, additional chances of pregnancy in that same treatment cycle, and is therefore extremely valuable because it reduces total treatment duration and costs per patient. Further, as patients must undergo painful and/or invasive hormonal stimulation in the first weeks of IVF to overstimulate oocyte production (see **Figure 5.2**), offering an additional chance of fertilization per stimulation phase would reduce patient discomfort. The cost of the rescue-ICSI cycle is comparable to large IVF-Combi cycles, as rescue-ICSI cycles require the same activities and utilize the same resources (it also involves processing oocytes twice using first the IVF technique and then ICSI like in the combination cycle). However, delivering a rescue-ICSI cycle thus exceeds the allotted DRG of €3064, but if successful avoids an additional IVF cycle (thus saving between €2479-€4089). Thus, if a clinic chooses to invest in this technique and intervene in a failed IVF cycle using rescue-ICSI, the clinic incurs financial losses. However, if this rescue-ICSI is successful in either causing pregnancy or in generating frozen embryos that can be used in subsequent FET cycles (which are less costly than IVF or ICSI cycles), this rescue-ICSI procedure will have improved patient comfort, reduced the total costs of care across the patients' treatment pathway, and will have reduced resource wastage by avoiding one cycle of IVF or IVF-ICSI.

Our analysis revealed further opportunities for value improvements. Due to the high costs associated with all types of IVF, value could be increased and workload decreased by improving the flow of preparatory work in the laboratory through e.g., automated dish labelling or bar coding. Another factor would be to improve cycle size estimation techniques, as the preparatory work is done based on estimated follicle counts. To illustrate, the preparatory work one day prior to the follicular aspiration costs on average €143 and €346 for IVF and IVF-ICSI, respectively, which is greater for high-volume cases (refer to **Table 5.3**). These opportunity costs associated with vitrification, rescue-ICSI, and AI embryo selection cannot currently be determined by clinicians using DRGs, because DRGs don't account for which technology is used, how large a cycle is, or how decisions made in one treatment impacts costs in later treatments for the same patient.

5.4 Discussion and conclusion

We conducted a comprehensive cost analysis of entire patient pathways from initial consultation to pregnancy to examine cost variations and determine the minimal costs of delivering fertility treatments under European standards. Because treatments are repetitive and inter-dependent, and laboratory phases of care are most costly, our results show that clinical decisions in one treatment impact costs and value in subsequent treatments. Our analysis demonstrates the importance of granular cost evaluations for decision-making in settings where aggregate DRGs alone don't enable such comparisons. We contribute to the emergent literature on TDABC, to literature on the economics of subfertility, and to policymakers hoping to address rising costs of subfertility. By providing granular costing infrastructure using real-world data, and by evaluating emerging technologies vs. usual care, we also offer actionable tools to healthcare providers to implement value-based strategies for personalized fertility care.

5.4.1 DRGs vs. organizational cost estimates

First, our study contributes to the ongoing discussion of the applicability of DRGs for economic analyses (Busse et al., 2008; Ederhof & Ginsburg, 2017; Malmmose & Lydersen, 2021; Porgo et al., 2021; Špacírová et al., 2022, 2020; Tanet al., 2011), as we directly examine their utility and relevance to decision-making and analysis in the European fertility care setting. Our approach (TDABC using participant observations) has generated insights into cost variation within DRG/treatment categories, which has enabled both managerial decision-making and opportunity cost explorations within treatment categories at the clinic (Ederhof & Ginsburg, 2019), which was not possible using aggregate DRGs (Špacírová et al., 2022). Our findings suggest that IVF and ICSI reimbursements should be updated to reflect the current high practice variety in treatments present in Europe, as the DRG categories hide the significant resource requirement differences between sub-categories – for example, costs vary by 60% (€2585-€4089) in the case of ICSI treatments, and large ICSI cycles are most common (41% of our sample), but drastically exceed their DRG (€4089 costs vs. €3064 reimbursement, 33% shortcoming to cover costs estimated under ideal conditions). We thus illustrate that implementing TDABC for complex care at scale is feasible, advantageous, and can inform economic analyses, which complements recent work from non-complex care settings like surgical interventions (Defourny et al., 2023;

Etges et al., 2020; Keel et al., 2020; Leusder et al., 2022). In this study, we focused on cost variation, and the impact of emerging technologies on costs and outcomes. Future research should explore determinants of total patient journey costs and outcomes, e.g. in relation to multimorbid diagnoses like endometriosis or ovulation disorder, or patient-level characteristics like age. This could shed light on the causes of variation in the cost predictors we identified (e.g. number of consultations needed). Additionally, whilst we compared IVF costs with DRGs, future work could compare total patient journey costs and DRGs, as the demand for IVF specifically is increasing. This would shed light on whether clinics are facing financial struggles due to increasing IVF treatment volume and cycle size increases.

5.4.2 Value-based fertility care

Secondly, we contribute to the health economics literature on fertility care (Copp et al., 2020; Geeta Nargund & Datta, 2022), which has featured recent and explicit calls for granular cost evaluations, given the increasing practice variation within treatments (Leusder et al., 2023). This need is accentuated by escalating subfertility prevalence, treatment demands, and the desire to deliver patient-centered treatments tailored to individuals' needs (i.e. personalized care) (Dancet et al., 2010; ESHRE, 2022; Gerris & Fauser, 2020; Geeta Nargund & Datta, 2022; WHO, 2023). In patient pathways involving IVF or IVF-ICSI, our analysis reveals notable cost discrepancies among treatment modalities, patient pathways, and technologies, resulting in diverse costs and outcomes not reflected by broad treatment labels. Notably, current Dutch DRGs fail to promote per-patient cost reductions due to inter-cycle dependencies (e.g. choices made during IVF impact the costs of FETs) and inadequate coverage for interventions like rescue-ICSIs, leading to organizational financial losses for clinics despite long-term cost savings per patient from the perspective of healthcare systems. We problematize this because clinics need to be able to invest in new technologies that improve costs and outcomes per patient, and because the demand for IVF is rising as subfertility rates rise. Delivering one large IVF cycle with a rescue-ICSI procedure would be favorable compared to two separate cycles, but this would result in organizational losses to clinics, because this essentially requires two treatments in one cycle that is currently only reimbursed one DRG. While reaffirming previous research on IVF costliness compared to OI and IUI (Bahadur et al., 2020; Bouwmans et al., 2008; Chambers et al., 2013; Collins, 2002; Connolly, Hoorens, et al., 2010), our study identifies causal sources of cost variation at treatment, process, and patient levels, highlighting how clinical choices causally relate to cost differences.

Our findings suggest a structural gap in the current reimbursement system, which assumes static resource consumption per treatment (Bahadur et al., 2020;

Bouwmans et al., 2008; Connolly, Ledger, et al., 2010; Katz et al., 2011), and which fails to incentivize treatments like IVF-Combi or rescue-ICSI despite their value to patients (Paffoni et al., 2021). Providing these treatments is very valuable to patients and society but generates short-term financial losses for clinics, which remain economically invisible when relying on aggregate DRGs alone. This finding may explain part of the significant variation in total fees documented in the UK (Bahadur et al., 2020), US (Katz et al., 2011) and globally (Chambers et al., 2013; Connolly, Hoorens, et al., 2010), as these studies have relied on DRGs and thus assumed static laboratory burden per treatment type. Given that cost information accuracy is crucial for decision-making (Drummond et al., 2015; Špacírová et al., 2020), our results highlight the need for granular cost estimates that reflect patient-level (e.g., oocytes and embryo volumes) and treatment-level (IVF, IVF-ICSI, rescue-ICSI, IVF-Combination, FET with vitrification vs. FET with cryopreservation) cost variation for the purpose of local organizational decision-making and economic analyses or policies. Economic analyses rely on differential costs that accurately reflect the resource consumption – thus, granularity is necessary within IVF and ICSI to reflect these significant differences (Špacírová et al., 2022).

When considering entire patient pathways, technologies that enable more efficient preparation and work in the laboratory (e.g., vitrification) have a significant impact on per-patient costs, even if per-cycle cost reductions seem limited, due to the number of repetitions of treatments. Whilst prior research emphasized the need to reduce medication costs or monitoring costs in IVF (Bouwmans et al., 2008; Cassettari et al., 2016; Gerris & Fauser, 2020; Katz et al., 2011), our findings suggest that future work should also consider reducing laboratory burden, specifically in high-volume cases that are increasingly common (e.g., 64,9% of IVF-Combi are large, and 41% of IVF-ICSI are large). Because annual FET cycle numbers are rising in Europe and globally, with e.g., the US predicted to exceed 1m annual FET cycles (ESHRE, 2022, 2023b), clinics are encouraged to adopt vitrification to reduce the total economic burden of subsequent FET cycles.

5.4.3 Time-driven activity-based costing for managerial insights in personalized care

Thirdly, our study contributes to the recent and active debate regarding the feasibility and utility of TDABC in personalized and complex care settings (Etges et al., 2020; Leusder et al., 2022; Tan et al., 2012), and the associated infrastructure requirements of routine cost estimations to enable appropriate economic analyses (Bahadur et al., 2020; Bouwmans et al., 2008; Cossio-Gil et al., 2022; Ederhof & Ginsburg, 2017, 2019; Eldenburg et al., 2010; Gerris & Fauser, 2020). This is particularly relevant in settings such as IVF, which feature constantly developing medical technologies, all of which change treatment protocols and thus result in cost differences within treatment categories (Veiga et al., 2022). Our study, and the tool we have developed (**Appendix J**) demonstrates the feasibility and utility of combining TDABC with PM for routine cost estimation in complex care settings, addressing current calls for the implementation of patient-centered cost measurement that can account for care personalization (Etges et al., 2020; Leusder et al., 2022; Porgo et al., 2021; Tan et al., 2012). Specifically, we demonstrate that TDABC can be used to create tailored costing systems that allocate direct and indirect costs of care to patient trajectories, that support decision-making through comparisons of alternatives that are not reflected in prices. As care delivery becomes increasingly personalized, and as the medical science of embryology continues to discover alternative laboratory techniques, such comparisons are very relevant. This addresses prior concerns regarding the feasibility of TDABC implementation in complex care (Cossio-Gil et al., 2022; Defourny et al., 2023; Porgo et al., 2021), as we demonstrate how it can be incorporated with real-world clinical data using PM to capture entire patient pathways. Our study further highlights the need for transmural data collection regarding care activities (rather than medical outcomes) and organizational accounting data (rather than reimbursements) (Llewellyn & Northcott, 2005; Špacírová et al., 2022).

5.4.4 Extensions to TDABC: Participant observations and process mining

Our study also offers practical insights to practitioners applying TDABC. One limitation of TDABC is that it overstates cost-savings related to automation, by representing the cost-time relation as causal and linear, whereas other contextual factors also affect costs (e.g., minimum staffing requirements in IVF laboratories). Whilst some studies suggest that time estimates are sufficient for TDABC analyses (Etges et al., 2019; Kaplan & Anderson, 2007; Leusder et al., 2022), our experience in complex care has been different. Specifically, we relied on participant observations to derive duration measurements, as staff were unable to confidently estimate durations for procedures that varied. Duration measurement limits estimation error and reduces chances of model manipulation (Maussen et al., 2024; Maussen & Hoozée, 2022). Because observational measures were key to identifying the variation and cost predictors, we encourage future work to incorporate duration measures as best practice, which builds on prior best practice reports (Keel et al., 2017; Leusder et al., 2022). In addition to this, future research using this methodology should publish the choices made in such analyses transparently (i.e., activities costed, CCRs constructed, time estimates used) as cost accounting methodologies like TDABC cannot be standardized (Campanale et al., 2014; Clark, 1923; Eldenburg et al., 2010; Malmmose & Lydersen, 2021; Špacírová et al., 2020; Tan et al., 2011; Tan et al., 2014). Our work underscores the importance of CCR granularity, as CCR granularity determines the granularity of the results generated (Demeere et al., 2009). Specifically, exploring within-treatment variation requires that CCRs are more granular than DRG or treatment categories themselves, and/or that duration measurements vary within DRG categories and ideally depend on patient-level factors (such as in our case cycle volume, number of consultations, etc.).

One limitation of TDABC generally and our study specifically is that this method does not allocate fixed overheads when they are shared with other departments (Špacírová et al., 2020). To limit the impact of this shortcoming, we conducted this study at a clinic not physically embedded in a hospital. This means that minor fixed overheads (e.g. website maintenance) were excluded from this analysis. A second limitation of this study relates to generalizability, as our study is generalizable to other clinics following European guidelines but will require updates in future as treatment protocols evolve and new laboratory technologies emerge.

5.5 Conclusion

In conclusion, this cost analysis has revealed significant cost variation *within* treatment categories for IVF and ICSI treatments, which add up across patient journeys when considering entire trajectories from initial consultation to pregnancy or birth. Costs within the various sub-categories of IVF are significantly influenced by the volume of patient material handled in the lab, which varies per patient and laboratory method. Reducing the number of unsuccessful cycles of care is the most meaningful way to realize value-based fertility care, which current aggregate DRGs may not incentivize or make visible. IVF related DRGs could be improved by introducing granularity through the categories identified throughout this study. Care providers are encouraged to use the costing tool developed in this study, by inputting their own annual cost data and duration measures to estimate costs for patient pathways, and treatment cycles. This would allow for routine (e.g., quarterly) updating of cost estimates in line with the rapid development of medical science and technology in embryology, and transparent publication of granular cost estimates could inform appropriate and timely reimbursement policies and economic analyses.

Chapter 6

Toward value-based care using cost mining: cost aggregation and visualization across the entire colorectal cancer patient pathway.

Published in BMC Medical Research Methodology (2024)

This article is the product of my academic visit at the University of Melbourne (School of Global Population Health, Cancer Health Services Research Unit).

Abstract

Background The aim of this study is to develop a method we call "cost mining" to unravel cost variation and identify cost drivers by modelling integrated patient pathways from primary care to the palliative care setting. This approach fills an urgent need to quantify financial strains on healthcare systems, particularly for colorectal cancer, which is the most expensive cancer in Australia, and the second most expensive cancer globally.

Methods We developed and published a customized algorithm that dynamically estimates and visualizes the mean, minimum, and total costs of care at the patient level, by aggregating activity-based healthcare system costs (e.g. DRGs) across integrated pathways. This extends traditional process mining approaches by making the resulting process maps actionable and informative and by displaying cost estimates. We demonstrate the method by constructing a unique dataset of colorectal cancer pathways in Victoria, Australia, using records of primary care, diagnosis, hospital admission and chemotherapy, medication, health system costs, and life events to create integrated colorectal cancer patient pathways from 2012 to 2020.

Results Cost mining with the algorithm enabled exploration of costly integrated pathways, i.e. drilling down in high-cost pathways to discover cost drivers, for 4246 cases covering approx. 4 million care activities. Per-patient CRC pathway costs ranged from $10 379 AUD to $41 643 AUD, and varied significantly per cancer stage such that e.g. chemotherapy costs in one cancer stage are different to the same chemotherapy regimen in a different stage. Admitted episodes were most costly, representing 93.34% or $56.6M AUD of the total healthcare system costs covered in the sample.

Conclusions Cost mining can supplement other health economic methods by providing contextual, sequence and timing-related information depicting how patients flow through complex care pathways. This approach can also facilitate health economic studies informing decision-makers on where to target care improvement or to evaluate the consequences of new treatments or care delivery interventions. Through this study we provide an approach for hospitals and policymakers to leverage their health data infrastructure and to enable real time patient level cost mining.

6.1 Introduction

Recent years have witnessed significant advancements in complex care, particularly in oncology, with rapid introduction of innovative technologies and therapies. This has led to better patient outcomes but has also resulted in higher patient-specific costs due to increased complexity and specialization of care delivery (Karikios et al., 2014; Smith & Hillner, 2011). Recent estimates suggest that the total global economic burden of cancers will reach $25.2 trillion during the period of 2020 to 2050 (Chen et al., 2023). This rapidly growing cost of care is unsustainable and considered one of the major challenges for health systems worldwide (Smith & Hillner, 2011). Value-based healthcare (VBHC) is a lens through which this issue is increasingly discussed; broadly speaking, VBHC suggests that healthcare must be organized and incentivized in a way that prioritizes outcomes and minimizes resource utilization and costs, per patient, across the integrated treatment pathway from screening or initial consultation to outcome (Leusder et al., 2022). While patient preferences and outcomes are increasingly studied, estimating costs at the patient level remains challenging (Cossio-Gil et al., 2022), especially in complex care settings with extended patient journeys or repetitive treatment cycles with regular diagnostic work-ups, such as colorectal cancers (CRC). As new treatment variations and alternatives are introduced, and protocols become more tailored to individual patients, these pathways increasingly resemble interdependent webs which complicates decision-making (Alves et al., 2018; Keel et al., 2020; Leusder et al., 2023; Rafiq et al., 2019).

Model-based health economic studies often use population-level aggregate costs and rely on ad-hoc exploration of variability or cost drivers within these aggregates, usually based on patient characteristics like age (Ederhof & Ginsburg, 2019; Llewellyn et al., 2022; Špacírová et al., 2022; Tan et al., 2011). While suitable for evaluating interventions, this approach is less accurate for hospital-level capacity planning and process improvement (Agostinelli et al., 2020; Aguirre et al., 2019; Benevento et al., 2019; Canjels et al., 2019; Cho et al., 2020; van Hulzen et al., 2022). Additionally, healthcare professionals report a lack of tools to easily identify and target specific cost drivers relevant to their local context (Cho et al., 2020; Ederhof & Ginsburg, 2019; Jacobs et al., 2004; Wicky et al., 2023). Determining cost drivers across patient pathways is a significant research challenge (Atkins et al., 2014; Chen et al., 2023; Goldsbury et al., 2021, 2018; Nauta, 2011), as decisions made in one treatment impact subsequent treatments' costs and outcomes, prompting calls for better tools to systematically explore variation across integrated pathways (Cho et al., 2020; Gerhardt et al., 2018; H. Huang et al., 2016; Keel et al., 2020; Leusder et al., 2023; Phan et al., 2019; van der Spoel et al., 2013). Granular cost data spanning the full patient cycle, from primary care to end-of-life care, are difficult to generate (Augusto et al., 2022; Leusder et al., 2022; Vathy-Fogarassy et al., 2022), and determining variation in healthcare delivery characteristics remains a core challenge.

To address these challenges, this study presents process mining with cost estimation, which we call "cost mining," as an approach to uncover high-cost pathways and specific cost drivers using real-world patient-level data. Process mining (PM) can complement existing health economic approaches (De Roock & Martin, 2022; van Hulzen et al., 2022), by enabling patient-level cost estimates in models and generating visuals that capture patient-level variation and treatment interdependencies. PM uses low-level event data from electronic health records (EHR), such as individual consultations, procedures, and medication prescriptions, with timestamps to derive process models and discover real-world patient pathways (Munoz-Gama et al., 2022). It presents granular data in steps or phases, providing descriptive insights into patient movement through systems and resource consumption (Litchfield et al., 2018; Munoz-Gama et al., 2022). As of early 2022, approximately 263 healthcare PM studies have been published (De Roock & Martin, 2022), exploring care trajectories in acute ischemic stroke, sepsis (Quintano Neira et al., 2019), chronic diseases (Balakhontceva et al., 2018; Z. Huang et al., 2015), cancer (Marazza et al., 2020; Poelmans et al., 2010; Toth et al., 2017), primary care (Litchfield et al., 2018), and COVID-19 cases (Augusto et al., 2022). This work has concluded that PM is powerful, but should include cost or resource data to make it actionable, which is indeed what we contribute in this study.

Costs have received limited attention in prior PM and VBHC studies. PM has been used to assess resource requirements and queuing improvements in emergency departments (Agostinelli et al., 2020; Benevento et al., 2019; Cho et al., 2020; Ibanez-Sanchez et al., 2019), but its use in cancer care is limited due to the complexity of tracing integrated care episodes and the chronic nature of cancer (Goldsbury et al., 2021, 2018). To support case-mix group evaluations and hospital capacity planning, additional data and analyses are needed with PM (Agostinelli et al., 2020; Aguirre et al., 2019; Benevento et al., 2019; Nauta, 2011). Cost mining can identify patient subgroups incurring additional costs due to factors like cancer stage, treatment timing, or protocol changes. It complements existing health economic methods by providing contextual information on patient pathways and the timing of treatment decisions (e.g., early-stage vs. late-stage chemotherapy). This information can serve as KPIs or benchmarks for healthcare practitioners, policymakers, and researchers, extending PM's usefulness in health services (De Roock & Martin, 2022). Given that only nine of 236 recently reviewed studies employed cost estimation (Cho et al., 2020; Huang et al., 2016; Phan et al., 2019; van der Spoel et al., 2013), the algorithm we have developed particularly enhances PM's utility for studying the cost drivers in CRC and other complex diseases in scope for VBHC initiatives.

To develop and illustrate cost mining, we created a unique linked dataset to cover the entire colorectal cancer (CRC) pathway in Victoria, Australia, which serves as an illustrative case study throughout the paper. Colorectal cancers, which have long trajectories beginning in primary care, are the most costly cancers in Australia (Goldsbury et al., 2021) and the second most costly cancer globally (Chen et al., 2023), making CRC a highly relevant research context for the study of healthcare costs.

6.2 Methods

In this section we describe the data requirements for cost mining integrated pathways. For a detailed description of PM techniques, we refer the reader to Munoz-Gama et al. (2022) and van der Aalst (2016). In this study, we combined data from six Australian databases, detailed in **appendix A** and summarized in **Figure 6.1**. The study received ethical approval by the Royal Melbourne Hospital Ethics Board through the BioGrid application (202003/8) prior to starting.

PM structures event-level data chronologically into so called process models, which depict a linear, visualized flow of patients through a series of processes (Litchfield et al., 2018; van der Aalst, 2016). Processes can have several states and attributes (e.g. a blood test can be complete or incomplete, etc.). PM describes as-is states of pathways using retrospective data; it summarizes and visualizes real world pathways, and does not make any predictions, assumptions, or imputations (Andrews et al., 2022; Balakhontceva et al., 2018; Litchfield et al., 2018; Vathy-Fogarassy et al., 2022).

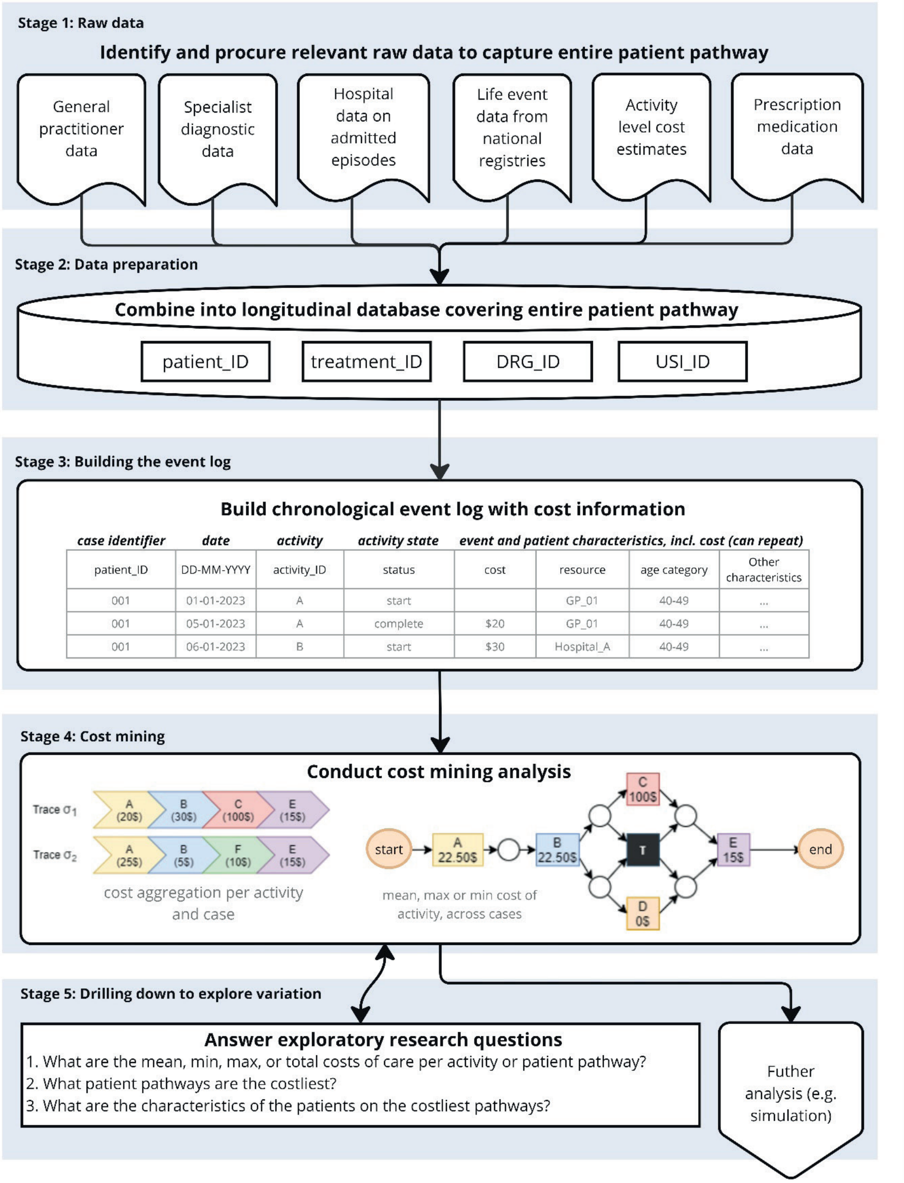


Figure 6.1 Explanatory diagram summarizing the flow of raw data into the research results when using cost mining (PM with cost aggregation)

6.2.1 Stage 1: Raw data

The method requires activity and cost information of a patient's complete treatment history (screening, diagnosis, treatment, follow-up), and these activity data need to include dates or timestamps. Patients don't need to complete their treatment to be included in the analysis, as costs are estimated at the activity level, including patients still undergoing treatments is a key strength of this method. However, for group comparisons or total cost estimations, it's crucial to have treatment start dates to filter out incomplete cases and avoid downward bias in total pathway cost estimates (Leusder et al., 2023; Nauta, 2011). Costs can be estimated using activity-based microcosting approaches (Keel et al., 2020; Leusder et al., 2023), or through reimbursement data such as DRGs (Goldsbury et al., 2021; Leusder et al., 2022; Špacírová et al., 2022). The Australian reimbursements are granular, meaning that this method will produce cost statistics that capture inter-dependencies across integrated pathways. For example, the chemotherapy stage consists of several activity-based reimbursements, which means that the cost statistics will reflect differences between patients, as e.g. a patient requiring chemotherapy at a later stage of CRC may require more consultations, treatments, or regimens than a patient undergoing chemotherapy at a different CRC stage. The data requirements are summarized in the first stage of **Figure 6.1.**

6.2.2 Stage 2: Data preparation

The data need to be linked into a longitudinal database covering the integrated patient pathways and associated costs per activity. This implies that each data source identified in stage 1 of **Figure 6.1** needs to contain unique identifiers, e.g., anonymized patient identifiers. Further, it implies that data requirements are significant, because data linkage results in the exclusion of incomplete cases. In the CRC case shown in **Figure 6.2**, this resulted in a set of 4246 patient records covering approx. 4 million activities (**appendix K**). Before conducting the analysis, it is important to assess if combining the data introduced bias through data loss, by comparing patient characteristics across data sources and the final set (**appendix L**).

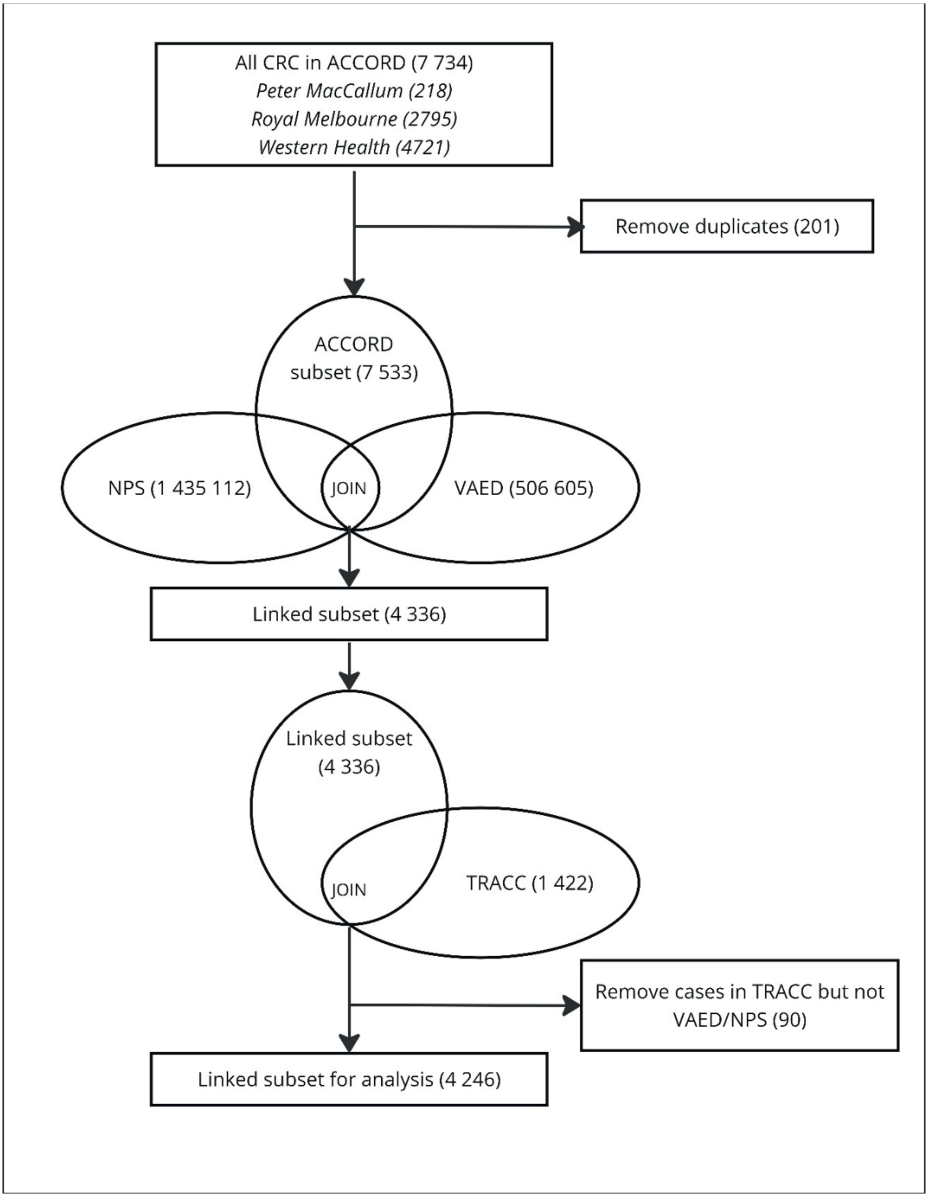


Figure 6.2 Patient record selection for the case study of colorectal cancer (CRC) based on 4,246 cases and approx. 4 million treatment activities..

Note: ACCORD: Australian Comprehensive Cancer Outcomes and Research Database; MBS: Medicare Benefits Schedule; PBS: Pharmaceutical Benefit Scheme; TRACC: Treatment of Recurrent and Advanced Colorectal Cancer; VAED: Victorian Admitted Episodes Dataset.

6.2.3 Stage 3: Building the event log

Next, data need to be formatted in an event or activity log, which is subject to the requirements summarized in **Table 6.1.**

Table 6.1 Event log requirements, based on De Roock and Martin (2023).

Element	Description
Timestamps	Dates, timestamps
Case identifier	A case identification code that is consistent and unique, e.g. one code per patient
Activity identifier	An activity identification code that is consistent and unique. This requires data cleaning and preparation to avoid cases where identical activities or events are coded inconsistently (e.g. “Chemo” vs. “Chemotherapy”)
Event status	Activity status information, e.g. started, complete, in progress associated with the timestamps
Cost of event or activity	Cost estimates, stemming from e.g., diagnosis-related group codes or microcosting
Additional data	E.g. patient characteristics, case-mix group

An activity log contains one row per activity, with start and end times, and therefore only supports additional data at the unit of analysis of an activity as shown in **Figure 6.3.** On the other hand, event logs offer more flexibility because they contain two or more rows per activity, as start and end points of activities are considered individual events. As such, it is possible to model data in which e.g. different resources are executing different elements of a single activity. A practical example of this would be a patient starting a medication-based treatment at a specialist care facility but completing it weeks later whilst being treated at a hospital for acute complications. For the purposes of cost mining, an event log is favorable to an activity log, because some healthcare activities can take weeks or months (e.g. medication treatment regimens), and others minutes (e.g. phone consultation) (De Roock & Martin, 2022). The largest challenge in PM in the healthcare sector is related to the inconsistent nature of the data required (De Roock & Martin, 2022). It can be challenging to link and combine data sources to cover integrated pathways in settings like CRC, due to the length or dispersion of treatments. Possible solutions for this include using heuristics to estimate process end times if these are unknown (Leusder et al., 2023), or assuming that the start date of a specific activity signifies the end date of the prior one. In our CRC case, we did not make assumptions or imputations, because we constructed entire integrated care pathways from primary care up to outcomes like survivorship.

The event log should be built in software optimized for efficient coding, recoding, and reformatting of large data sets. We used R with the tidyverse library, which is freely available. The required event log format is shown in **Figure 6.3 exhibit A.** Note that row 1 in the activity log contains the information from rows 1-2 in the event log. Further, note that the activity log in exhibit B loses some of the information contained in the event log (rows 3-4). The activity log cannot support data pertaining to an activity instance (start, end). Therefore, it summarizes the costs of activity B ($30) whereas the event log can show when and where these costs are incurred ($10 at start, $20 at completion).

Once the event (or activity) log is built as presented in the methods section (stage 1-3), the cost mining analysis can be conducted. Modern commercial PM software packages[29] support the display of common statistics, such as the median number of cases per activity, but do not support customized statistics such as cost information. For this reason, we wrote a customized cost mining algorithm in Python, which is used in the following analyses (available https://github.com/chsr-uom/PM_token_decoration.)

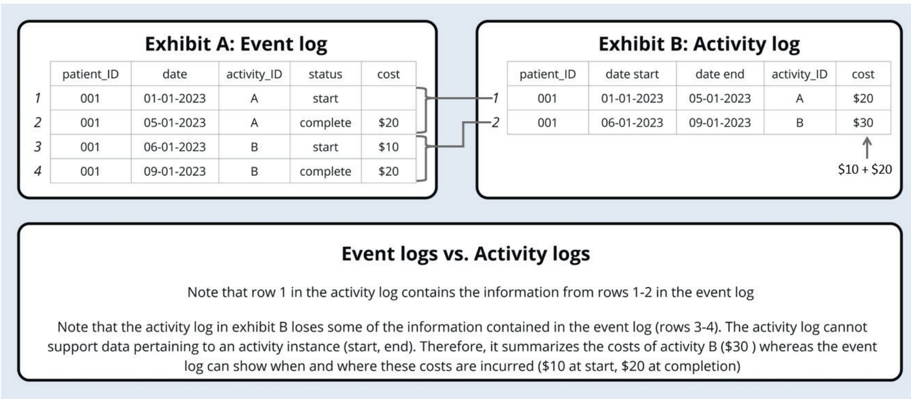


Figure 6.3 Minimum requirements of an event log for cost mining (PM with cost aggregation).

29. https://www.fluxicon.com/disco (commercial)
https://www.celonis.com (commercial)
https://www.apromore.org (commercial)
https://www.promtools.org (free)
https://pm4py.org (free for use in Python)
https://www.bupar.net (free library for use in R)

6.3 Results

6.3.1 Stage 4: Cost mining

The analysis starts with executing PM on the entire event log built in stage 3 using an inductive miner algorithm. It is particularly suitable to healthcare processes, because it produces inspectable process maps with a large degree simplification (Litchfield et al., 2018; Maldonado-Mahauad et al., 2018; Malmberg et al., 2015; Saint et al., 2021). Using the code we provide, the resulting process map displays cost statistics (mean, minimum, maximum, total) for each activity displayed in the form of a 'decoration' (Berti & van der Aalst, 2021; Lim et al., 2022), i.e. a label on the process map. For any given process model generated, the visual output provides the summary statistic of the costs per activity, based on the number of cases that have passed through the activity in that analysis. Similarly, it produces a summary statistic of the total costs of care per trace, i.e., per individual patient trajectory included. At this point, it can be useful to restrict the sample to cases that are completed to avoid under-estimating total pathway costs, by e.g. restricting the data to cases with an observed life event (e.g., survivorship, death, no treatment within 2 years). The cost mining code is described in pseudocode in **appendix M.** Figure 6.4 summarizes how the algorithm aggregates cost data; it draws on the traces derived from PM, which are sequences of events observed per case (patient) in the dataset. In simple terms, for each process map generated, the algorithm aligns all traces of the current model to calculate a statistic of the costs of each activity. In **Figure 6.4 exhibit B**, both instances of 'activity A' are compared and translated into a mean (in this case, the average of $20 and $25 is $22.50). To do so, the algorithm accounts for all patients that have undergone activity A, across all traces (sequences of activities). Because, for example, only a single instance of activity C is observed in this hypothetical example, the label returns the value of $100 attached to activity C. In a final step, the code attaches the generated statistic value to the process map as a 'decoration' label (Berti & van der Aalst, 2021; Lim et al., 2022).

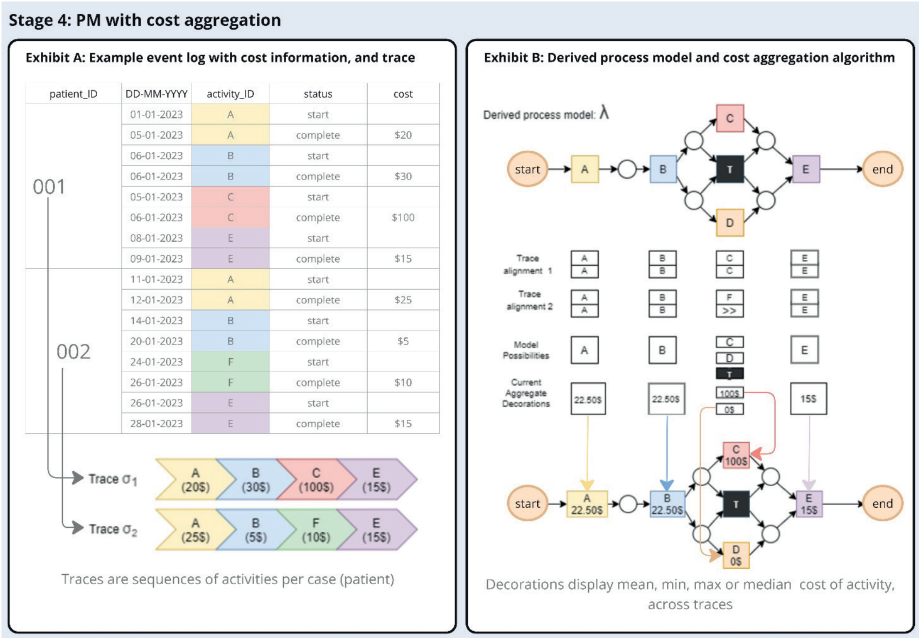


Figure 6.4 Explanatory diagram depicting how data traces are transformed into cost estimates

Note: The aggregation algorithm uses the data provided in the event log (exhibit A), transforms it into traces with cost information, and then derives cost statistics by aligning traces to compute mean, median, minimum, or maximum costs (exhibit B).

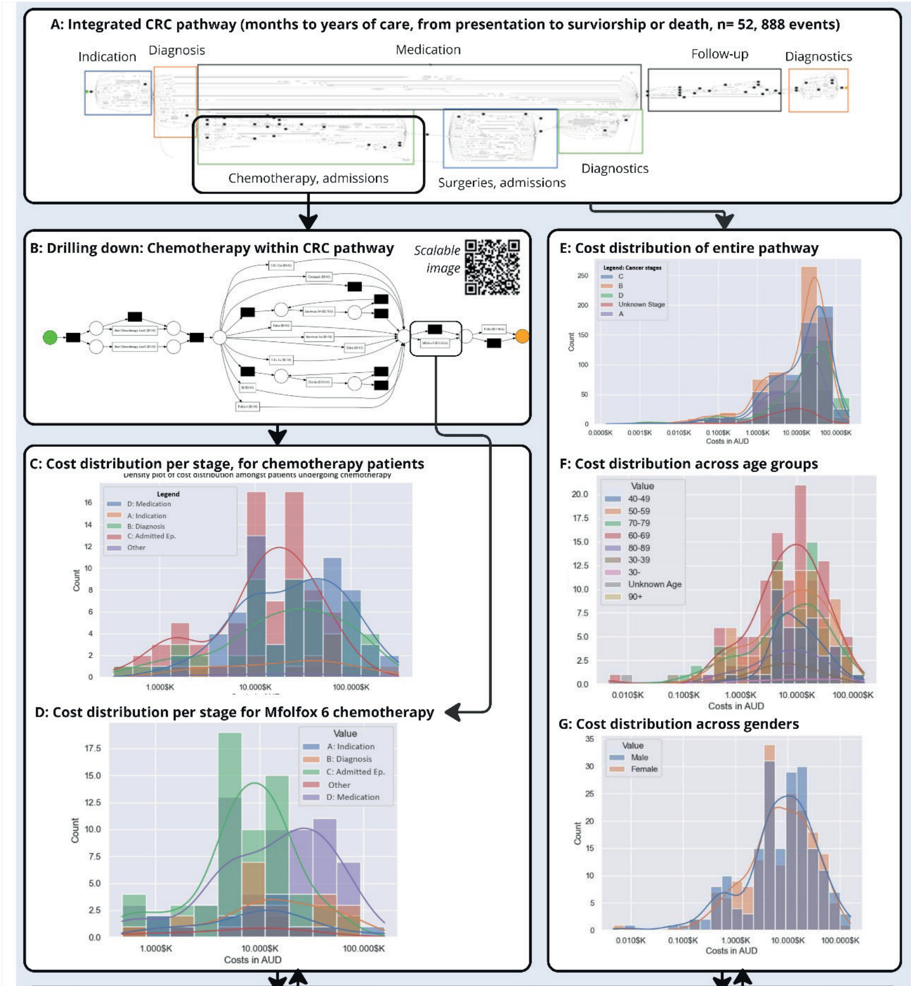
6.3.2 Stage 5: Drilling down to explore variation

The generated process model will display pathways, which warrant further exploration in terms of e.g. case-mix groups, diagnoses, or indications, which we term 'drilling down' into the data to further understand rare, desirable, or undesirable pathways and cost drivers (De Roock & Martin, 2022; Litchfield et al., 2018; van der Aalst, 2016). This allows us to quantify mean and range per patient group as well as to determine subgroups based on certain cost outcomes (e.g. most expensive).

We illustrate the method in **Figure 6.5** using the CRC case. We were able to identify crucial decision points (after which pathways were significantly different in complexity and costs), pinpoint costly processes, and make case-mix comparisons across groups (sex, age group, tumor location, tumor stage, CRC-type, patient's rurality, and indigenous status; see right side of **Figure 6.5**). In CRC, we found that the average costs of care ranged from $10 379 AUD to $41 643 AUD per patient (**Figure 6.5 panel H**) and differed significantly per stage of treatment.

Drilling down in our data revealed that colon cancer was associated with significantly greater costs across the entire care continuum than rectal cancer, and admissions and chemotherapy were by far the most expensive elements of treatment (**Figure 6.5**, **panels C, D**). Admitted episodes (n=1965 patients) cost a total of $56.6M AUD (93.34% of total costs covered by the data, $ 60.63M AUD). In comparison, the total cost of chemotherapy drug treatments (n=218 patients) was 6.62% of total costs. GP visits, diagnostic testing, and prescriptions made up less than 0.01% of the total costs. Our results reveal that treatment-related factors, namely cancer stage, significantly related to costs (**Figure 6.5, panel H**).

When drilling down into the chemotherapy treatments, treatment with a specific regimen (Mfolfox 6; **Figure 6.5 panel D**) was extremely costly, at an average cost of $35K AUD per patient. However, these costs significantly varied across the different cancer stages, with stage C cancer patients incurring much higher costs associated with the Mfolfox 6 chemotherapy regimen than other patients, which warrants future qualitative and quantitative research. In this way, this exploratory technique can account for the temporal nature of care, as the costs of e.g. receiving chemotherapy during late-stage cancer are higher than early-stage. In future, if protocol changes are introduced to e.g. circumvent the use of Mfolfox 6 during stage C CRC, the cost and duration impact of this change can be traced using cost mining.



H: Descriptive cost statistics, per cancer stage, increasingly specific

Colon cancer stage	Ave. cost pp., integrated pathway	Ave. cost pp., admissions only	Ave. cost pp., chemotherapy only
% of total costs in sample	100%	93.34%	6.62%
Stage A	AUD 17,808	AUD 15,000	AUD 25,007
Stage B	AUD 20,988	AUD 75,000	AUD 21,025
Stage C	AUD 27,162	AUD 45,000	AUD 11,227
Stage D	AUD 41,643	AUD 100,000	AUD 23,295
Unkown stage	AUD 10,379	AUD 20,000	AUD 9,887

Figure 6.5 Selected results gained from cost mining CRC pathways in Australia

Note: The figure shows how the method supports 'drilling down' to understand where high costs are being incurred, for which patient groups, and which treatment modalities.

6.4 Discussion

In this case study, we draw on recent PM work in healthcare settings (Andrews et al., 2022; Cho et al., 2020; Lim et al., 2022; Munoz-Gama et al., 2022; Phan et al., 2019; van Hulzen et al., 2022) to develop and trial a method to support VBHC. Because cost mining aggregates cost information across entire patient journeys using real life data, this method translates large volumes of data into useful and practical information with which care can be made more efficient, accessible, and sustainable. In doing so, we have answered several recent calls for research (Born et al., 2023; Martin et al., 2020; Robert et al., 2020; Zimmerman et al., 2021) and built on recent methodological work calling for PM with financial KPIs (De Roock & Martin, 2022).

6.4.1 Applications for cost mining

This method is relevant to achieving process efficiency, cost reduction, improved resource allocation, continuous process improvement, and data driven medical decision-making to ensure financial sustainability in a landscape of increasing complexity.

At the international level, this method could facilitate financial benchmarking across different standards of care and healthcare systems by comparing large patient cohorts in terms of patient pathways, to identify high-cost or long-duration pathways to target with interventions. Thus, it would supplement ongoing analyses, or large retrospective or prospective cohort studies, by providing patient flow information alongside traditional health economic analyses (Martin et al., 2020).

At the national level, this method can aid researchers and policymakers in tracing and evaluating increasing healthcare delivery variation, for instance in response to medical protocol changes over time, technological advancements in medicine, and digitalization of healthcare service delivery. This is particularly relevant in countries that feature strong or increasing care concentration, such as the Netherlands (Gajadien et al., 2023). Further, cost mining could uncover the long-term consequences of shifting standards of care, by mapping and aggregating the costs associated with specific procedural guidelines by comparing patient groups before and after policy changes, or across locations. Even in less fragmented systems (e.g., US) where patient-level data is more integrated, cost mining still holds relevance. Although one could directly determine costs from patient-level data, cost mining offers the ability to uncover underlying patterns, sequences, and relationships within the care process, which can complement traditional microcosting studies by providing contextual information, and by exploring how sequences or timing impact costs, outcomes, and durations.

At the clinical level, it can reveal whether specific patient groups are consuming disproportionately more care than others, as we have demonstrated in our CRC case, or face significantly longer or more invasive trajectories. This may also enable assessment of care equity by, for example, comparing advantaged to disadvantaged or underrepresented patient groups. By exploring utilization patterns in a systematic way using cost mining, future research could identify whether disadvantaged groups are consuming more or less care than their counterparts, which opens up new avenues for prevention and intervention strategies relating to health equity. Moreover, this information would, in turn, provide valuable insights for future health technology assessments or cost-effectiveness assessments, enabling them to estimate the process and cost impact of e-health technologies from financial, sustainability, and equity perspectives (Granath et al., 2022). Further, this method could be used to explore the economic impact of prevention, early diagnosis (Goldsbury et al., 2021, 2018; McGarvey et al., 2022) and excessive routine diagnostics (Moriates, 2023) or prescriptions (Luetsch et al., 2023) by assessing and comparing integrated pathways longitudinally.

6.4.2 Costs of CRC in Australia

The contribution of the present study is that we find that cancer stages relate to costs, and that costs of specific elements of CRC care are dependent on the relative timing in which they are administered during a patient's integrated pathway. Previous studies in New Zealand (Blakely et al., 2015), England (Laudicella et al., 2016), the US (Mariotto et al., 2011), Europe (Henderson et al., 2021), and Australia (Goldsbury et al., 2021, 2018), reported on costs of care for CRC cases in relation to control variables like age and sex. Building on this, we report treatment-specific factors like cancer stage as explanatory factors of cost variation. Only two prior studies found CRC costs to relate to cancer stage (Goldsbury et al., 2021; Laudicella et al., 2016). Our results extend these findings by showing that stages B and C have the highest total costs, and stages C and D have the highest mean cost per patient, which suggests that treatment-related factors and timing influence costs. Whilst prior work focused on treatments (Goldsbury et al., 2018; Mariotto et al., 2011), we included primary care and life events and captured the integrated pathway, covering all treatments and events related to CRC. Importantly, our results show that chemotherapy costs depend on the cancer stage, with specific patient groups requiring high-cost regimens like Mfolfox 6 at specific stages (e.g., stage C) relating to high per-patient costs. These findings extend recent work and illustrate the benefits of mapping integrated patient pathways with data from multiple providers (e.g., GPs) to explore costs in relation to cancer stage and timing of treatments. By incorporating the entire pathway, we show that the total healthcare burden of CRC in Australia is predominantly related to inpatient episodes, but that per-patient costs within chemotherapy vary and relate to specific regimes in specific cancer stages. Future research should utilize cost mining to investigate whether preventative interventions or earlier screening and diagnosis lead to quicker patient pathways or comparatively lower-cost inpatient and chemotherapy episodes, given the significant correlation between cancer stage at the time of treatment and costs. Beyond CRC, future studies could expand on our algorithm to develop routine cost mining evaluations in other costly contexts, complementing and informing traditional economic and qualitative methods.

6.4.3 Limitations of cost mining

Cost mining has limitations inherent to PM and the use of historical patient data, namely significant data requirements, descriptive nature, and a lack of predictive power. The method primarily visualizes as-is states using retrospective data, describing costs faced by patients who have completed (parts of) their care trajectory. This may not reflect current costs for treatments with recent technological developments, and the analysis should be repeated periodically to discover new pathways as they occur.

Due to the descriptive nature of this analysis, the method requires significant volumes of data to be representative, and results must be interpreted cautiously. The method can uncover high-cost pathways and identify paths or patient groups that completed unusually costly pathways. However, the method cannot be used to judge whether medical decisions were cost-effective not, and the user must assume that pathways were chosen out of medical necessity. The resulting visualizations should therefore be used to uncover cost drivers to inform VBHC projects, or to identify patient groups that face unusually costly or lengthy treatments, and should be used in tandem with methods like micro costing or cost-effectiveness analyses, and qualitative approaches like realist evaluations that uncover situational or causal mechanisms (Luetsch et al., 2023; Leusder et al., 2023). Low patient numbers in specific branches of pathways are not problematic if the patient number is representative of the entire study population. Because the analysis is descriptive, it is sensitive to omissions, so excluded cost or activity data will result in an underestimation of cost statistics. Lastly, some contexts may be difficult to model with PM. Systems with free choice of GP and healthcare provider are challenging due to fragmented patient data across providers, necessitating manual linkage. In contrast, systems with seamless electronic health records, like those in the Netherlands, are easier to model as they capture all general and specialist care regardless of location.

6.4.4 Conclusion and future research

The cost mining method identified inpatient and chemotherapy episodes as particularly costly in Australian CRC care, driven by cancer stage, accounting for 99% of the $60.63M AUD economic burden on the Australian health system (2012-2020). Our analysis underscores the benefits of linked registries and cost mining for assessing healthcare costs across integrated pathways to inform VBHC projects. Future research could extend this method, and address some of its limitations, using predictive PM utilizing machine learning (Pishgar et al., 2022), to produce process maps that are not only actionable but also predictive. Additionally, our method relies on static cost estimates per activity using DRG data, whereas future work could develop algorithms that allow resource usage to vary per activity per patient, using cost equations (Leusder et al., 2023).

Part 3: Changing compromises

Chapter 7

Standardized hope, personalized losses: Improving the value of pregnancy trajectories through compromises

Based on: Leusder, M. (*under review*) Standardized hope, personalized losses: Improving the value of pregnancy trajectories through compromises.

This article has benefitted from helpful comments and mentorship provided by Hilco van Elten, Kees Ahaus, Carina Hilders, and Evert van Santbrink over the course of a 3-year project. Special thanks are due to Rita van de Poel and Hardwin van den Doel. The study was approved by the ethics committee of the Erasmus School of Health Policy & Management (ETH122-0355) and the participating hospital.

Chapter 8

Psychological needs, motivation, and behavior in cost management practices

Based on: Leusder, M, van Elten, HJ. (*under review*) Designing organizations to foster motivation, wellbeing, and cost management practices. *Public Management Review.*

Chapter 9

The invisible work of 'doing' transdisciplinary research

Based on; Howe, S*., Michels, R*., and Leusder, M*. (*under review, revision*). Mixed Methods Anonymous: The Invisible Work of Early Career Transdisciplinary and Interparadigmatic Researchers. *Research Policy*.

*All authors contributed equally.

This chapter has benefitted from comments provided during conference presentations (EASST-4S Amsterdam, 2024), and a research seminar presentation of the full paper (Healthcare Governance group, ESHPM, 2025). This article also benefitted from comments provided by Milou Silkens and members of our respective PhD supervisory teams (Diana Delnoij, Rik Wehrens, Bert de Graaf, Hilco van Elten, Kees Ahaus, Carin Uyl-de Groot, Carina Hilders).

Chapter 10

General discussion

> There are no facts, only interpretations.
> *Nietzsche, 1954*

I opened this dissertation by explaining how and why healthcare costs impact us all, directly or indirectly. I listed figures and statistics that paint a grim picture of rising costs, a struggling clinical workforce, and a lack of evidence on how to strive for cost management or 'value' as care is increasingly personalized to patients. This personalization, I have illustrated, makes care valuable in practice but can lead to cost variation per patient. I problematized the disciplinary divide in research concerned with costs in healthcare, by pointing to the fact that economic evaluations deliver population-based averages without implementing cost management practices or systems, whilst social studies of VBHC initiatives report lack of access to data or infrastructure to estimate or manage costs or resource consumption. Whilst organizations like hospitals generate significant quantities of data, this data is not typically transformed into meaningful metrics tailored to departments, units, or local ways of working, and is typically 'decoupled' from actions or practices (Kurunmäki et al., 2003). This dissertation has shown that, even if accounts are decoupled from practice, they significantly shape how care organized, managed, and delivered.

Using practice theory, I argued that co-creating cost management systems with users would not only generate a system that is tailored to the decision-making needs of clinicians in a specific organization but also allow individuals to tailor such systems to their needs, autonomy, and willingness to accept cost-related responsibility. The research aims required a combination of quantitative and qualitative research, and intervention in practice. In healthcare organizations, constructing systems like performance dashboards and time-driven activity-based costing systems (TDABC) require choice-making with regards to what variables are viewed as 'manageable' sources of variation. For instance, the cost predictors chosen in **chapter 5** represent variables that clinicians, in this organization, were able to influence and manage. They reflect the local equipment and technologies available and are likely to differ in other organizations. By co-creating the TDABC system with clinicians, I hypothesized that learning about sources of cost variation would develop greater practical understandings[31] in the organization which, over time, could enable clinicians to choose technologies and protocols that suited their goals and needs, or minimally shed light on the compromises such technologies introduce by changing how care is organized and delivered. These research aims have, over the past four years since starting this research, gained in relevance. For instance, Dutch HCPs have cited the lack of data and infrastructure as reasons for abandoning VBHC initiatives (van

31. 'Practical understandings' are one of the four elements of practices, per Schatzki's (1996, 2002, 2005, 2010) definition of practices described in **chapter 3 section 3.2**. In short, practices are socially shared and consist of rules, teleoaffective structures, general understandings, and practical understandings.

Engen et al., 2025), healthcare providers are experiencing greater (human) resource challenges (Hao & Zhang, 2024; Schuurmans et al., 2024; van de Bovenkamp et al., 2023; Walshe et al., 2024; WHO, 2024), and this has led to increasing calls for research into how cost management practices can be embedded (e.g., Bal & Wallenburg, 2023). Simultaneously, recent reports show that fertility treatment use in Europe rose by 20% between 2020 and 2021 (Smeenk et al., 2024), suggesting that treatment demand is still rising, and that efficiency improvements would benefit a significant number of HCPs and patients.

After having conducted this research, I am convinced that foregrounding the actions, practices and infrastructure[32] underlying cost management practices makes 'value' both actionable and attainable. In other words, making explicit how healthcare professionals and managers learn what is valuable to do, in their specific organization and for a specific patient, can reduce costs (**chapters 2-5**), improve the sustainability of care delivery (**chapter 3-5; 7**), and improve the psychological wellbeing of the workforce (**chapter 8**) under pressure to do more with less (Arnaboldi et al., 2015). By studying how and why enabling cost information contributes to the psychological wellbeing of healthcare managers, the dissertation has bridged two distinct challenges plaguing health systems (cost management, workforce wellbeing) and explored how, when, and why co-creation can help accounting systems become situationally useful in practice.

For the purposes of this research, I defined value as the outcomes achieved through care delivery in relation to the monetary costs of materials, staff, equipment and other resources used to generate these outcomes in one specific place at one specific time (Maguire & Murphy, 2022; Porter, 2010; Porter & Teisberg, 2006). This specificity, I have demonstrated across the chapters, makes it possible for cost estimations to come to matter in practice by informing local actions and local decisions, relevant to the current protocols and practices of the organization, which can aggregate to economically significant differences in resources used per patient (**chapter 5**). This

32. I mention infrastructure here as a separate category for emphasis. However, from a practice-based view, infrastructure *consists of* routinized actions and practices during which individuals use, shape, and are influenced by objects like performance measures or cost estimates. For example, an implemented TDABC system consists of actions like recording and classifying expenses, allocating these to treatments or patients, and evaluating their outputs during medical and managerial practices. Infrastructure comes to matter through actions. By co-creating TDABC systems with users (clinicians in this case), individuals can embed these systems in their local and socially shared practices, thereby (a) making the system situationally useful to them, (b) allowing them to choose which cost accountabilities to accept or reject, and (c) foster the development of practical understandings of how actions in the present moment may lead to cost outcomes in future, during valuations (**chapter 3**).

assertion implied that the actions that amount to 'value-making', and the actions that amount to 'wasteful' resource use or process inefficiencies (Llewellyn et al., 2022; Llewellyn & Northcott, 2005), can be specific to one healthcare organization (with its own norms, protocols, expenses and equipment), and to one specific patient (with his or her own peculiarities and needs). This perspective is in line with the argument that value is 'multiple' and context-dependent (de la Bellacasa, 2011; Jerak-Zuiderent, 2015; Mol, 2002) and rejects the assumption that simply delivering more care is synonymous with value (see also Llewellyn et al., 2022). This is exemplified by the specialized care setting of fertility treatments, where overtreatment carries risks, some treatment cycles have next to no success chances but pose a significant burden on patients and clinics (**chapter 7**), and each patient receiving administratively identical treatments can require different resources (**chapter 5**).

In this final chapter, I condense the technical, social, and organizational insights that emerged across the chapters. Doing so allows me to adapt and answer the research questions (**sections 10.1-10.2**), present several theoretical and methodological contributions (**section 10.3**), and summarize concrete practical and policy-related implications (**section 10.4**). In addition, I offer avenues for future research on cost management in healthcare (**section 10.5**), with emphasis on efforts to generate more resilient healthcare organizations through co-created infrastructures that enable individuals to strive for cost efficiency and/or sustainability to experience greater wellbeing and motivation. Because significant parts of the research are ethnographic, I end in **section 10.6** with a methodological reflection to discuss the role of context on this research.

10.1 Adapting and answering the research questions

In the introduction of this dissertation I posed an overarching research question,

> **How do costs manifest in daily work, impact practice, and how can and should cost management be implemented improve the value of healthcare delivery to patients, the organization, and society?**

which I broke down into several sub-questions relating to (i) daily actions and valuations – so tradeoffs made when caring for specific patients, (ii) cost management practices in healthcare organizations, and (iii) cost management and workforce wellbeing. These aims entailed both technical, social, and ethical components when researched in the context of a fertility clinic aiming to aid patients in becoming parents. As the studies and the fieldwork proceeded, I adapted or expanded some of these questions, based on my observations. Additionally, as is customary with ethnographic work, new questions emerged as the research unfolded. In this section, I offer answers to both the original and new research questions. Because each chapter includes contributions to its respective discipline, I will not repeat those points here. Instead, I will suggest overarching implications for research and practice that might inspire future work.

RQ1: How do cost considerations manifest in clinical practice, impact accountability, and impact the value of care provided?

Cost considerations manifest in valuations during daily care delivery, during moments in which clinicians explicitly consider the costs and potential benefits of specific resources for patients' unique situations and needs (**Figure 10.1**). In these moments, under significant uncertainty about how decisions will lead to outcomes such as costs or pregnancy, clinicians make judgements about how much time and material must be allocated to achieve pregnancy and parenthood for individual cases (**chapter 3**). Because care delivery involves applying abstract protocols to specific patients, fertility care protocols require clinicians to make choices based on e.g. patient indications, and clinicians must rely on *practical understandings* to judge how much time and resources are needed to treat each individual. This generates cost variation, and value per patient, for patients receiving administratively identical treatments (e.g. IVF' treatments can vary in resource usage by between **€**2479 - **€**4089, **chapters 3** and **5**). The extent to which costs are incorporated in daily decisions is limited by the extent to which clinicians can predict how their actions (now) relate to desired outcomes in the future (e.g. pregnancy, childbirth, patient satisfaction, costs of care), and resources are managed across entire patient trajectories as total packages, rather than individual treatment rounds (**chapter 7**). For example, some patients require more diagnostic steps than others or respond to hormonal stimulation differently (resulting in different oocyte counts per patient, and thus different workload for the laboratory), and this aggregates into economically significant cost variation within broad treatment categories like "IVF" **(chapters 3-5**).

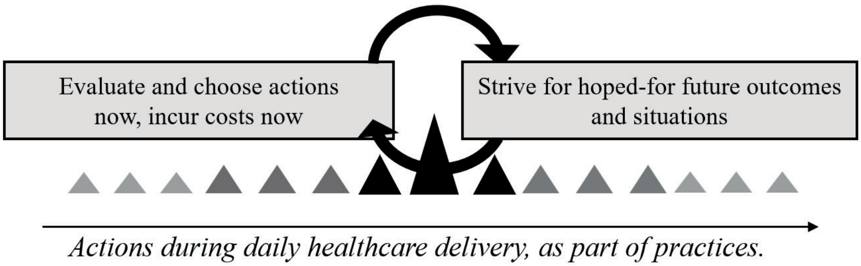


Figure 10.1 Valuations in the medicine-accounting practice mesh during healthcare delivery (based on figure 3.1).

These valuations, expressed as actions, aggregate into patient outcomes (e.g. time to pregnancy, pregnancy), organizational outcomes (e.g. treatment success rates, total annual expenses), and societal outcomes (e.g. waiting times for treatments). It follows, from all of this, that enabling cost management systems must enable clinicians to make decisions *during* treatments, as they unfold, if they are to reduce costs and/or resource usage. Total cost sums, or average cost estimates for entire pathways as typically called for by VBHC proponents (Cossio-Gil et al., 2022), can inform investment decisions to some degree (**chapter 2**) but do not help clinicians to choose what is valuable to do in the moment – their ability to anticipate this, and their autonomy to act on such insights, are limited. For instance, an embryologist can choose to use more petri dishes, check embryo development more frequently, or can choose to thaw additional embryos if it appears that one degenerated. This autonomy is restricted to specific activities, which is why total cost sums or averages can be uninformative to clinicians or managers delivering and managing fertility treatments. Instead, sources of variation relating to patient-level characteristics or protocols, i.e. cost predictors, can guide decision-making at the patient (**chapter 3**) and organizational level (**chapter 5, 7**).

Chapters 2-5 further revealed that cost estimations are integral to modern healthcare strategies like VBHC, which spread cost-management aspirations within organizations (**chapter 3**), but which typically only seek to change or challenge reimbursements rather than to reduce resource usage and costs locally to make care more valuable or sustainable (**chapter 2**). To facilitate value improvements, cost estimates should be based on local resource usage and should reflect both direct and indirect costs of care (**chapter 2, 5, 7**), so that clinicians experience them as 'real' and legitimate by being able to trace how expenses or decisions lead to particular cost estimates in transparent ways (**chapter 7**). Value improvements like the ones documented in **chapter 5** are rare in prior research and are typically only achieved in highly standardized care settings. Cost estimation and management practices improve value through four mechanisms identified in **chapter 2**, namely:

1. identification of cost drivers or predictors, and
2. pre and post comparisons when treatment methods are changed, and
3. comparisons across patient groups, and
4. longitudinal comparisons over time within one organization,

which rely on three best practices in cost estimation (process mapping, clinician input, direct observations to time durations). Chapter 5 illustrates how and why these three best practices matter, as they allow clinicians to tailor the system, and as they ensure traceability between input data and cost estimates. Whilst prior research has allocated such costs to treatments (**chapter 2**), I find that allocating costs to patients is crucial for local learning and change in the fertility care setting (**chapters 3-5**) where cost variation per patient, within identical treatments, is high.

Taken together, the chapters offer several contributions regarding how cost considerations lead to actions that aggregate into patient, organizational, and societal outcomes. First, taken together, these chapters reveal the **temporal dimension of striving for patient-level value. Chapter 3** revealed that clinicians must make decisions that contribute to value as each patients' trajectory unfolds, at a point in time when costs and value for that patient cannot yet be calculated or even known. In **chapter 3**, we coined this the *teleological indeterminacy* of care delivery, which captures the fact that it is challenging if not impossible for clinicians to anticipate how their actions will contribute to goals in the distant future. In this process, key traces of information that would enable explorations of cost variation in future (e.g. how much time was spent, how many petri dishes were prepared) are not recorded, but clinicians must engage in accounting actions like logging their task performance. This contributes to the literature on healthcare strategy, VBHC implementation, and efforts to generate 'enabling' cost estimation infrastructure (Cossio-Gil et al., 2022; Heberle et al., 2024; Maguire & Murphy, 2022), because it establishes that cost estimation systems like TDABC must contribute to clinicians' practical understandings of how their actions (now) can lead to desirable outcomes in the distant future (e.g. pregnancy, per-patient costs), which can (for instance) be done through the identification of cost predictors as demonstrated in **chapter 5**. Whilst most prior VBHC literature emphasizes estimating total treatment costs as averages per treatment, my results suggest that such information is neither helpful nor informative to clinicians and can even lead to negative unintended organizational consequences like overwork, stress, and high (but administratively invisible) costs (**chapter 3, 5, 7**). For example, the instances explored in **chapter 3** detailed how, as IVF is delivered, resource usage can (in some specific cases) greatly exceed what is administratively assumed, and **chapter 7** further explores how early treatment cycles in fertility care require more resources than later treatment cycles.

Secondly, taken together, the chapters reveal that, as standardized protocols are applied to patients, **care delivery becomes personalized, which generates cost variation.** This process of personalization, demonstrated in chapters 3-7, generates value and necessarily implies cost variation. This suggests that we should let go of the dominant assumption that standardized care features standardized costs in specialized care settings (e.g., Etges et al., 2022; see also van Weert & Hazelzet, 2021) and instead seek to explore and understand sources of variation within organizations. By exploring how and why some patients require more resources during administratively identical treatments – such as the differences in costs within IVF treatments explored in this thesis – such costs can be made visible and acted on (**chapter 5**), by fostering local learning and local resource use and cost reductions. Importantly, this requires us to accept "specific needs of caring in each situation, instead of pre-supposing there is only one way" of care delivery (de la Bellacasa, 2011, p. 96; Jerak-Zuiderent, 2015). This finding speaks against suggestions to develop a 'standard set' of cost estimates for medical conditions (Etges et al., 2022), because such averages may not be viewed as real or legitimate by clinicians and may not reflect the current protocols and methods used in specific organizations. Instead, such efforts should focus on building tools or infrastructure that care providers can use to generate their own estimates, based on their local expenses, equipment, and practices. Producing such standard sets that suggest "comparable packages" could ironically resemble DRGs (Kurunmäki, 1999a, p. 123) and may face the same resistance from clinicians like other imposed budgets or rules. Further, however, such averages may not empower clinicians and may therefore not contribute to wellbeing and motivation (**chapter 7**).

Thirdly, taken together, the chapters reveal that clinicians experience **felt accountability** for resource consumption and cost outcomes (Helle & Roberts, 2024; O'Dwyer & Boomsma, 2015; Wang et al., 2024), regardless of whether they are quantified or not. Here, managerial and clinical goals overlap and are inseparable, and clinicians (who carry managerial responsibilities) actively seek for ways to reduce costs and resource wastage to improve value (**chapters 2, 3, 5, 7**). Paradoxically, this felt accountability can increase costs and workplace stress, such as the instances described in chapter 3, because such outcomes (e.g. overwork, doing more work for specific patients) remain invisible in contemporary hospital settings that do not record traces of actions or resource usage. For instance, the significant additional work frequently completed by embryologists described in **chapter 3 vignette B** was not recorded, and instead such tasks were only recorded as complete or incomplete.

This notion of felt accountability contributes to the interdisciplinary literature on clinician' responses to accounting systems, which has previously questioned if clinicians can feel attachment towards outcomes that don't directly impact them, like organizational costs (Carr & Beck, 2020; e.g., Iedema et al., 2005; Kurunmäki et al., 2003). It advances this debate by illustrating how clinicians experience accountability for costs, and how protocols spread cost containment goals, which impacts situational judgment of what resource use is appropriate – for instance, as analyzed in **chapter 3**.

It further contributes to the VBHC implementation literature, by illustrating why cost estimates must be used to inform payment agreements in a bottom-up fashion. Whilst prominent proponents of VBHC argue that payment system changes are needed to incentivize actions or decisions on the medical work floor (Porter & Kaplan, 2016; Porter & Lee, 2013; Porter & Teisberg, 2006; see also Steinmann, 2023), my results suggest that process and cost analyses are necessary to enable clinicians to strive for value to begin with (**chapter 2, 3, 5, 7**). In **chapter 3**, even though the additional work done exceeded what was reimbursed, DRGs or budgeted cost sums did not feature in clinicians' patient level decision-making processes. In Dutch fertility care, these DRGs do not incentivize VBHC because they do not reflect how resources are used during fertility treatments – for instance, the resources required to deliver the first IVF treatment to one patient are much greater than the resources required to deliver the second cycle to that same patient[33]. Whilst the majority of TDABC studies aim to change reimbursement systems, using cost sums for the total episode of care, my results urge for such studies to focus instead on generating granular and local cost estimates that help clinicians act on their felt accountability in consequential ways. These should inform appropriate payment agreements, bottom-up, given that technologies are implemented rapidly and shift resource use from later treatments onto earlier treatments (**chapter 7**). This emphasizes local decision-making to manage and reduce costs, materials usage, and waste, rather than pleading for higher reimbursements to cover (potentially inefficient) ways of working. Further, this literature has previously hypothesized that cost estimation is rare because clinicians are not motivated to estimate costs (Steinmann, 2023, pp. 154–159), whereas I find that such motivation is high, and related to sustainability and waste concerns. This advances the VBHC implementation debate, by illustrating

33. I discuss this further in **section 10.4.**

how enabling cost information may best be understood as a *precursor* to motivation and cost management behavior, rather than conceptualizing such calculations as an end product of VBHC implementation (cf. Steinmann, 2023; Van der Nat, 2022).

To sum up, cost considerations feature in the daily decisions of clinicians, who must make judgements in situ about what actions and resources are needed to treat each patient. Delivering 'standardized' care according to protocols involves the personalization of resource use to patients, in line with protocols, which generates cost variation. Such decisions resemble situational valuations (Muniesa, 2011), which occur day to day, regardless of whether costs are quantified or not. These actions aggregate into both desirable and undesirable patient, organizational, and societal outcomes. During these decisions, cost concerns are inextricably intertwined with considerations of sustainability and waste avoidance. This suggests that, to be impactful, cost information must contribute to clinicians' practical understandings of how their actions, in the present moment for this specific patient and his or her circumstances, will lead to hoped-for outcomes in the future. These valuations are specific to organizations, their facilities, and local protocols and routines.

RQ2: How can and should costs be estimated to facilitate medical and managerial decision-making in the implementation of VBHC? How and where can value be improved in contemporary Dutch fertility care?

In response to the technical and social challenges identified in chapter 1 (see **Table 1.4**), and building on the best practices identified in **chapter 2**, we developed a bespoke method for the intervention (TDABC-PM, chapters 4-5, 7).

The method extends time-driven activity-based costing (TDABC) with process mining (PM), and patient-level input parameters that account for variation within specific activities (such as, for instance, fertilization or embryo thaws), to estimate costs per patient across the entire care continuum. **Chapter 5** presented the quantitative results of implementing TDABC-PM for value improvements, by estimating the costs of treating individual patients for entire medical episodes4[34] of subfertility or infertility, identifying cost drivers, and reducing the cost of fertility treatments

34. The VBHC literature emphasizes the importance of this (Porter & Lee, 2013; Porter & Teisberg, 2006). A medical condition is "a set of patient health circumstances that benefit from dedicated, coordinated care. The term medical condition encompasses diseases, illnesses, injuries, and natural circumstances such as pregnancy. A medical condition can be defined to encompass common co-occurring conditions if care for them involves the need for tight coordination and patient care benefits from common facilities" (Porter & Teisberg, 2006, p. 44).

through care delivery redesign. Drawing on one decade of clinical and cost accounting data (13 203 treatments, 6 822 patients, 4190 patient pathways) and two years of participant observations, the analysis reveals that the per-patient costs (and value) of fertility treatments vary immensely when analyzing the entire trajectory from first consultation to pregnancy and birth. The chapter evaluated three value-improving interventions and reported on their implementation:

1. an improved method of freezing and thawing embryos (vitrification)
2. an improved method of embryo selection (using artificial intelligence embryo evaluation)
3. Combination (IVF and IVF-ICSI) or Rescue-ICSI cycles for cases when no fertilization occurs with IVF.

The value improvements implemented at the clinic and evaluated in the chapter correspond to cost savings of €1.311.396 for the Dutch healthcare system, or €322 - €1998 per patient at this clinic (taking into consideration that patients undergo many treatments across their medical condition). These were based on the implementation of vitrification, which changes the care delivery process in the laboratory phases of all IVF treatments. The cost savings of AI embryo selection correspond to prevention and can only be estimated now and will take years to materialize, but avoiding just one additional cycle of treatment saves between €940 - €4089 per patient and avoids one invasive and painful month-long treatment for the patient.

10.1.1 TDABC-PM for VBHC implementation

The novel method (TDABC-PM) extends prior cost estimation methods in 3 core ways (discussed below), and in doing so contributes actionable insights to the **implementation literature on VBHC** (Bensink et al., 2023; Ramos et al., 2021; Ramsdal & Bjørkquist, 2020; Steinmann et al., 2021; Storkholm et al., 2017), and extends debates in the **management accounting** literature concerned with cost management in healthcare (Eldenburg et al., 2010; Heberle et al., 2024; Llewellyn et al., 2022). Estimating costs and outcomes per patient is considered foundational to VBHC, as summarized in **Table 1.2**. Yet, consensus reports have shown that patient-level cost measurement and management are the least implemented elements of VBHC in Europe (Cossio-Gil et al., 2022; Malmmose & Lydersen, 2021; Steinmann et al., 2021; Vijverberg et al., 2022). The thesis extends this literature by developing TDABC-PM, by exploring how specific trade-offs in granularity and accuracy can support clinical and managerial decision-making, and by illustrating how such analyses can improve 'value' even in the absence of patient-reported outcome or experience measures. These contributions are outlined below.

First (1), **TDABC-PM considers the patient the cost object**, rather than viewing an entire treatment a cost object, as others have suggested (e.g., Kaplan & Anderson, 2007). This was crucial to the fertility care setting because patients require different diagnostics, treatments, and consultation volume depending on their circumstances (**chapter 3-5. 7**) – a fact that is observed in specialized care delivery more generally (van Weert & Hazelzet, 2021) [35]. In this setting, what is accurate on average, may not apply to any one single patient, due to the high variation in costs per patient across entire trajectories, and within treatments. This granularity facilitated local decision-making (**chapter 5**) and enabled us to follow the best practices identified in **chapter 2**, by enabling comparisons between alternative care delivery methods and comparisons across patient groups.

Secondly (2), whereas its creators argue that TDABC should be conducted at the process level to generate process level cost estimates, our results suggest that clinicians find highly granular cost estimates (that illustrate cost variation within specific activities) most useful and actionable. Whilst prior management accounting literature has suggested that activity-based costing systems are unlikely to be accurate in healthcare settings, I find that the **high granularity achieved in this project made the system appear actionable and enabling to individuals with limited autonomy**, who accepted the fact that estimates were not necessarily accurate on a case-by-case basis but valued the granularity of the model. TDABC-PM as we developed it purposefully uses activity flow charts (rather than only using process-level flow charts), displaying variation through optional activities only done under conditions, reflected in the cost equations. This enhanced the degree to which it enabled clinicians to act on the cost estimates we generated. For example, the variation in the number of embryo thaws required per patient, and the variation in costs and resources used across different kinds of thawing protocols, informed the shift towards vitrification (**chapter 5, 7**) which had significant impact on how entire patient trajectories unfold. This granularity in terms of activities, and being able to compare alternative ways of working within specific activities (e.g. vitrification vs. cryopreservation in the activity of "thawing embryos" described in vignette A

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35. This personalization of care delivery, wherein some patients require more diagnostics, consultations, or other care delivery activities than others during administratively identical treatments, is implicitly documented across multiple disciplines and medical settings (van Weert & Hazelzet, 2021), which suggests that it is not wholly unique to the MAR setting. My findings, however, put this fact in a new light by exploring how day-to-day mundane actions, as care is personalized to patients, aggregate into economically significant cost and resource use differences (**chapter 3**), and by exploring how changing patient populations and medical protocols can lead healthcare organizations to incur financial losses as time-to-pregnancy is reduced (**chapter 5, 7**).

of **chapter 3**), rendered the calculations actionable in practice, because clinicians' autonomy relates to one or few activities, which we captured in cost equations using TDABC-PM but which would not be captured in TDABC as it is sometimes presented by its creators (Kaplan & Anderson, 2007) or prior studies (**chapter 2**)[36].

Thirdly (3), rather than relying on time estimates provided during interviews as is oftentimes suggested (Kaplan & Anderson, 2007; Lukka & Granlund, 2002; Sánchez-Rebull et al., 2023), this tailored method requires the researcher (or clinicians) to observe and time how long activities take using a stopwatch, in line with the best practices established in **chapter 2**. Specifically, **activities that vary per patient are observed more frequently to identify cost predictors** (variables that correspond to longer durations – e.g., fertilizing 10 embryos takes longer than fertilizing 3, etc., which are in turn depicted on the activity maps and incorporated into the cost equations) to be able to identify key variables and decision points that can be targeted with interventions. This makes it much less labor intensive to implement than traditional activity-based costing systems using multiple cost drivers, but more labor intensive than how some authors portray it (Kaplan & Anderson, 2007; see also Malmmose & Lydersen, 2021).

These extensions to TDABC, and the implementation of the TDABC-PM system, reveal trade-offs between actionability and accuracy, which builds on findings of prior managerial accounting studies (Campanale et al., 2014; Eldenburg et al., 2010). Notably, I can conclude that TDABC sacrifices accuracy for actionability (**chapter 5, 7**), because the assumption that resources are used in proportion to the amount of time spent by a clinician does not always hold (Kaplan & Anderson, 2007), and because the 'raw' input data required are not typically available and must first be generated, and because the complexity of care delivery necessitates actors to make choices regarding what is viewed as random vs. manageable variation. Furthermore, although we identified that 13 CCRs were minimally necessary to respect TDABC's principle of homogeneity in this fertility clinic (Kaplan & Anderson, 2007, p. 49), it may be concluded that this principle is violated for some specific patient cases if additional or unusual resources are required, and that one single "departmental cost rate" is never valid in healthcare departments offering more than one type of treatment (idem, p. 49). Additionally, the expenses associated with ensuring uninterrupted service levels (such as having a backup microscope, ensuring constant staff availability) may not be

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36. For instance, rather than costing each activity of the laboratory phases of care, it is more common for TDABC systems to only measure the total process duration. Therefore, many TDABC systems generate estimates without accounting for variation within specific activities such as embryo fertilizations (which we did, by for instance accounting for the number of embryos cultured when estimating costs per pregnancy trajectory).

accurately captured in 'unit cost' estimates calculated using methods like TDABC-PM, because TDABC only allocates costs based on resources used and leaves out resources 'wasted' – including staff availability to maintain and monitor the IVF laboratory regardless of workload (Veiga et al., 2022), which I further discuss in my suggestions for future research.

Additionally, TDABC has repeatedly been called a solution the current cost crisis in healthcare, and specialized care in particular, because it is disproportionately negatively impacted by the use of budget-based prices like DRGs (Llewellyn et al., 2022, p.18) due to practice variation (Llewellyn and Northcott, 2005). Building on this work, this research suggests this variation is not caused by differences in clinicians' practice styles as previously suggested, because clinicians are severely restricted by clinical protocols, and instead is caused by clinician's efforts to maximize task-based outcomes for which they are accountable (**chapter 3**), which implies that patients undergoing the same treatments require different resource levels to reach the same medical outcomes. This dissertation demonstrates the potential power of analyses like TDABC-PM to uncover variation, i.e. make visible how practice variation relates to actual organizational costs, and the need to estimate costs retrospectively based on actual consumption (rather than relying on per-treatment prospective estimates). Our findings show that how much effort and materials clinicians spend on administratively identical cases (e.g., IVF) is – and should be – variable (**chapter 5**). Put differently, whilst medical performance goals were standardized, the actions and materials needed to reach them were not, and costs therefore must be estimated retrospectively as care trajectories unfold.

RQ3: How and why does enabling cost information improve workforce wellbeing, and how does it facilitate cost management in daily practice?

The insights generated throughout **chapters 2-6** illustrate that cost concerns are integrally linked to the ongoing workforce crisis in healthcare, because clinicians and managers experience significant pressure to manage and reduce costs but lack systems that enable this. In **chapter 8**, we bridge the literature on cost management and workforce wellbeing, and tailored a multi-item construct to the healthcare setting to evaluate how 'enabling' middle managers perceive their local cost estimation systems to be[37]. Central to this argument is that different cost estimates serve different purposes (chapter 5, see also Clark, 1923), and that cost accounting systems must impact the local actions and practices of clinical staff to be impactful

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37. This construct is given in appendix N and discussed in **chapter 8**.

and reduce costs (**chapters 1-5**). Their ability to generate impact through cost and resource use reduction, therefore, is dependent on how they are perceived by their users (those individuals they should guide and benefit). This conceptualization is particularly useful and applicable to studying healthcare costs, because as chapter 2 has shown, methods like ABC and TDABC cover a "melange of competing, and often contradictory, ideas and practices"(Jones & Dugdale, 2002, p. 159), and because the value of TDABC depends wholly on the extent to which it is tailored to the decision-making needs and autonomy of users (**chapter 2, 5**).

Using Self-Determination Theory (SDT) and a large sample of Dutch healthcare managers, we found that when cost information is perceived as enabling, it contributes to manager's sense of *autonomy*, *competence*, and *relatedness*, and motivation to manage costs, which is associated with cost management behavior. To the best of our knowledge, our study is the first to empirically test if and how cost information in healthcare organizations leads to cost management behavior, and if or how wellbeing and motivation play a role herein. Taken together, *autonomy, competence, relatedness* represent the overall psychological wellbeing of an individual, and our findings support the hypothesis that cost estimation systems can improve workforce wellbeing in the current Dutch climate of cost and resource management pressures. This sheds light on how and why some kinds of cost information lead to cost management practices, whereas others do not. As the previous chapters have shown, middle managers (and/or clinicians with managerial responsibilities) act as change agents, with the ability to spread new cost management ambitions and practices, which is why we targeted them in this survey[38]. Contrary to recent prior findings on generic performance measurement systems outside of healthcare (Van der Hauwaert et al., 2022), we find that relatedness mediates the relationship between enabling cost information and autonomous motivation, which we relate to the growing multidisciplinary teamwork underscoring care delivery processes, established in **chapters 1-5** (c.f. Kemp et al., 2013).

Importantly, these findings contribute to the **VBHC implementation literature**, by (a) illustrating that motivation to manage costs follows the implementation of enabling infrastructure (item 6 of the VBHC strategic agenda, see **table 1.2**), and (b) by exploring the characteristics of cost information for daily cost management practices

38. This argument, that middle managers (or clinicians with managerial responsibilities) act as change agents in healthcare settings, is also supported by prior literature that has been cited and discussed throughout the prior chapters. This literature explicates this argument (Begkos, 2016; Llewellyn, 2001; Moleman et al., 2021, 2022; Oldenhof et al., 2016), or implicitly demonstrates it (Begkos & Antonopoulou, 2021; Begkos et al., 2023; Campanale et al., 2014; Carr & Beck, 2020; Eldenburg et al., 2010; Le Theule et al., 2023; Morinière & Georgescu, 2022)

(repair practices, internal and global transparency, flexibility). Whilst proponents of VBHC make claims that it can prevent burnout and empower clinicians (Cossio-Gil et al., 2022; Teisberg et al., 2020), our results suggest that the presence of enabling infrastructure is one relevant prerequisite to such hoped-for benefits.

Lastly, these findings extend the findings from chapters 2-7. **Chapter 2** found that methods like TDABC are implemented in haphazard ways, and **chapters 5** and **7** illustrate how and why TDABC must be customized to the decision-making needs of users. **Chapter 8** suggests that, regardless of the method used, such systems should offer clinicians and managers global and internal transparency of how cost are incurred during care processes, enable repair practices like improving local efficiency of routines, and offer flexibility to users. Reflecting on the intervention at the clinic, we may conclude that the process improvements we implemented to improve value constituted repair work, enabled by global transparency the TDABC-PM system provided by shedding light on when and where costs are incurred across entire patient trajectories. This revealed that about half of all treatments are frozen embryo transfers (FET) (**chapter 5**). This knowledge made the shift to vitrification particularly impactful, as this method reduces costs during each FET, and reduces the number of FET required. Additionally, the cost-breakdown per CRR revealed how a significant majority of costs are incurred in the laboratory, particularly in IVF and ICSI treatments (internal transparency), which is why the intervention focused on laboratory techniques and technologies. Taken together, these four elements of *enabling cost information* offer a standardized method to assess tailored systems like TDABC, by focusing on how individuals experience them in practice – whether they impact autonomy, competence, relatedness and motivation positively, or not.

RQ4: How do treatment-level cost budgets (e.g. DRGs) and rules (e.g. protocols) impact daily practice and cost management system creation?

The prior chapters revealed a fundamental challenge in cost estimation, related to the increasing personalization of care to patients. This personalization, I have shown, generates cost variation. **Chapter 3** revealed how managerial clinicians use rules to constrain resource use, but in the clinic analyzed here, rules are interpreted through goals. Therefore, rules relating to resource usage and costs were rejected during instances when they were thought to stand in the way of achieving pregnancy and parenthood, even when these actions and costs (e.g. maximizing embryo volume, storing and monitoring unused embryos) did not necessarily contribute to value. Yet, such rules spread cost containment goals from managerial to non-managerial clinical staff and generated new practices such as cost cutting and expense tracking.

Based on these findings, I can formulate a contribution relating to the interrelation of budgeted cost sums (like DRGs) and the implementation of managerial accounting systems like TDABC. The chapters reveal that cost estimates in healthcare, even ones that reflect local practices and resource usage such as the one presented in **chapter 5**, can be born into and intertwined with reimbursement systems like DRGs. TDABC is typically implemented to 'challenge' current reimbursement systems (**chapter 2**), which imposes treatment categories and cost objects (e.g. IVF treatments) upon a system that might better be set up per patient or pregnancy trajectory, whilst ignoring such categories. As **chapters 6** and **7** reveal, the resources used during treatments can depend on the relative timing of the treatment in the patients' entire trajectory – early IVF treatments were, for instance, more resource intensive than later ones as they required more consultations, diagnostics, and other work in comparison to later ones. To enable comparisons with DRGs, the categories like "IVF" were used in this project, but it could be argued that they limited the impact of this system given that patients' early treatment cycles required more resources than later treatment cycles for that same patient. Because clinicians viewed such trajectories as whole packages, not individual treatments or products, it could have been more meaningful to develop a costing system that allocated costs based on activities as and when they were consumed, whilst ignoring categories like "IVF". However, the system was in part designed to enable comparisons to DRGs, which was requested by clinicians who associated VBHC with changes to reimbursements. It follows that, when co-creating these systems, other budgeting systems influence what users find useful or important in designing TDABC systems, and that clinicians view such systems as a means to not only improve local practice, but also delegate accountability to other institutions such as those that set DRGs. As Gosselin and Journeault (2021, p. 38) have put it, systems like TDABC can hardly find their place "without being clearly linked to the budgeting process", but designing systems in this way may anchor them in older systems or practices that limit their accuracy or usefulness for internal cost management practices. DRGs shape locally co-constructed TDABC systems by prescribing categories, and by suggesting how costs are expected to behave (e.g. that each IVF consumes roughly similar resources). Consequently, the benefits of constructing TDABC systems – identifying cost variation, opportunities to reduce material usage, and key decision-making moments that impact how resource consumption unfolds over time, may be hampered when such systems are designed to mimic DRGs. Instead, it may be more useful to allocate costs to patient trajectories based on activities, and to subsequently evaluate whether the 'chunks' of the trajectory that are covered by a specific DRG (and medically defined as one specific treatment) depict stable activities and resource consumption across patients, and across patients' trajectories.

RQ5: What are the emerging skills and practices of junior scholars engaged in transdisciplinary & interparadigmatic (T/I) research?

This question emerged as the research progressed. **Chapter 9** reveals that conducting research projects with the ambition to generate local impact through care delivery shifts, wherein quantitative and qualitative methods are used in tandem to generate data-driven interventions (as done in this thesis), can necessitate transdisciplinary and interparadigmatic research focused on improving value (Maguire & Murphy, 2022). Such T/I research, we find, requires 3 translation practices that set it apart from monodisciplinary research projects - *condensing*, *staging*, and *trespassing*. When T/I scholars operate in multiple disciplines, some work that is recognized as 'research' in one discipline can come to feel like 'dirty work' in another discipline or organization, and such scholars must build skills such as being able to reframe and paraphrase their work to different audiences and disciplines, which involves removing key findings and data. Whilst prior research has viewed interdisciplinarity as the trait of a team (French et al., 2024; Rau et al., 2018; Rosenfield, 1992; Stock & Burton, 2011), our study illustrates that it can become the trait of an individual, which suggests that T/I scholars may benefit from different kinds of education and mentorship than monodisciplinary PhD students. The advice offered in **chapter 9** is relevant to research teams hoping to tackle interdisciplinary challenges (e.g. workforce issues, waste reduction initiatives) in healthcare through interventionist research, particularly when such projects aim to generate data-driven interventions that change local practices, because such projects are likely to require both positivistic and/or quantitative research in conjunction with qualitative interpretive research focused on human perceptions and behavior.

10.2 Shifting costs, value, and practices in an IVF clinic

Returning to the overarching research question, I can conclude that cost considerations impact the day-to-day decisions of clinicians and managers, that cost estimates should be co-created with clinicians to generate local practical understandings of how value can be improved, and specifically that *Enabling Cost Information* contributes to the psychological well-being and motivation of healthcare staff. Such perceptions, of what is enabling or not, are unrelated to the costing method label (e.g. TDABC, ABC, etc.) and instead depend on how actionable individuals perceive these systems to be. Considering these findings results, I can offer three overarching implications regarding the role of cost and resource management systems in healthcare organizations and/or VBHC implementation.

First, I offer the concept of **temporospatial coupling**, to capture the fact that cost estimates may only support local value improvements for a limited time and in a relatively small 'site' or group of individuals[39]. They only reflect current ways of working, current protocols, and current practices for a limited amount of time before they can be considered outdated or insufficiently specific by staff. They are tied to the time, space, and choices made during their construction. A significant body of prior research has used the concept of decoupled or 'loosely coupled' organizations to characterize healthcare organizations (Kurunmäki et al., 2003; Lapsley, 1994; Richardson, 1987; see also Weick, 1976), wherein accounting figures like cost estimates cannot inform decisions because of their reliance on protocols that don't perfectly apply to specific patients (**chapter 3**). In this project, the estimates calculated were briefly coupled to practice before slowly growing outdated; They may best be understood as a snapshot of an evolving reality, given how quickly protocols are updated and new technologies become available. Building on these findings, and using a practice theoretical view, the concept of temporospatial coupling captures the fact that such estimates must be maintained to remain useful. For example, the comparison made in **chapter 5** between the vitrification method and the cryopreservation method was wholly dependent on the local norms and practices of the IVF laboratory at that very moment (i.e. how much material was used, the workflow of the cryopreservation method, etc.). By now, the ways of working have changed, and new comparisons may have become relevant to explore. The care delivery shift to vitrification was enabled, at that moment in time, by the comparison of how both techniques were conducted following this laboratory's practices and expenses. This suggests that future VBHC implementation efforts must focus on building enabling information systems locally, using locally produced data, rather than aiming to produce averages or 'reference' costs. This is in line with findings by Eldenburg et al. in a standardized care setting (2010) and contributes to research on ABC-type system implementation (Campanale et al., 2014; Conceição et al., 2023; Defourny et al., 2023; Gosselin & Journeault, 2021; Malmmose & Lydersen, 2021). Importantly, any future efforts to implement TDABC should use local data in traceable ways and allow users to select suitable cost predictors and update these as processes and protocols evolve.

39. This term is inspired by Barad's notion of "spacetimemattering" which refers to the fact that measurements are tied to the space, time, and matter in which they are constructed. They are subject to the (scientific) practices in which they were constructed (Barad, 2007, pp. 179–185), just like a cost estimation system like TDABC involves significant choice-making.

Secondly, taken together, the studies suggest that building an 'enabling technology platform' is a process (not an outcome) and should be prioritized as the first step towards VBHC. It is typically listed as the last and final element of VBHC implementation, as also shown in **Table 1.2** in the introduction of this thesis. Recent prior work on VBHC has concluded that identifying value improvements remains challenging, even if outcomes and costs are quantified, because such quantifications do not help individuals identify improvement opportunities (van der Nat, 2022). This fact – that outcome measures alone do not inform actions - is in line with prior findings that DRG-type cost estimates become black-boxed as nuance and complexity is removed (Chua, 1995; Preston et al., 1992; see also Robson, 1992). The findings of this dissertation suggest that such figures are not useful if individuals do not understand what actions or decisions led to them; Instead, by co-creating infrastructure like TDABC, clinicians and managers may gain understandings of how decisions lead to particular cost or performance outcomes. In this process of infrastructure construction, value improvement opportunities can become visible, debatable, and to some degree manageable if sources of variation are identified and 'managed', for instance by choosing new protocols that alleviate workload for specific resource groups like laboratory staff in the case of vitrification (**chapter 7**). Whilst this step of information technology or infrastructure construction typically described as being the last step towards organizational implementation of VBHC strategies (see **Table 1.2**), the results of this dissertation suggest that it is a *prerequisite and ongoing process* that units or departments must undergo to identify value improvement opportunities as care delivery methods evolve over time. From this practice-based perspective, the process of measurement and evaluation can lead to the discovery of sensible future paths of action – such as, for example, choosing to invest in the vitrification technology to alleviate workload in the most frequently repeated type of treatment (FET). This performative perspective of measurement and evaluation is in line with findings from other fields and settings that emphasize the performative power of accounting in organizations (Revellino & Mouritsen, 2015; Salais & Mennicken, 2021; Sharma & Lowe, 2023). Future VBHC implementation projects should therefore start by building an enabling infrastructure, and in doing so, explore opportunities for reorganization and efficiency as systems like TDABC shed light on how, where, and when resources are used and whether such resource consumption is valuable. Doing so in a bottom-up fashion, rather than imposing particular systems in a top-down manner, is vital.

Thirdly, while most (Dutch) VBHC initiatives have emphasized improving patient outcomes through the use of patient-reported outcome and experience measures (PROMs and PREMs) (Cossio-Gil et al., 2022; Steinmann et al., 2021; van Engen et al., 2024; Vijverberg et al., 2022), I argue for a shift in emphasis. By focusing first on the cost side of the value equation—particularly through reducing workload for HCPs and improving resource efficiency through process improvements—VBHC initiatives may yield meaningful improvements in performance and sustainability without immediately relying on PROM/PREM data. In the context of fertility treatments, for example, laboratory protocols and technologies impact success rates and costs but do not directly shape the patient's experience of care. The precise technology used to freeze and thaw embryos, or evaluate them, significantly impacts costs and success chances but do not change the patient's experience. While PROMs and PREMs remain important components of VBHC, this research shows they are not always essential for enhancing value—especially in clinical processes that occur outside the patient's view. A cost-first approach can also reduce the burden on clinicians by avoiding the early introduction of additional data collection and evaluative tasks. By streamlining workflows and improving efficiency before layering on new responsibilities (such as evaluating and acting on PROMs and PREMs), VBHC efforts may prevent clinician overload and the frustration or VBHC abandonment that can stem from lacking adequate infrastructure. Recent research has, for instance, shown that PROMs or PREMs are challenging to implement and may rarely be opened or used by clinicians overwhelmed with new responsibilities (van Engen et al., 2025). This cost-first approach to VBHC may better support workforce wellbeing and lay the groundwork for more sustainable and resilient care delivery.

10.3 Implications and paradoxes of studying 'value'

The findings offer overarching implications for studying 'value' and cost management in healthcare. These implications appear as three methodological paradoxes. Being aware of them, and theorizing them further, may be relevant for future research or projects tackling rising healthcare costs through data-driven interventions or accounting (e.g. using dashboards, TDABC).

First, the chapters reveal that studying healthcare value improvements implies studying something that does not exist *yet*. The costs of treating one patient, across an entire medical condition, can only be calculated once the patient is 'finished' with their trajectory. Yet, to reduce costs of care as these treatments unfold, individuals must make decisions now, in the present moment, as the patients' trajectory is unfolding (**chapter 3**). Specifically, because

(a) hospitals and healthcare providers feature only 'loosely coupled' systems that do not offer cost estimates at the patient or treatment level **(chapter 2, 3)**, and

(b) cost estimates are wholly dependent on the method used to quantify them and are not 'out there' for us to 'observe' **(chapters 2-6)**, and

(c) healthcare delivery is personalized such that costs and value vary per patient, and are constantly evolving as new technologies shift resource use patterns **(chapter 3, 5, 6)**,

(d) healthcare processes evolve over time, such that the methods and protocols used to deliver (for instance) IVF are not identical to the methods and protocols to deliver that same IVF treatment one year later

studying 'value' (defined as performance in relation to the costs of resources used) implies studying how individuals strive to achieve something that is not yet there and constantly changing. Paradoxically, value can only be calculated by the time it is too late to intervene, to improve it, to act for that patient. Additionally, by the time a trajectory has elapsed, treatment processes have changed, rendering the calculations of prior patients only limitedly relevant to clinicians treating new patients. I argue that a practice-theoretical approach to is particularly effective for studying such non-existent things (cost estimates) and how individuals in organizations learn to strive for incalculable goals like 'value'. Practice theories are post-structuralist; they reject the idea that social phenomena are 'out there' for us to discover; instead, these phenomena are viewed as being in a constant state of becoming or change (Schatzki, 2002, p. 255). The key takeaway here is that, by engaging with the field and providing new cost and performance management systems, the researcher is co-creating the phenomenon they are trying to study and impacting what is considered good or valuable to do. This has practical and ethical implications to consider.

Secondly, taken together, we might be able to conclude that value as I have defined it here can best be understood and studied as an epistemic object (Knorr Cetina, 1997; Nicolini et al., 2012). Value is constantly out-of-reach but just barely-in-sight. For instance, at the time of conducting the quantitative analysis, and when it became apparent that the vitrification technique improves the value of all subsequent treatments for any patient treated with it (**chapter 5**), choosing it appeared obvious. Improving value was just out-of-reach, only dependent on making this one choice, training staff to be able to use the new technique, and so on. By now it is 'usual care', and there are new out-of-reach techniques that the clinic is currently exploring in the hope of further improving value (for example, the Rescue-ICSI procedure quantified in **chapter 5**). Yet, such choices are only rendered barely-in-sight through the analysis that was conducted, making it performative. What is calculated and measured shapes what is strived for or considered 'valuable' to do. However, there are many other avenues for value improvement we did not calculate, and that therefore were not considered 'valuable' and thus never strived for[40]. Whilst some research has suggested that cost or performance estimates can act as boundary objects, my results point to the epistemic (practice-generating) nature of value quantifications (Nicolini et al., 2012). What is calculated becomes the aspirational goal, visible only through the practices in which the calculations are made by researchers, data specialists, clinicians and managers (Scott & Orlikowski, 2012). As care processes, patient populations, and the costs of resources (materials, salaries, etc.) change, so do perceptions of what actions are or are not 'valuable'. This perspective is in line with the perspective that accounting infrastructures don't simply make ideas operable, but "shape economic thinking itself" when viewed as relational phenomena (Kurunmäki et al., 2019, p. 19; Reilley & Scheytt, 2019; Star & Ruhleder, 2001).

Thirdly, I suggest that future research into value improvements, via implementing TDABC and/or other quantitative technologies like dashboards, views these systems as shifting **apparatuses of practices** (Barad, 2007). Apparatuses are collections of material-discursive practices such as those explored in **chapters 3 and 7** (e.g. recording expenses in an excel sheet, calculating cost estimates according to particular rules and norms). This would lead to impactful research, because the preceding chapters have revealed the fundamental role that record-keeping plays in (attempting to) implement new calculations or technologies, and in shaping what can or cannot be calculated and strived for. Record-keeping practices thus introduce path dependency, when calculations are required to choose or legitimize some decisions

40. A notable example of this is alternative methods or processes of petri dish preparation one day prior to IVF procedures. During this costly treatment step, petri dishes are prepared manually based on uncertain estimates of how many oocytes are likely to be extracted and fertilized the following day. It is highly reliant on the embryologists' skills and experience and can cause stress, fatigue, and repetitive strain injury over time (Zhu et al., 2023). **Chapter 3** revealed how costly these steps are, and **chapter 5** suggests this avenue for future research, but the clinicians/managers did not wish to explore this line of calculation. This was due to a perceived lack of autonomy to change these processes, even though automated dish preparation and barcode tagging are used elsewhere, and might reduce waste, improve value, and reduce work pressure (Novo et al., 2014; Zhu et al., 2023). In offering this example, I am not saying that this should be done, I am only seeking to illustrate my argument that the calculations led to some explorations of value improvement opportunities (and thus practice shifts) but not others.

over others, because hospitals generate specific and limited forms of data and performance traces. The analysis in chapters 3-5 required vast quantities of manual data collection, and revealed that the data produced in healthcare organizations is never 'raw' (Harper, 2003, p. 47) but rather tailored for specific practices such as DRG billing. Developing a TDABC system, therefore, required significant raw data collection, and maintainting such as system requires new and different data collection practices going forward. By viewing TDABC as an apparatus of practices, future research should explore how new record-keeping practices lead to long-term learning and/or value improvements, when the new 'raw' data that is collected can ultimately make it into calculations that legitimize different paths of action in future. The paradox, in this case, relates to the fact that infrastructure (like cost estimation systems) are *nothing but* practices, but that past data collection or logging practices limit future quantification practices. Studying how calculations come to matter in practice, by reducing resource consumption, is therefore never about the calculations or metrics themselves but only about how they are perceived and what actions and practices they can set in motion (see also Kurunmäki et al., 2019).

Lastly, taken together, the chapters raise several noteworthy ethical and practical challenges to consider when co-creating cost management systems and intervening in practice. First (1), across the chapters, the work required to develop an enabling TDABC-PM system is evident, and much of this work relates to the mismatch between how hospital data systems are organized vs. what contemporary clinicians and healthcare managers currently find informative. Whilst some research suggests that metrics, like total cost sums, are generated more or less 'automatically' (Begkos et al., 2023), this thesis sheds light on the labor this requires in personalized care settings and when treatments involve multiple medical specialists (as is the case with IVF, see **chapter 5** and it's lengthy appendix, which illustrates how much 'raw' data must be generated to make such a system feasible). It would be imperative for future research to focus on generating enabling infrastructure that is maintained in the organization long after research projects are completed, because the chapters collectively suggest that cost estimates will become outdated at an increasingly rapid pace, and because they must come to influence decisions and actions to actually reduce resource use. Secondly (2), given that cost information may just make the inevitable trade-offs of care delivery more evident to clinicians, I reiterate here that introducing ever-more granular cost estimates might contribute to clinicians' workplace stress if there is no actionable way for clinicians to improve such metrics. This warning goes beyond stating that such metrics should never be used to evaluate individuals' performance – given that clinicians experience felt accountability towards cost outcomes, presenting such metrics (even without coupling them to performance measures) may have detrimental effects, and this thesis in no way advocates for mandatory or greater use of performance or cost measures in daily medical practice.

10.4 Implications for policy and practice

The work offers concrete implications for policy and practice. Based on the discussion so far, it may be concluded that (1) cost estimates must reflect local practices and expenses to be reflective of organizational costs and to be viewed as relevant and actionable by HCPs, (2) should be traced retroactively as new technologies and protocols shift practices and resource use in unpredictable ways across entire patient trajectories/medical conditions, and (3) can improve the psychological wellbeing and motivation of the workforce if they are experienced as enabling. By satisfying psychological needs, enabling cost information can improve motivation and cost management behavior.

10.4.1 Value-based fertility care

These implications relate to the ongoing implementation of VBHC and value-based fertility care in the Netherlands (e.g., Bensink et al., 2023), and how fertility treatments are reimbursed and incentivized. By developing, implementing, and evaluating a novel method of patient-level cost estimation, this research contributes the infrastructure needed to inform payment schemes and benchmark costs and practices in the form of a customizable tool developed in **chapter 5**. Moving forward, to continue such evaluations as technologies change (Perrotta & Geampana, 2020), it would be important to maintain the infrastructure developed during this project. Such updates should occur as changes are made to technologies and protocols (**chapter 7**), to trace their impact as it unfolds. Beyond updating the CCRs and duration estimates (as input costs and care delivery practices change) it would be important to reevaluate the cost predictors chosen in **chapter 5**, and to continuously investigate core activities or decision-making moments that greatly impact costs later down the line of a pregnancy trajectory. For instance, while the implementation of vitrification in IVF treatments impacted later costs (**chapter 5**), during FET treatments, other technologies and protocol changes may bring about other unanticipated changes. For instance, structural use of rescue-ICSI protocols would shift resource use to earlier treatment rounds and may again decrease the total number of treatment rounds needed.

The preceding chapters and discussion raise several policy issues worth discussing. Firstly, the analysis revealed that IVF treatments are (on average) under-reimbursed which may endanger the sustainability of care delivery now (**chapter 5, 7**). Specifically, because the costs of delivering large cycles of IVF and IVF-ICSI exceed their reimbursements, and because such large cycles are most common in the patient population and, this means that IVF treatments currently generate financial losses in the Dutch system, particularly as clinics implement value-improving technologies like vitrification (**chapter 7**). If this is not remedied, this issue may escalate because:

1. The prevalence of subfertility is rising (WHO, 2023), which is increasing treatment demand and waiting times, whilst the availability of staff is declining.

2. Improving care delivery, in terms of patient outcomes and total pathway costs, implies increasing costs during a single treatment cycle early in the trajectory (**chapters 4, 5, 7**).

3. Patients increasingly request IVF and ICSI over other (less costly, less invasive) treatments during shared decision-making (Gerrits, 2016), and a relative rise in IVF or IVF-ICSI vs. other treatment options (IUI, OI) may further endanger the financial viability of clinics (**chapter 7**).

4. Increased adoption of vitrification over cryopreservation methods may lead to decreases in FET treatment numbers, further reducing clinics' ability to recover financial losses incurred during large IVF or IVF-ICSI treatments.

In combination, these factors suggest that the reimbursement for IVF treatments specifically (IVF, IVF-ICSI, IVF-Combi) should be reconsidered. That is, as more resources are used and more work is done in the laboratory phase of treatment of a single treatment, and early on during entire patient trajectories to reduce total treatment durations, reimbursements must be adjusted reflect these changes. The analysis suggests that per-treatment DRGs are not optimal for reimbursing fertility treatments more generally. Patient trajectories, from initial consultation to pregnancy and birth, consist of an initial diagnostics phase followed by some combination of treatment types, which adhere to common patterns and are perceived as total packages (**chapter 7**) rather than individual treatment rounds (see also Gerrits, 2016). Given that clinics are increasingly shifting resource use toward earlier treatment cycles without necessarily decreasing the overall workload per patient, a bundled payment per pregnancy could offer a better alignment between reimbursement and actual resource use (Eijkenaar, 2020). The average per-patient trajectory costs calculated in **chapter 5** using TDABC-PM can serve as a foundation for such payment negotiations but should ideally be complemented by similar analyses across multiple clinics.

Secondly, the analysis suggests that the value of IUI treatments is dependent on their relative timing in the patients' trajectory, and that clinics should reconsider the policy to require 6 IUI treatments before granting patients access to IVF or ICSI. As the 5^{th}, 6^{th} or 7^{th} consecutive IUI treatment rarely or never resulted in pregnancy, and were followed by other treatments, clinics should consider only requiring patients to undergo four cycles of IUI prior to more invasive treatments. The timing of treatments within the care trajectory should therefore be considered a potential explanatory variable in retrospective analyses, as it may significantly influence both outcomes and resource use.

Lastly, these chapters underscore the need to prioritize research into the prevention of male-factor infertility, which clinicians identify as a key driver of increasing cycle sizes and reliance on ICSI specifically. The most resource-intensive treatments identified in **chapter 5** —large ICSI or IVF-ICSI combination cycles—are often initiated when male-factor subfertility is diagnosed or suspected (Levine et al., 2017). In such cases, it can be common to generate a high number of oocytes and embryos that ultimately degenerate, or do not result in pregnancy after implantation. Additionally, these treatments place a disproportionate psychological, physical, and economic burden on female patients, as the majority of procedures are carried out on their bodies—even when they are healthy and fertile. Therefore, efforts to prevent male factor subfertility, or improve clinicians' ability to identify sperm with higher success chances, could significantly aid in preventing treatments and thus resource consumption per patient.

10.4.2 Value-based care and workforce challenges

The results illustrate that methods like TDABC may best be used to evaluate care delivery shifts after they have occurred, rather than to prospectively 'inform' investments. **Chapters 5** and **7** illustrate that, as new technologies are implemented, they have unpredictable consequences on workload and care delivery costs that stretch beyond the activities they change in the process. For instance, the fact that vitrification increased costs and disposables use early during the pregnancy trajectory, but prevents later FET treatment cycles, could not be predicted and the cost impact of this choice unfolded over time.

Future policies hoping to enable VBHC in the Netherlands should enable and incentivize healthcare providers to invest in 'enabling infrastructure' for local cost estimations, without pressure to follow any specific method, and without pressure to publish or benchmark such costs[41]. Doing so may not only improve resource efficiency, but also the wellbeing of staff that is struggling with resource constraints. The chapters reveal that fertility clinics and hospitals more generally are currently unaware of (and unable to estimate[42]) the costs they incur to deliver care. It cannot be assumed that Dutch healthcare organizations are able to lead informed negotiations regarding appropriate cost-covering reimbursements for fertility treatments in the Netherlands (Busse et al., 2013, 2011). Such initiatives can use the materials made available in chapter 5 (appendix J) and can use the survey instrument developed in chapter 8 (appendix N), to monitor how such enabling cost information contributes to healthcare staffs' psychological well-being, motivation, and cost management behavior over time.

On a broader scale, the method developed in **chapter 6** can guide policymakers in identifying specific resource consumption patterns in larger patient populations. Because the cost mining method can identify treatments that are both resource intensive and utilized by a high absolute number of patients, it should be used to select treatments for future cost and workload improvement studies. It could be used to, for instance, identify organizations that would benefit from enabling infrastructure construction.

10.5 Suggestions for future research

10.5.1 Workforce challenges

Considering the findings and contributions discussed, I can encourage several broad avenues for future research. My first recommendation relates to the topic of workforce skills and wellbeing, given the growing adoption of cost and performance technologies including TDABC and dashboards, and ongoing workforce challenges in health systems (Abdul Rahim et al., 2022; Walshe et al., 2024; WHO, 2022). Currently, the healthcare workforce is struggling to keep up with patient volume and requesting

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41. This advice opposes arguments made by some proponents of TDABC, who argue for publication of total cost sums.

42. The preceding chapters have revealed technical and social barriers to cost estimations. **Chapters 4-5** illustrate that the data required to do this originates in decoupled hospital systems (these were manually extracted, cleaned, and merged by the researcher) or is not routinely recorded and digitized (e.g. laboratory expenses – these were manually digitized by the researcher), and that clinicians and managers lack the practical understandings and time to set up such systems. Taken together, the efforts required to build the TDABC infrastructure illustrate why such systems are rare.

infrastructure and support to manage scarce resources (Ahumada-Canale et al., 2023). Future research could generate and implement co-created systems (such as TDABC-PM), whilst tracing if and how doing so changes local practices and user's wellbeing (*autonomy, competence, relatedness*) and motivation using the constructs from **chapter 8**. Such research could generate insights regarding how, when, and why enabling cost information leads to psychological wellbeing, motivation, and behavior. This approach could compliment the approach I have taken here, by longitudinally assessing if and how the implementation of a (hopefully) enabling accounting technology improves staff wellbeing. Such research should explore if elements of 'enabling cost information' are temporally related (e.g., perhaps global transparency is a prerequisite to repair work), which would expand our conceptual understanding of when and how cost information becomes 'enabling' as found in **chapter 8**. Together, **chapters 2-8** reveal that cost information needs to be tailored to its users, and customizable by users, to be integrated into practice and contribute to psychological wellbeing – whilst this speaks against hospital-wide implementations of the same system, it does suggest that new infrastructure could be evaluated in a standardized way by tracking individual's perceptions of wellbeing and motivation.

10.5.2 Personalized care, performance measures, and cost variation

My second recommendation relates to the topic of personalized care and cost variation[43]. Collectively, this thesis illustrates how care that is labelled standardized (in a medical sense) can generate cost variation, because each patient undergoing the same treatment requires different care activities and resources during care delivery (**chapter 3-5**). What is labelled standardized care can, in practice, imply tailor-made care delivery and thus personalized resource use and costs (cf. Llewellyn et al., 2022). Future research should qualitatively research if and how medical protocols are adjusted in response to performance variation data, such as those generated in **chapter 5**, to further explore the complex role of rules (like medical protocols) in cost reduction strategies. Whilst rules did not improve practical understandings in **chapter 3**, there may be better ways to formulate and present protocols to support clinicians in making challenging ethical tradeoffs between resource use, treatment success chances, or other important goals. Further, this research should examine when, how, and why clinicians deviate from protocols as they increasingly engage in accounting practices like cost cutting, cost allocations, or cost evaluations, and continue to gain practical skills in cost allocations beyond the skill levels observed

43. This term, 'personalized care', is not to be confused with 'personalized medicine'. Personalized medicine commonly refers to customized medications, such as gene therapies, which can be produced in standardized ways. On the contrary, 'personalized care' refers to treatments in which, according to protocols and indications, different patients require different or adapted care activities in a care path (**chapter 3, 5, 7**).

here. In the shift towards evidence-based care towards value-based care tailored to individual patients, healthcare organizations could consider conducting retrospective multidisciplinary team evaluations of how or where value was generated for a specific patient.

This recommendation also relates to future VBHC implementation studies. Such research typically assumes that both costs and outcomes can be standardized, and that improving the value of care implies treating treatments as cost objects[44]. Instead, these chapters establish that VBHC initiatives need to treat patients as cost objects, rather than costing treatments (Robson, 2008), to enable local cost reductions or cost management, as e.g. Dutch fertility care treatments are tailor-delivered to individual patients. This holds true for many other medical conditions (e.g., van Weert & Hazelzet, 2021), but also makes intuitive sense. Clinicians do not prescribe diagnostics, consultations, or additional treatment steps for all patients – instead, these are prescribed as and when they are needed. Understanding how and why patients or patient groups need more resources, receive greater value, or incur lower costs requires researching cost variation within treatments, across patient's trajectories, not average costs per treatment. Within fertility care, it would be particularly relevant to study such deviations (and the resulting cost and performance variation using e.g. TDABC and PREMs/PROMs) for patients suffering from endometriosis, which is an extremely costly and painful condition with long patient trajectories and poor outcomes (Simoens et al., 2007; WHO, 2023).

10.5.3 Accounting for healthcare (and automation) to ensure financial sustainability

Third, I urge future research to revisit the definition of variable and fixed costs in (healthcare) settings that are increasingly automated using technology, because relying on TDABC or unit cost estimates in such cases is misleading and may inadvertently displace costs (rather than reduce them), and may introduce new organizational risks. When allocating costs using TDABC, any intervention that reduces the time spent by clinicians immediately appears favorable, everything else being equal, because all costs are allocated based on time spent 'directly' delivering care. However, automation through technologies like AI embryo selection (**chapter 5**), while potentially streamlining clinical workflows, introduce other costs and tasks, and these costs are typically excluded from TDABC analyses. For example, time-

44. In the health services literature, this issue is rarely discussed (Malmmose & Lydersen, 2021). In economic literature, it is standard to assume that one rendition of one treatment always costs the same to deliver and the lengths of time covered by DRGs vary per country (Špacírová et al., 2022). In the managerial accounting literature, the appropriate 'cost object' for healthcare cost accounting has long been debated (Robson, 2008, pp. 352–357).

lapse embryo monitoring in IVF (analyzed in **chapter 5**) reduces the time spent by staff on 'direct care delivery' tasks but necessitates new skills and tasks, such as evaluating the AI's output at desks 'away' from the care delivery process. Such "Digi-work" is necessary (Justesen & Plesner, 2024), can take significant time and skill, and thus generates new costs not previously incurred (e.g. because the clinician must spend time evaluating the output data). Automation technologies that require digi-work may thus shift costs from care production to organizational overhead tasks, rather than reducing costs, rendering the unit cost calculated misleading, or minimally, irrelevant to projections about how new technologies will reconfigure resource use once they are implemented (**chapter 7**). Such tasks must be included in TDABC analyses, e.g. via CCRs, to prevent false conclusions. Yet, doing so would increase the relative volume of indirect costs that must be allocated based on time spent, making the TDABC system even more sensitive, and dependent on accurate duration measures. Nonetheless, excluding such tasks from analyses not only risks underestimation of total costs, but also risks adopting automation technologies such as AI or telemedicine under false pretenses or promises of efficiency (Carboni, 2024), as also illustrated to some extent in **chapter 7**. As healthcare delivery is increasingly mediated by digital and physical machines, research should explore how distant 'indirect' staff time should be allocated appropriately. This might, for instance, imply that machines generate the direct costs of care delivery (Clark, 1923, p. 26), and healthcare professionals' salaries are viewed as indirect costs to be allocated as they maintain and coordinate the machines around them (Hui, 2016; Simondon, 2017; Stiegler, 1998)[45]. From this perspective, staffs' daily work will increasingly consist of valuation practices and tasks that cannot be automated (as shown in **chapter 3**), e.g. deciding which patient receives what element of care delivery and why, as the mundane or automat-able elements of care delivery are automated, leaving the ethical and evaluative work to clinicians. Relatedly, investing in such technologies under premises of efficiency may introduce organizational risk that can endanger care delivery, especially in the IVF setting. Many laboratory tasks are dependent on the tacit, practical skills of clinicians, who only reach this mastery through repetition (Zhu et al., 2023). Replacing such tasks with automated technologies risks 'deskilling' embryologists, who may lose the skill to e.g. evaluate many embryos under time pressure (**chapter 5**), which may pose risks to clinics in case of system failures.

45. Such tasks – coordinating, maintaining, and evaluating the output of machines is classified as an indirect cost because such tasks do not relate to one specific patient. This is opposite from how costs are classified now, as equipment is often viewed as an indirect cost and staff's salaries are viewed as direct costs.

10.5.4 Sustainability and planetary health

Further, I encourage future research to expand on the themes explored in this dissertation, particularly in relation to sustainability and the topic of planetary health (Myers, 2017). This dissertation has introduced a novel method for allocating organizational costs to patient trajectories based on resource consumption (TDABC-PM). As shown in **Chapter 3**, however, concerns around cost and sustainability are deeply intertwined in medical practice. Physical objects—such as petri dishes or single-use plastics—visibly confront staff with the volume of waste generated daily. Some waste-intensive practices, like treating reusable instruments as disposables to cut organizational costs, can lead to inefficient workarounds because staff can feel accountable for this. Future research could extend TDABC-PM to incorporate and allocate planetary costs—such as carbon emissions or waste production— thereby enabling the design and evaluation of targeted waste-reduction initiatives (e.g., Di Russo et al., 2024). Applying TDABC-PM to a broader definition of costs by, for instance, allocating planetary costs to treatments using time spent as a driver, could help identify where, when, and why waste is produced in pragmatic ways.

In doing so, researchers could follow the same longitudinal, interventionist approach outlined earlier, by examining how such systems influence staff wellbeing, motivation, and capacity for action as examined in **chapter 8**. As shown in **chapter 7**, efforts to co-construct new practices may lead to novel compromises—such as trading off organizational cost-efficiency for reduced environmental impact or other notions of worth. This would involve allocating these broader costs of healthcare delivery to treatment processes or trajectories and analyzing how such new forms of accountability are received in practice—whether embraced, resisted, renegotiated, or even rejected as suggested by some (Patrizia et al., 2023; Vollmer, 2019, 2020, 2023). As TDABC-type systems are constructed, decisions must be made about which factors are seen as 'manageable' cost drivers and which are treated as random or beyond control – this process offers unique insight into how individuals or groups deliberate accountabilities, or act on the information produced through TDABC-type systems. Future research tracing such interventions could focus explicitly on how individuals accept or reject accountabilities to others in practice, and how they customize accounting systems to suit their current autonomy or even expand it.

10.5.5 Teleological indeterminacy and the 'cost' side of the value equation

The chapters have illustrated that, to impact costs or resource consumption in consequential ways, clinicians must anticipate how actions (now) may lead to distant outcomes like organizational costs or medical outcomes – such outcomes may only manifest months or years later. In **chapter 3**, we have explored how the fertility care setting features significant distance and uncertainty within what practice theorists like Schatzki call 'teleoaffective structures' – the actions, tasks, and goals of socially shared practices. In this setting, the actions and tasks completed during care delivery are very distant from the outcomes they hope to achieve, such as pregnancy, and we coined this feature of the setting *teleological indeterminacy*. Further, the chapter suggests that task-level performance measures, such as embryo counts, can performatively increase the amount of work done during individual tasks. This was partially due to fears of 'compromising' a treatment by doing too little during any one task, and partially due to clinicians' desire to maximize such short-term performance measures which were viewed as indicators of success. Overall, it was evident that clinicians (when in doubt) chose to do more, rather than less, and that this can lead to high-cost cases and greater work pressure than potentially necessary.

Future research should investigate the circumstances in which clinicians consider it appropriate and beneficial to do less, rather than more. This could contribute valuable insights into workforce wellbeing and the management of resource scarcity. For example, such studies could inform revisions to institutional rules or protocols that currently discourage clinicians from deviating from standard procedures by doing less—even when their professional judgment suggests that doing less is more valuable or appropriate. At present, personalized care tends to create a baseline level of work for all patients, with additional peaks when clinicians believe more intensive care is justified. During observations, clinicians frequently remarked that certain tasks felt unnecessary for specific patients, or that they performed additional work primarily to avoid feelings of having compromised a treatment cycle by, for instance, injecting as many oocytes as possible even when it was evident that they would not develop into embryos and instead degenerate. Future research could explore when and how "doing less" is seen as acceptable—especially in cases where clinicians recognize that extra work does not improve outcomes. Supporting such decisions may would reduce workload and allow HCPs to focus their efforts on cases with the greatest need, rather than necessitating work that professionals know not to be valuable. Ultimately, value can also be enhanced by avoiding unnecessary tasks or resource use that do not meaningfully contribute to outcomes or patient experience. This side of the metaphorical 'value' equation deserves greater scholarly attention and may offer significant insights into how, when, and where waste and overwork can be avoided.

While research often emphasizes success stories, future studies focusing on the cost dimension of the value equation should, where possible, also report on implementation challenges and failures. Throughout this dissertation, I have incorporated critical reflections informed by a rich body of accounting literature on ABC-type systems and their limitations in public sector contexts (e.g., Jones & Dugdale, 2002; Briers & Chua, 2001; Gosselin & Journeault, 2021). The chapters illustrate not only the successes but also the practical difficulties of implementation, highlighting how the co-created system has both achieved impact and encountered setbacks. For example, although the system helped justify the investment in vitrification (**Chapters 5 and 7**), the findings demonstrate how cost and resource consumption patterns can evolve in unexpected ways, shaped by technologies and equipment. By openly reflecting on such failures and the compromises made during system development and use, future research can help prevent hospitals and other provider organizations from misallocating scarce time and resources. Crucially, such research should focus on the process by which these systems are constructed and how they inform medical practice, HCP wellbeing, and lead to local learning, rather than only publishing their quantitative results.

10.5.6 Accounting as actions in medical practices, and practices that transform medicine

Lastly, it must be noted that the practice-theoretical perspective on accounting taken in this dissertation deviates from prior work, but may inspire future research to explore how accounting transforms medical practices from within. Prior research has, for the most part, explored how top-down imposed accounting practices or rationales compete with caring or curing logics, or restrict medical autonomy on the work floor (Begkos & Antonopoulou, 2021; Carr & Beck, 2020; Fırtın, 2022; Gebreiter, 2021; Kurunmäki et al., 2003; Llewellyn et al., 2022; Morinière & Georgescu, 2022). For instance, prior research in the UK has explored how managers encourage non-managerial clinicians to engage with accounting (Begkos & Antonopoulou, 2021), or how some medical professionals accept managerial logics to improve their ability to care for patients (Llewellyn, 2001). From this perspective, economic rationales colonize and displace clinical culture, and can threaten clinical practice or caring and curing logics through the spread of accounting ideas (Lapsley, 2007, p. 371; Sjögren & Fernler, 2019, p. 898). Instead, this dissertation has found that care delivery practices consist of and rely on accounting actions to make them function in practice, and that decisions regarding how to act and proceed for individual patients involve a combination of cost and performance considerations. This perspective is in line with broader definitions of accounting as processes of recording and evaluation in daily life (Power, 2022; Stiegler, 1998; Vollmer, 2024). The findings illustrate that there (a) is no clear divide between managerial and medical practices, in line with prior research that has questioned such divides in other settings (Jacobs, 2005a; Sjögren & Fernler, 2019), and (b) suggests that this dichotomy between 'economic' or 'professional' reasoning may not be useful to future research in medical settings, given their reliance on accounting actions and practices in daily work.

By recognizing that clinicians look to accounting to manage and coordinate care, I would recommend that future work traces how specific medical practices change as clinicians develop and maintain new cost estimation systems like TDABC, and how this may change their views or opinions of what is valuable to do over time. Such work could build on the findings of this dissertation and prior work on ABC implementations (e.g., Arnaboldi & Lapsley, 2004; Campanale et al., 2014; Conceição et al., 2023; Gosselin & Journeault, 2021; Briers & Chua, 2001). Whilst this literature has often viewed ABC systems as processes of legitimation that allow healthcare organizations to become 'modern' (Jones & Dugdale, 2002), the results of this research project suggest that clinicians may view such systems as learning opportunities, particularly when resources are scarce or when treatments place a significant burden on patients (as is the case with fertility treatments). Further, during the process of system construction, some of the inevitable cost variation explored in clinical data is chosen to be viewed as random and averaged out, particularly when clinicians cannot act on it or improve it. This reduction of complexity contributes to the actionable character of such systems but may limit their long-term impact or relevance for internal cost management; If they are not updated to reflect present-tense processes, they may even suggest standardization where there is none or anchor outdated beliefs – this should be studied further. These findings align with recent research on algorithms, which has suggested that AI systems must be open and traceable to gain trust and/or influence actions in healthcare settings. Future work may benefit from considering the similarities between algorithms and complex cost allocation systems.

10.6 Reflecting on the methods: Interventionist research using ethnographic and quantitative methods

In this dissertation, I combined a qualitative systematic review and organizational ethnography with quantitative, applied methods like TDABC-PM, and a survey study. This approach is uncommon, and considered risky by some5[46]; these methods require different skills (Lukka & Wouters, 2022, p. 7), draw on different types of data (e.g. quantitative, qualitative), and lend themselves to different or opposing epistemological and ontological assumptions (i.e. research paradigms). Essentially, to combine interpretive ethnographic and quantitative methods, you have to multiply yourself, and move fluidly between positivistic and constructivist modes or styles of thinking, reading, and writing (Lukka & Wouters, 2022, p. 7). **Chapter 9** has explored how and why this can be challenging. Here, I offer a personal reflection on my influence on the ethnographic research, reflect on the important role of context, and comment on how the combination of ethnographic and quantitative methods benefitted the dissertation.

When conducting interpretive organization ethnographies, researchers must reflect on their personal influence on the research (e.g., Bryer, 2018; Kunda, 2006; Mol, 2002; see also Van Maanen, 2011a). My field notes and observations were influenced by my education, background, and personality, which shaped what I found surprising or noteworthy. First, my business school education has attuned me to notions of efficiency – normative ideals suggesting that work can be organized efficiently to reach some form of 'optimum', in a positivistic sense, and this assumption influenced how I entered the field, what I recorded in fieldnotes, and the questions I asked. At the start, for instance, I was baffled by the idea that hospitals do not allocate or their costs, and that unit-level management typically doesn't know if their revenues (DRG reimbursements) cover their costs or not. Having been taught to develop strategies,

46. The outcomes of ethnographic work are uncertain (Neyland, 2007), the timeframe of fieldwork and subsequent theorizing is challenging, and the work associated with an interventionist field study can be high. For instance, I spent considerable time cleaning and merging clinical data to enable the quantitative analysis, given that hospital data systems are fragmented and disconnected, and these fragmented data were (in some cases) extracted or received with more than a year of delay. Such fieldwork may not be feasible for every PhD project. However, by conducting this fieldwork and reporting on it, this dissertation has offered significant and nuanced insights into how, when, and why co-created cost management systems can result in practice shifts.

depreciate assets, and build impressive slide decks that 'tell stories' with data[47], I was expecting to find cost data and cost management practices to report on – a lack thereof surprised me, initially, and featured heavily in my notes, observations, and meeting minutes, and led me to investigate more implicit ways in which cost considerations impacted daily decisions. Additionally, because I have been a foreigner my entire lifeF[48], it was easy for me to be curious, ask questions, and thereby gain access to the field and to gain emic insights[49] – this gave me a significant advantage in conducting the research, and in combining methods in this way. Wearing scrubs and observing medical practices felt like yet another culture to assimilate into and came very easy to me. Although many researchers report feelings of loneliness during ethnographic immersion, I did not experience this, in part because the fieldwork involved significant cooperation with clinicians, managers, and data specialists. In that regard, the research greatly benefited from the openness and enthusiasm of the participating clinic, without which some of this research would not have been possible. Whilst this ease meant that I collected too much data, and risked 'going native' through my curiosity (Hopwood, 2008), I argue that this welcoming atmosphere in combination with my significant curiosity made this project possible.

Additionally, the broader context in which the research was conducted positively impacted the findings and feasibility of the project. Of note here is the high current popularity of VBHC in the Netherlands – increasingly, clinicians wish to

47. This is not hyperbole. In my MSc. Strategic Management, I followed a course called "Strategic Management Consulting" in which the construction of effective slide decks was the content of the course. This is a useful skill to have. However, if you are taught to construct stories in slide decks, you quickly come to assume that it is normal for organizations to have the data that you hope to scrutinize and build those slide decks about. Going into the field, I was expecting there to be cost data to evaluate, and cost management practices to study. This was not really the case, as **chapters 3,5, 7** illustrate, but my expectations led me to find this surprising during the field work. If you walk into the field with such expectations, and don't learn to unlearn them, they will blind you to "how things work" in practice (Watson, 2011). Learning how things really work right now, in a particular place for specific individuals, is the core of ethnography. It requires naivete, and a high degree of curiosity, both of which are hindered if you have strong assumptions about how things 'ought to be' and what you hope to 'discover'. This can be more difficult if your presence is associated with strategic change or a particular agenda (Kunda, 2006).

48. I was born in Germany but grew up in Thailand and New Zealand and spent brief parts of my childhood in the UK and Australia. I moved to the Netherlands when I was 19 and only started learning Dutch as a third language at age 23.

49. Ethnography requires a balance between emic or "experience near" understanding and etic "experience far" insights (Dent, 1991; Geertz, 1985; Jönsson & Lukka, 2006, p. 374). Emic insights "result from studying human behavior from inside the system", whereas the etic viewpoint refers to studying it "from the outside" (Jönsson & Lukka, 2006, p. 374). Such emic insights, therefore, are necessary to study how (new) accounting practices shape perceptions and medical practices (Burchell et al., 1980; Hopwood, 1994).

prove that they deliver 'value' and not *just* medical performance, and methods like TDABC are often associated with becoming more modern or professional (Jones & Dugdale, 2002). This, perhaps, relates to the decreasing rate of improvements that medical science can deliver, including embryology – the interventions explored in this research (vitrification, AI embryo selection, combination protocols) are more incremental than, for instance, the introduction of ICSI was to the field of embryology and medically assisted reproduction. Potentially, some clinicians now seek other ways to prove themselves beyond clinical performance, particularly as budgets shrink and cost containment is increasingly emphasized within medical professions and communities. This may explain why this dissertation reports greater enthusiasm towards cost accounting amongst clinicians than prior literature from other contexts, which has mostly focused on top-down imposed accounting systems like DRGs rather than bottom-up accounting initiatives (e.g., Carr & Beck, 2020; Jacobs, 2005b; Kurunmäki et al., 2003; Le Theule et al., 2023; Ramos et al., 2021). Furthermore, our choice to focus on the fertility care setting enabled the research, because Dutch clinics tend to operate as outpatient clinics and independent practice units (IPUs), which meant that we were able to trace patient journeys from start to finish and had access to all organizational costs incurred.

Overall, combining ethnographic field work with quantitative research offered three key benefits to this project. First, this approach allowed me to be "grounded in the action" rather than just the data (Jönsson & Lukka, 2006, p. 375), which allowed me to develop both conceptual and practical contributions. By learning what mattered to individuals delivering and managing care, the infrastructure we built was tailored to the decision-making needs of its users, and thus useful to them in the moment (Broadbent & Guthrie, 1992; Zuiderent-Jerak, 2015).

Secondly, this interparadigmatic approach to related phenomena, in which I not only combined quantitative and qualitative methods but also engaged with different paradigms throughout the chapters, has made me humble with regards to the implications of the quantitative work. Observing how accounting systems, numbers, and rules influence clinicians in practice, and how numbers influence behavior in unexpected ways, taught me to be cautious regarding the implications I draw from quantitative research. For instance, although it would be possible to calculate much broader cost-savings, waste-savings, or workload reduction projections in **chapter 5** (e.g. projections regarding potential workload reductions across Europe), I refrained from doing so because of the insights I gained ethnographically. Although numbers can travel, the practical understandings they generate in practice (through the process of calculating and negotiating them) do not travel to other organizations.

Suggesting that such projections are generalizable would, inadvertently, undermine the key implications of this dissertation, namely that 'value' is local and temporal. Process efficiencies in healthcare, that result from using less time and/or fewer resources whilst serving or satisfying a patient equally well or better – are highly localized. What is efficient in one unit or department may not be in others, and comparing such (in)efficiencies requires that such differences are made visible (rather than hidden in averages).

Thirdly, because qualitative data informed the quantitative intervention, this made the quantitative analysis more impactful, due to the high level of detail incorporated and the discovery of interrelations between treatments. The observations enabled me to ask questions that others would not know to ask, and to pursue lines of inquiry in the quantitative analysis that respondents did not originally suggest during interviews or meetings. For instance, the relationship between decisions made during IVF, and their cost consequences during FET, only became clear through the observations. Without the use of participant observations and vignettes, these relationships would not have been discovered and would not have informed the quantitative analyses. Such relationships are not commonly analyzed in medical studies, which focus on treatment cycles without considering that decisions made in one treatment impact costs and outcomes in later treatments for that same patient.

It could be argued that this thesis could have better been written as a monograph than a collection of articles aimed at multiple disciplines. This could have, for instance, prevented some repetition across the chapters related to the need to build academic contributions in each stand-alone article. The doctoral regulations and publishing requirements of my institute prevented me from doing so. However, beyond that, I argue that the choice to produce stand-alone publications adds to the rigor and accessibility of this research, because each chapter is written in the language and style of the discipline it contributes to and was reviewed by experts in each domain or method.

I conclude that interventionist research approaches offer significant potential for future research with practical and theoretical ambition. This combination of ethnographic and quantitative research generated societal impact, as Dutch fertility care pathways offered by this clinic now require fewer resources to reach better outcomes, and total treatment durations from initial consultation to pregnancy have declined. Co-creating enabling cost management systems (and TDABC in particular) may be one effective way of conducting such research, particularly because such systems could also be used to identify or allocate other costs (e.g. carbon emissions, waste production, use of single-use devices), and enable studies focused on how accounting system co-creation allows users to redesign local practices and accountabilities.

Whilst methods like TDABC have been presented or marketed as methods that will 'save' healthcare (e.g., Porter & Lee, 2013), I can conclude that their usefulness and impact depend entirely on how they are designed and tailored to practice within organizations. The popularization of the method, due to its association with VBHC, can perhaps be understood as a type of self-fulfilling prophecy. Their popularization is encouraging implementation efforts, and greater attention to how resources are used and allocated, and such explorations are likely to find opportunities for improvement. If such projects are published as research, it is also likely that they will emphasize the positive impact of the project and downplay the potential hurdles or challenges involved in constructing them. Such 'successes' are not thanks to any one cost estimation method, but purely because such analyses can uncover variation and invite improvement. It follows that their success and usefulness depend on how they are designed, implemented, and used in practice, which places responsibility on researchers to engage with future users (e.g. clinicians) to design such systems in enabling ways. In my view, critical, interpretive (accounting) research should strive for both academic and practical impact in this process. Co-producing new accounting systems with users, and remaining engaged to observe if, how, and why they influence practice in consequential ways over time, holds great promise for research seeking to address pressing societal challenges. By studying how users shape such technologies in their development, future accounting research should pay attention to how individuals in healthcare settings accept or reject specific accountabilities towards patients, their organizations, or the planet, how users shape accounting systems to redesign or challenge local practices, and how users themselves are impacted by this process.

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Appendix

Appendix A: Search Strategy

Period: 2003-1/1/2022

embase.com

(((value-based OR valuebased) NOT ((value-based OR valuebased) NEXT/2 (insuran* OR purchas* OR pric* OR reimburse* OR contract* OR payment* OR partnership*)) OR vbhc OR vb-hc):ab,ti) AND ('cost'/de OR 'health care cost'/de OR 'time driven activity based costing'/de OR 'activity based costing'/de OR (cost OR costs OR costing OR microcosting OR macrocosting OR tdabc OR abc OR (resource NEAR/3 assignment*) OR (direct* NEAR/3 estimat*)):ab,ti) NOT (cost NEXT/1 (eval* OR benefit* OR effectiv* OR utilit* OR consequen* OR minimi* OR outcome* OR reduc* OR saving*)):ti NOT [conference abstract]/lim AND ([dutch]/lim OR [English]/lim)

Medline Ovid

(((value-based OR valuebased) NOT ((value-based OR valuebased) ADJ2 (insuran* OR purchas* OR pric* OR reimburse* OR contract* OR payment* OR partnership*)) OR vbhc OR vb-hc).ab,ti.) AND ("Costs and Cost Analysis"/ OR Health Care Costs/ OR (cost OR costs OR costing OR microcosting OR macrocosting OR tdabc OR abc OR (resource ADJ3 assignment*) OR (direct* ADJ3 estimat*)).ab,ti.) NOT (cost ADJ (eval* OR benefit* OR effectiv* OR utilit* OR consequen* OR minimi* OR outcome* OR reduc* OR saving*)).ti. AND (dutch.la. OR english.la.)

CINAHL EBSCOhost

(((TI(value-based OR valuebased) OR AB (value-based OR valuebased)) NOT (TI((value-based OR valuebased) N2 (insuran* OR purchas* OR pric* OR reimburse* OR contract* OR payment* OR partnership*)) OR AB((value-based OR valuebased) N2 (insuran* OR purchas* OR pric* OR reimburse* OR contract* OR payment* OR partnership*))) OR TI(vbhc OR vb-hc) OR AB(vbhc OR vb-hc))) AND ((MH "Costs and Cost Analysis" OR MH Health Care Costs OR MH Value-Based Health Care OR AB(costing OR microcosting OR macrocosting OR tdabc OR abc OR (resource N2 assignment*) OR (direct* N2 estimat*))) OR (TI(cost OR costs) NOT TI(cost N1 (eval* OR benefit* OR effectiv* OR utilit* OR consequen* OR minimi* OR outcome* OR reduc* OR saving*)))) AND LA(dutch OR english)

Web of science

TS=((((value-based OR valuebased) NOT ((value-based OR valuebased) NEAR/2 (insuran* OR purchas* OR pric* OR reimburse* OR contract* OR payment* OR partnership*)) OR vbhc OR vb-hc)) AND ((cost OR costs OR costing OR microcosting OR macrocosting OR tdabc OR abc OR (resource NEAR/2 assignment*) OR (direct* NEAR/2 estimat*))) AND (care OR health* OR medicine OR clinical OR hospital* OR surger* OR therap* OR patient* OR oncolog* OR drugs OR medication* OR cancer* OR pharmac*)) NOT TI=(cost NEAR/1 (eval* OR benefit* OR effectiv* OR utilit* OR consequen* OR minimi* OR outcome* OR reduc* OR saving*)) AND DT=(article) AND LA=(dutch OR english)

Appendix B: Inclusion/exclusion criteria and data extracted

Appendix B table 1: Eligibility criteria and data collected. For a data file of all variables extracted please see appendix D.

Eligibility criteria	
Language	English or Dutch
Publication date	Between 2003 and 1.1.2022
Research type	Original, peer-reviewed, empirical research
Terms	Any variation of the terms “cost” and “value-based” in title or abstract
Full text content	Costs of an intervention, treatment, care path, or other healthcare activity must have been measured or estimated.
Variables collected	
Descriptive	Name, year published, authors, medical specialty, location
Costs included	Based on author reporting we classify studies into one of two categories: • Direct costs only • Direct and indirect costs
Cost perspective	We inductively classify studies into one or more categories: • Provider costs (e.g. hospital) • Payer costs (reimbursements, charges, payments) • Patient costs (out-of-pocket costs to patient)
Care path length	We inductively classify studies into one of the following categories: • Full care path • Full care path, full surgical episode (FSE) • Partial care path, full surgical episode (PSE) • Partial care path
Costing method label	Costing method used, as labelled by the authors. These include traditional cost accounting, ABC, or ABC excluding overheads, TDABC, or TDABC with some cost categories omitted, microcosting, bottom-up clinical costing, reference pricing, relative value units or DRG costs, direct variable costs, or direct costs as an estimate of total cost, reimbursements, charges, claims, payments, and cost-to-charge ratio.
Costing method applied	Costing method applied, based on method described by authors. We classified studies using management accounting literature (e.g., Zimmerman, 2015). We found the following categories represented in the literature. • Direct costing • Absorption costing, which includes: ▫ ABC ▫ TDABC ▫ Other Cases using reimbursements or charges to estimate costs were coded as ‘reimbursements’ or ‘cost-to-charge ratio’.
Facilitating factors	If the study discussed the consequences of the costing information generated, we collected the consequences. After we collected all consequences, we categorized these inductively.

Appendix C: All 215 studies included in chapter 2, categorized by costing method and perspective

Appendix C table 1: Overview of cost measurement methods used in value-based healthcare with references

Perspective	Method	n	studies
Provider	Direct costs only		
	Direct costing	23	[1–23]
Patient	Out-of-pocket costs to patient	5	[106,126,130,215,216]
	Absorption costing		
	ABC	7	[24–30]
	TDABC	31	[31–61]
	Other	47	[62–108]
	Not specified	3	[109–111]
Insurer	Charges & reimbursements		
	Charges, reimbursements, claims	81	[23,39,112–190]
	Charges adjusted with cost-to charge ratio	25	[108,191–214]
Patient	Out-of-pocket costs to patient	5	[106,126,130,215,216]

Note: Total number of studies here is 222; seven studies measure two cost types[23,38,39,106,108,126,130]. Studies are classified based on actual costs included and methods described, not necessarily the labels used by authors.

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References of all studies included in research question 1, categorized in table.

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Appendix D: Database of extracted data

The data extracted for the 215 studies included in this review are available online in the form of a spreadsheet: https://doi.org/10.25397/eur.20279883.v1

Leusder, M. (Creator), Porte, P. (Creator), Ahaus, K. (Creator), van Elten, H. (Creator) (2023). Digital online content package for "Cost measurement in value-based health care: a systematic review"10.25397/eur.20279883.v1

Appendix E: Schatzki's sites and the complementarity of an IVF clinic

In this supplementary appendix, we outline 5 core differences between Schatzki's three foundational settings on which he based his practice theory, and subsequently comment on the limited exploration of business practices like marketing or accounting in Schatzki's account. This text should not be interpreted as a critique of Schatzki's work, but only as a critical reading of Schatzki's settings and as a comparison to modern-day complex care delivery. Because Schatzki's site ontology is based on archival and anecdotal material of three settings that differ to the delivery of complex care in fundamental ways, we first compare our setting to those on which Schatzki's practice theory is based, to explain how and why an IVF clinic can deliver new insights that may challenge practice theory and therefore add to it in the context of accounting research. In developing his version of practice theory, Schatzki (1996, 2002, 2010) relied on archival or anecdotal materials of three settings: rudimentary medicine production processes used by religious Shaker villages in New Lebanon between the 1790s and 1890s (Schatzki, 2002, pp. 25-38), modern-day trading practices on the Nasdaq stock market (ibid, pp. 157-174), and farming practices in Kentucky (Schatzki, 2010). This allowed his theoretical account to "attain greater meaning, determinacy, and clarity" through "extremely detailed" examples (Schatzki, 2002, p. xix), but may limit the generalizability of his theory to contemporary complex healthcare settings such as fertility care, which Schatzki himself emphasizes when saying that "I do not claim that Shaker life is representative of or even congruent with contemporary life (…) Nor do I contend that all elements and principles required to describe and explain contemporary life appear in the Shaker example" (Schatzki, 2002, p. xxi). These settings have several things in common, which is why we argue that a social site exploration of an IVF clinic (which opposes Schatzki's settings in some ways) is beneficial for a practice-based understanding of the role of accounting in organizations.

First (1), all three settings feature "instant" and transparent gratification and the pursuit of "extremely short-term profit" (Schatzki, 2002, p.162-163), implying that actors knew the outcomes of their practices, and how their actions contributed to their goals and objectives – their 'teleologies', according to Schatzki (2002). For instance, making herb production processes more efficient clearly contributed to desired outcomes like profit because the processes were standardized. The Shakers could observe the state of their herbs by looking at them, how many vials they produced, and how much profit this generated, meaning that the relative contribution of individual practices, tasks or actions towards teloi like profitability were clear to actors and could easily be observed in a physical way (e.g. by looking at the state of the herbs). In contrast to this, outcomes in IVF clinics are long-term and lack transparency, taking months or years to materialize, unlike the immediate and transparent outcomes observed by Shakers and traders. For instance, teloi like patient satisfaction with treatments can only be observed at the end of a treatment, which may take months to years. The relative contribution of a task, such as a consultation or an embryo fertilization, is far less clear and furthermore cannot be observed in a physical sense. Instead, in medicine, intermediate outcomes are tracked using accounting systems like patient dossiers, and only come to exist in an abstract way.

Secondly (2), actors in all three settings had the freedom to ‘pioneer’ their practices to pursue their teleologies in more efficient, comfortable, or profitable ways – in contrast, clinicians do not have the autonomy to ‘pioneer’ or customize the delivery of (elements of) healthcare delivery, because they are bound by medical protocols and, certainly in the case of embryology, experimenting on patients of human embryos is illegal.

Thirdly (3), both the benefits from experimentation and pioneering, and the contribution of actions towards teloi, immediately ‘rebounded directly to the inventor and his or her colleagues' (Schatzki, 2002, p.32), as practices became more comfortable, or farmers or Shakers could spend less time doing certain things and instead enjoy longer breaks. In contrast to this, clinicians do not gain any personal benefits from making tasks more efficient; instead, they move on to the next task for a different patient or the next task for the same patient until their shift is over, which causes a separation between the ‘affect’ and ‘structure’ in teleoaffective structures (Iedema, 2005). Being efficient does not increase their pay, reduce their workload, or contribute to their teleologies like parenthood. Similarly, unlike Shakers and traders who directly benefit from efficiency and innovation, IVF clinicians gain no personal rewards from such improvements; benefits are organizational, but do not translate into any tangible benefits for the individual.

These first three features of the Shaker villages is the foundation to Schatzki’s conclusion regarding teleoaffective structures – that practices feature teleoaffective structures that both (a) suggest what tasks and goals are desirable, (b) how actors should feel about them, and (c) that teleoaffective structures are inherently teleological and transparent; that it is reasonably clear which tasks and actions contributed to desired states of affairs. However, in opposition to these features, complex care delivery like IVF operates on a time horizon of months to years and relies heavily on coordination and collaboration among specialists.

Fourthly (4), whilst both Shakers and day traders trivialized the pursuit of science and technology, and traders only leverage technology for immediate gains, IVF clinics celebrate and heavily rely on technological advancements to continuously improve medical outcomes. Scientific advancement is a goal in and of itself, and in fact the end that allows medicine to continuously invent and deliver new 'products' as afflictions or diseases are simultaneously discovered and treated.

Lastly, (5) the nature of labor in IVF clinics involves highly skilled manual and significant emotional labor, contrasting with the physical labor of Shakers or farmers and the individualistic, financially driven labor of traders. In his later work, Schatzki (2010, p.127) notes that emotions can "bypass practical intelligibility and its determination", and that there is a causal link between emotion and activity (idem, p.129), which he discusses at length in the 3rd chapter of his 2010 book.

Furthermore, throughout his writings, Schatzki paid significantly more attention to integrated practices close to the central farming, production, and trading practices than peripheral activities like marketing or accounting. For instance, Schatzki focused on organizational practices of production – e.g., drying and grinding herbs, completing trades, he purposefully ignored business practices like record-keeping (ibid, p.49), profit calculations (ibid., p 81, 25-38), or accounting (ibid, p.79) whilst constructing his theory. In his three settings, such practices were seen to purely cohere with production practices, to support goals like profitability, and occurred far away from the production processes in separate offices or buildings. On the contrary, record keeping plays a significant role in many organizations today, particularly in complex organizations delivering products of services with long time horizons (e.g., Universities deliver education to students with the goal to 'produce' graduates, Hospitals deliver healthcare with goals like healing patients). For this reason, exploring the role of something that has typically been viewed as either purely opposing or purely supporting integrated organizational practices can further support a practice-based understanding of accounting "in the context in which it operates" (Hopwood, 1983).

Appendix F: Brief clinical guideline descriptions, per fertility treatment type, in layman's terms

This appendix briefly describes in laymen's terms the treatment options available to patients diagnosed with subfertility in Europe, and the basic progression of these treatment options. The actual process of delivering care determines the results; the medical metro lines, and treatment protocols were foundational to the costing analysis. For detailed descriptions of the process, please refer to **follicles.**

Appendix G: Medical metro lines. The treatment guidelines described here and depicted in the medical metro line are subject to regulatory guidelines published by the European Society of Human Reproduction and Embryology (ESHRE) and the Dutch professional association for Obstetrics and Gynecology (Nederlandse Vereniging voor Obstetrie en Gynaecologie; NVOG). For detailed clinical guidelines, please refer to the published clinical guidelines from ESHRE or NVOG (available online; for references and links please refer to **Chapter 3**).

Initial diagnostics: the initial fertility assessment

Patients begin with a general diagnostics phase, the initial fertility assessment (IFA), to determine the potential cause of subfertility to inform the treatment plan. This can last 4 to 6 weeks and greatly depends on the case-mix and prior gynaecological history of both patients. Some patients require a consultation with a Urologist, a diagnostic laparoscopic operation or a hysterosalpingogram (HSG), whilst others may only require several consultations and an ultrasound. In all cases, patients start with an initial consultation with a gynaecologist and a lifestyle consultation with a nurse, and minimally one vaginal ultrasound.

For patients diagnosed with female and/or male subfertility, or those dealing with prolonged unexplained subfertility, treatment is recommended to start as soon as possible. In case of female subfertility due to anovulation (WHO group II), and without the presence of male-factor infertility, ovulation induction (OI) with clomiphene citrate (CC) is indicated. This is a non-invasive, home-based, medication-based treatment, during which patients require minimal assistance or monitoring. In case of prolonged anovulation with CC, low-dose FSH stimulation is the second line of treatment. OI with FSH stimulation requires significantly more monitoring and is therefore more invasive.

Patients using donor sperm, or with mild male factor or cervical factor subfertility, are recommended intra-uterine insemination (IUI) in the natural menstrual cycle before attempting more invasive options. IUI involves a specifically timed placement of prewashed sperm directly into the uterine cavity using a small catheter. It can be combined with an OI treatment regimen in case of anovulation. In case of unexplained subfertility or mild endometriosis IUI treatment is combined with hormonal stimulation to increase pregnancy chance by a double ovulation. Each month of treatment of OI or IUI ends with a pregnancy test and ultrasound. After 6 cycles of unsuccessful OI or IUI, patients are advised on whether to continue with their current treatment, or whether to switch to in-vitro-fertilization (IVF), which is more invasive. IVF is suitable for persistent, unexplained infertility, endometriosis, ovulatory dysfunction, or male factor infertility.

Ovulation induction (OI) and Intra-uterine insemination (IUI)

Ovulation induction medication simulate natural hormone secretion during the menstrual cycle, and encourage the production of a single dominant follicle, which needs to reach a required size before it can be released by the ovary (ovulation). The ovary releases the egg on about day 14 of the menstrual cycle.

Ovulation induction may be performed with two types of medication regimens:

- Clomiphene citrate (CC) or Letrozol tablets, daily, from 3nd to 7th day of the menstrual cycle.
- Gonadotropin injections, daily, from day 3nd of the menstrual cycle until ovulation may be induced by human Chorionic Gonadotropin (hCG).

The regimens have implications for the patient journey and clinic. In case of Clomid or Letrozole, patients can pick up their medication (in the form of tablets), follow the regimen at home, and come back to the clinic after 4-6 weeks for a consultation and ultrasound. The ultrasound is used to determine whether ovarian response is sufficient, or whether an increased dosage of medication is necessary. After one blood test, the patient may follow several treatment cycles at home at fixed dosage, without needing ultrasounds. If treatment is unsuccessful after 6 months, an evaluation consultation is scheduled to determine whether treatment should be continued or stopped in favor of a more invasive approach. In case of poor response at maximum dosage, further fallopian tube diagnostics may be required (laparoscopy or hysterosalpingogram). Ovulation induction can be attempted for a maximum of 12 ovulatory cycles. If, at any point, treatment is stopped, an evaluation consultation is scheduled during which a new treatment plan is discussed.

Contrary to Clomid or Letrozole treatment, the Gonadotropin regimen involves daily injections and requires regular monitoring of follicular response by means of ultrasound until the ovulation trigger. Due to a heightened chance of multifollicular growth or other complications 70, Gonadotropin stimulation requires more consultations and ultrasounds than necessary with Clomid. Intra-uterine insemination features a timed insemination for optimal chance of pregnancy. In some cases, IUI may be combined with OI, in which case a patient completes the OI trajectory as indicated on the medical metro line with the addition of an IUI on day.

In-vitro fertilization (IVF) with or without intracytoplasmic sperm injection (ICSI)

IVF differs significantly from the options, because the burden on patients and staff is far greater, and the treatment involves more invasive procedures. Because fertilization occurs ex-vivo inside the laboratory, this treatment poses significantly greater burden on clinics. In-vitro fertilization begins with an intake phase, during which patients are tested for infections (serology), undergo an ultrasound, and receive a consultation in which stimulation medication options and choices are discussed. If the most recent semen analysis is over one year old, it is repeated. Once a choice is made, patients consult with an IVF nurse about the exact timing and dosage of their medication protocol. On the first day of her menstrual cycle (CD1), the patient informs the nurse by email or phone call, and subsequent ultrasound consultations are scheduled. Patients require between 3 and 7 ultrasounds total, depending on their response to the stimulating medication, before advancing to the next phase of treatment. Various stimulation protocols are available, and patients are advised on the best option for them by their Gynecologist.

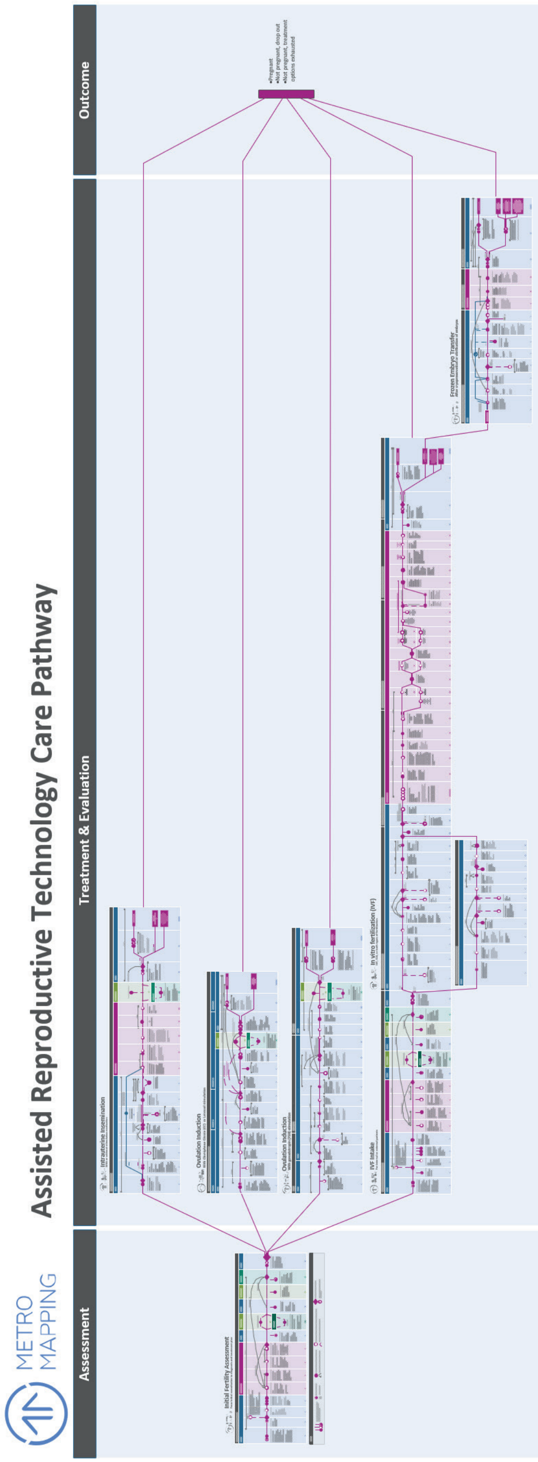
Phase 2, the 'egg retrieval' phase, is reached if one follicle reaches a size greater than 17 mm. Insufficient or excessive response to medication can result in the cancellation of the cycle, which is discussed in a consultation. One day prior to the follicular aspiration (FA), the lab prepares all dishes and media required for the follicular aspiration. Once the follicular aspiration has taken place, the laboratory collects and tracks all viable follicles. During ovum pickup/follicle retrieval, follicles are extracted from the follicular fluid removed by needle during the procedure. This happens under the microscope; all viable follicles are placed in a nutritive liquid (culture medium) and incubated under optimal conditions.

In phase 3, follicles are fertilized using sperm. In the case of traditional IVF, healthy mature follicles are combined with (appropriately prepared) sperm cells in a dish, then incubated and monitored. In the case of IVF-ICSI, sperm cells are selected and injected into mature follicular cells under a precision microscope. In some instances, when a patient is undergoing a first cycle, it is possible to opt for a split approach wherein half of the oocytes are fertilized in a petri dish, and half using the precision microscope following an ICSI protocol. In all cases, all fertilized oocytes are incubated, monitored, and tracked appropriately for several days. One successfully developing embryos are eligible to be replaced into the uterus in the following phase (embryo transfer). If no embryos (of sufficient quality) are available to transfer, the cycle is cancelled. During the embryo transfer, the single best embryo is placed back into the uterus. Soon after, the patient can administer a pregnancy test.

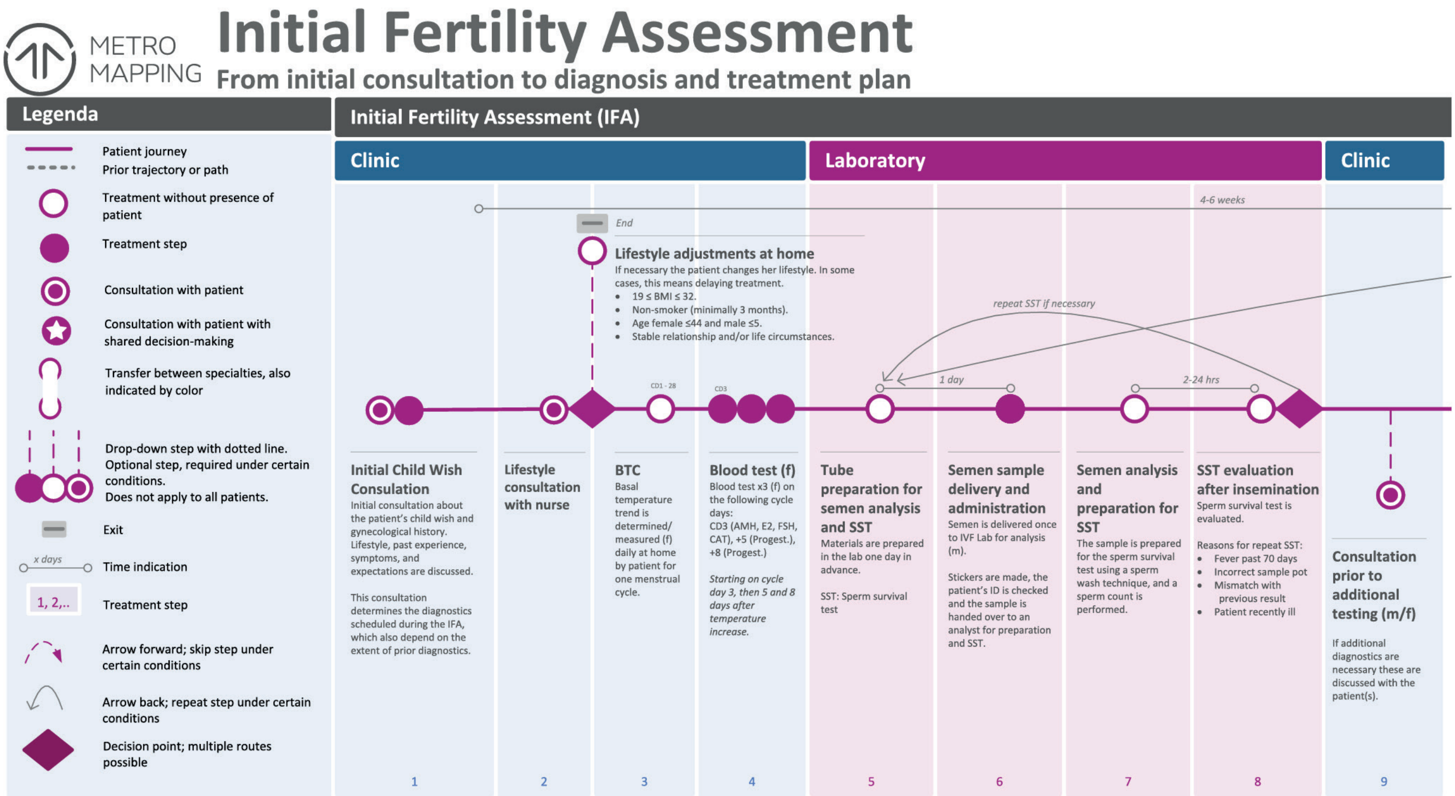
If pregnancy is not achieved, patients can enter frozen embryo transfer cycles (FETs) which are similar to IVF cycles, but do not require the collection and fertilization of oocytes. Instead, patients are prepared to receive a frozen embryo (in some cases, patients require stimulation medication), which is thawed on the day of the embryo transfer. If the embryo is damaged from the freezing and thawing process, another one may be thawed, but this needs to happen on time as the patient is ready to receive it in the procedure room. Thus, if multiple embryos are thawed and need to be discarded, it can happen that a FET cycle fails. Similarly, if no embryos are remaining, the patient may need to enter a new cycle of IVF including follicle stimulating hormones to induce over-production of follicles.

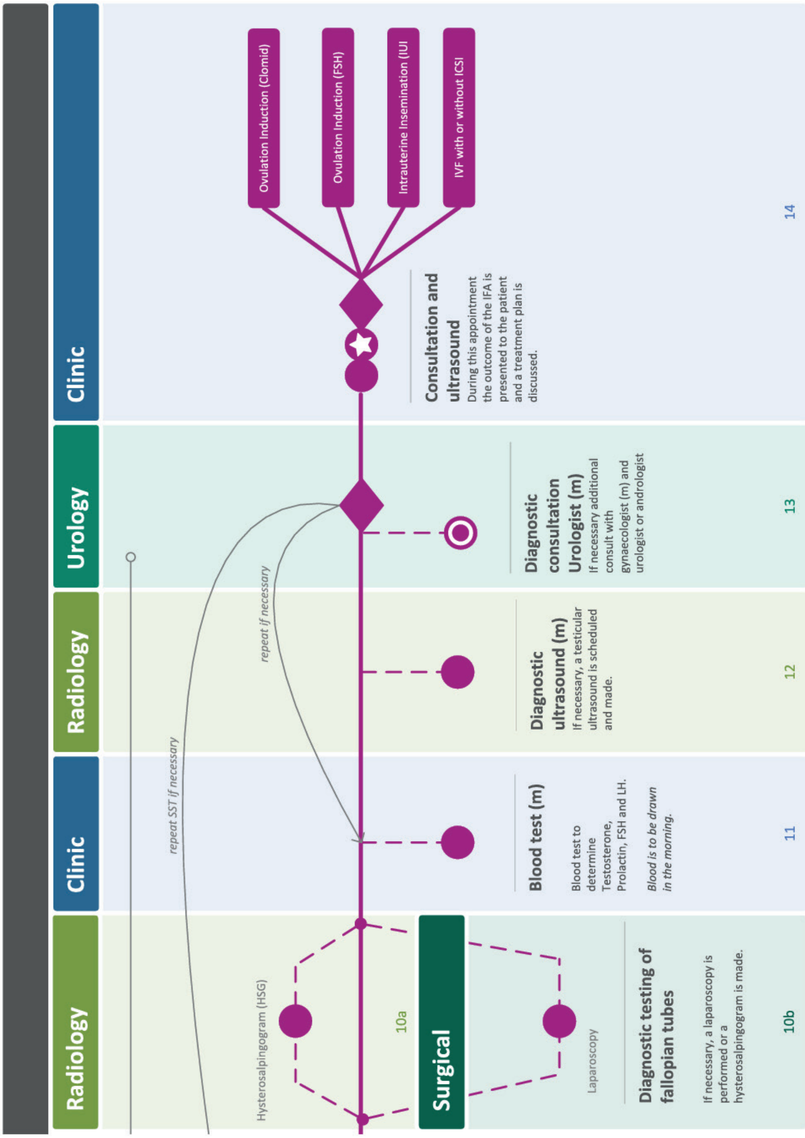
Appendix G: Medical metro lines

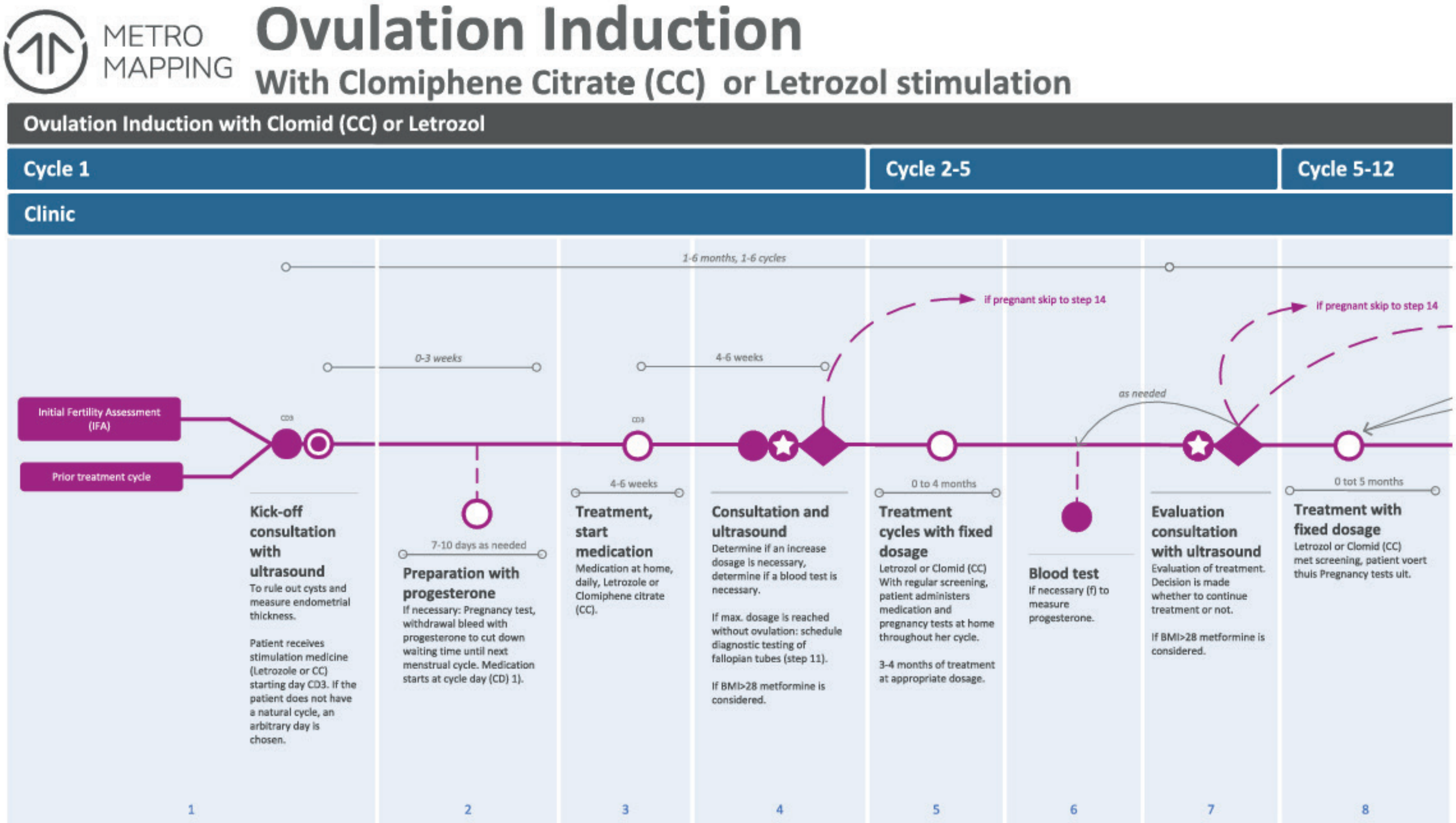
The following pages depict the Medical Metro Lines developed to facilitate the time-driven activity-based costing analysis with process mining (TDABC-PM). The objective of this schematic is to illustrate the care delivery value chain (CDVC) and patient journey from initial consultation up to ongoing pregnancy for patients undergoing fertility care. It depicts every action taken by medical staff in relation to a single case, with alternative routes and optional activities. The key/legend is shown prior to the initial fertility assessment (IFA). The entire schematic looks as follows, but is broken down into snippets in the following pages for readability. Each process summarized in chapter 4 figure 4.1, and chapter 5 figure 5.2, is depicted below at the activity level. The medical metro lines thus depict the processes described in the chapters at the activity level.

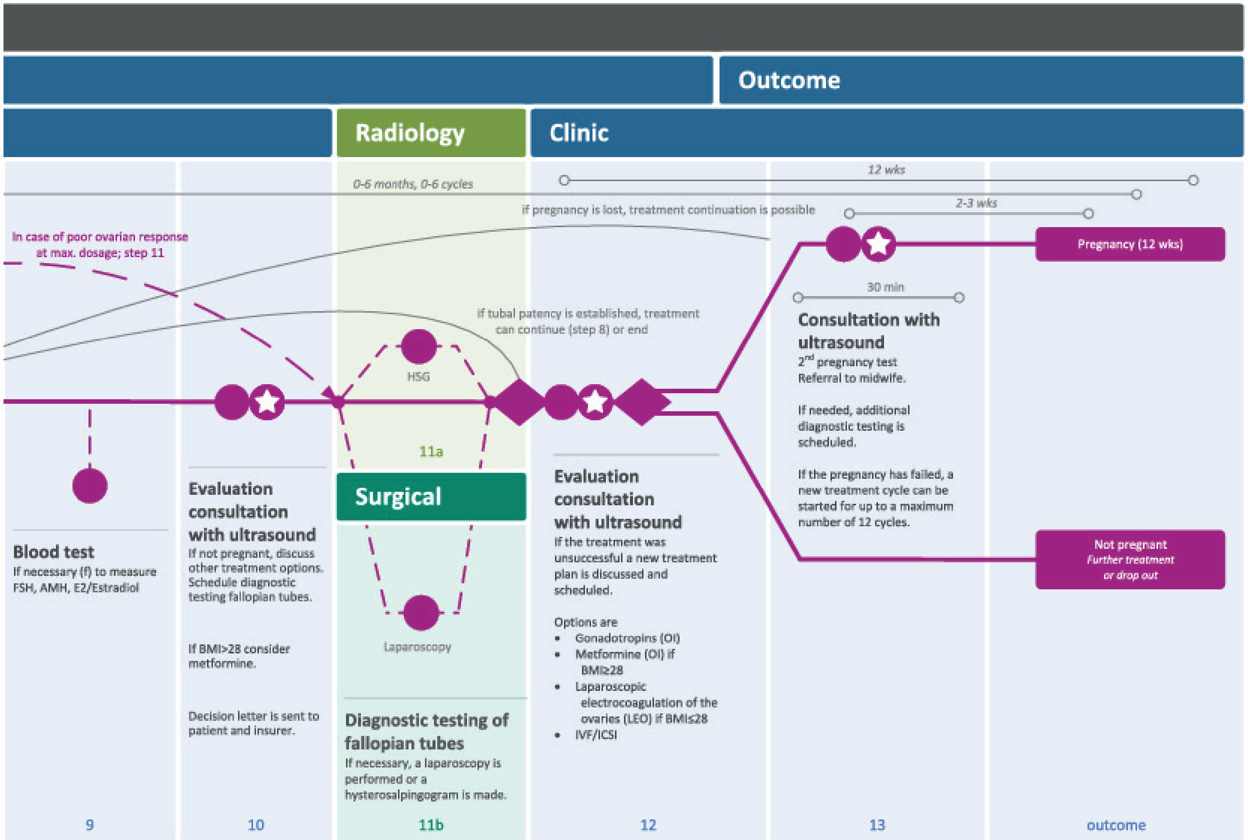

METRO MAPPING
Assisted Reproductive Technology Care Pathway
Assessment
Treatment & Evaluation
Outcome
Initial Fertility Assessment
Intrauterine Insemination
Ovulation Induction
Ovulation Induction
IVF Intake
In vitro fertilization (IVF)
Frozen Embryo Transfer
•Pregnant
•Not pregnant, drop out
•Not pregnant, treatment options exhausted

A


METRO MAPPING
Initial Fertility Assessment
From initial consultation to diagnosis and treatment plan
Legenda
Patient journey
Prior trajectory or path
Treatment without presence of patient
Treatment step
Consultation with patient
Consultation with patient with shared decision-making
Transfer between specialties, also indicated by color
Drop-down step with dotted line. Optional step, required under certain conditions. Does not apply to all patients.
Exit
x days
Time indication
1, 2,..
Treatment step
Arrow forward; skip step under certain conditions
Arrow back; repeat step under certain conditions
Decision point; multiple routes possible
Initial Fertility Assessment (IFA)
Clinic
Laboratory
Clinic
4-6 weeks
End
Lifestyle adjustments at home
If necessary the patient changes her lifestyle. In some cases, this means delaying treatment.
• 19 ≤ BMI ≤ 32.
• Non-smoker (minimally 3 months).
• Age female ≤44 and male ≤5.
• Stable relationship and/or life circumstances.
repeat SST if necessary
1 day
2-24 hrs
CD1 - 28
CD3
Initial Child Wish Consulation
Initial consultation about the patient's child wish and gynecological history. Lifestyle, past experience, symptoms, and expectations are discussed.
This consultation determines the diagnostics scheduled during the IFA, which also depend on the extent of prior diagnostics.
Lifestyle consultation with nurse
BTC
Basal temperature trend is determined/ measured (f) daily at home by patient for one menstrual cycle.
Blood test (f)
Blood test x3 (f) on the following cycle days:
CD3 (AMH, E2, FSH, CAT), +5 (Progest.), +8 (Progest.)
Starting on cycle day 3, then 5 and 8 days after temperature increase.
Tube preparation for semen analysis and SST
Materials are prepared in the lab one day in advance.
SST: Sperm survival test
Semen sample delivery and administration
Semen is delivered once to IVF Lab for analysis (m).
Stickers are made, the patient's ID is checked and the sample is handed over to an analyst for preparation and SST.
Semen analysis and preparation for SST
The sample is prepared for the sperm survival test using a sperm wash technique, and a sperm count is performed.
SST evaluation after insemination
Sperm survival test is evaluated.
Reasons for repeat SST:
• Fever past 70 days
• Incorrect sample pot
• Mismatch with previous result
• Patient recently ill
Consultation prior to additional testing (m/f)
If additional diagnostics are necessary these are discussed with the patient(s).
1
2
3
4
5
6
7
8
9

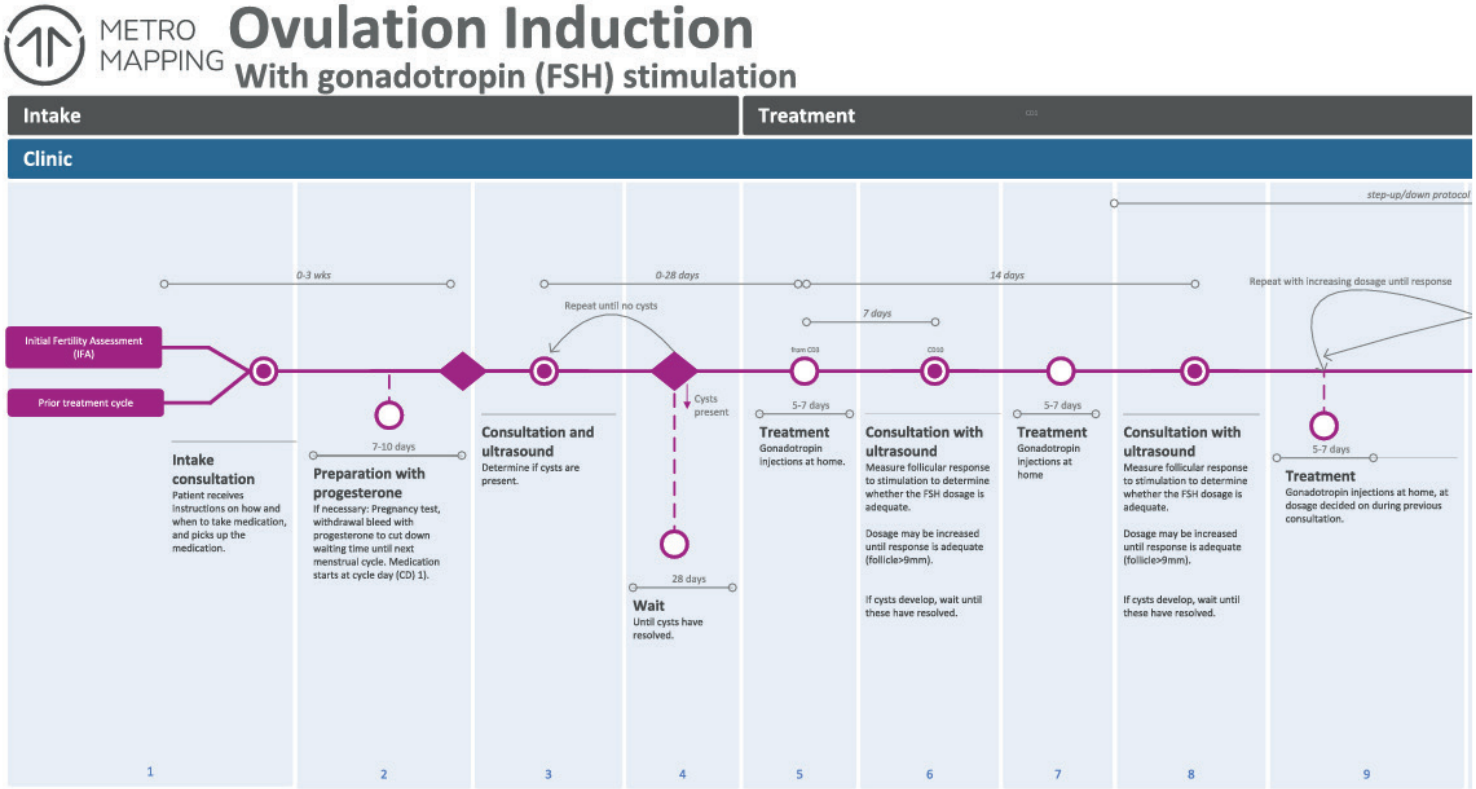

Radiology
Clinic
Radiology
Urology
Clinic
Surgical
Hysterosalpingogram (HSG)
10a
Laparoscopy
Diagnostic testing of fallopian tubes
If necessary, a laparoscopy is performed or a hysterosalpingogram is made.
10b
repeat SST if necessary
Blood test (m)
Blood test to determine Testosterone, Prolactin, FSH and LH.
Blood is to be drawn in the morning.
11
repeat if necessary
Diagnostic ultrasound (m)
If necessary, a testicular ultrasound is scheduled and made.
12
Diagnostic consultation Urologist (m)
If necessary additional consult with gynaecologist (m) and urologist or andrologist
13
Consultation and ultrasound
During this appointment the outcome of the IFA is presented to the patient and a treatment plan is discussed.
14
Ovulation Induction (Clomid)
Ovulation Induction (FSH)
Intrauterine Insemination (IUI
IVF with or without ICSI


METRO MAPPING
Ovulation Induction
With Clomiphene Citrate (CC) or Letrozol stimulation
Ovulation Induction with Clomid (CC) or Letrozol
Cycle 1
Cycle 2-5
Cycle 5-12
Clinic
1-6 months, 1-6 cycles
Initial Fertility Assessment (IFA)
Prior treatment cycle
CD3
Kick-off consultation with ultrasound
To rule out cysts and measure endometrial thickness.
Patient receives stimulation medicine (Letrozole or CC) starting day CD3. If the patient does not have a natural cycle, an arbitrary day is chosen.
0-3 weeks
7-10 days as needed
Preparation with progesterone
If necessary: Pregnancy test, withdrawal bleed with progesterone to cut down waiting time until next menstrual cycle. Medication starts at cycle day (CD) 1).
CD3
4-6 weeks
4-6 weeks
Treatment, start medication
Medication at home, daily, Letrozole or Clomiphene citrate (CC).
Consultation and ultrasound
Determine if an increase dosage is necessary, determine if a blood test is necessary.
If max. dosage is reached without ovulation: schedule diagnostic testing of fallopian tubes (step 11).
If BMI>28 metformine is considered.
if pregnant skip to step 14
0 to 4 months
Treatment cycles with fixed dosage
Letrozol or Clomid (CC) With regular screening, patient administers medication and pregnancy tests at home throughout her cycle.
3-4 months of treatment at appropriate dosage.
Blood test
If necessary (f) to measure progesterone.
as needed
Evaluation consultation with ultrasound
Evaluation of treatment. Decision is made whether to continue treatment or not.
If BMI>28 metformine is considered.
if pregnant skip to step 14
0 tot 5 months
Treatment with fixed dosage
Letrozol or Clomid (CC) met screening, patient voert thuis Pregnancy tests uit.
1
2
3
4
5
6
7
8

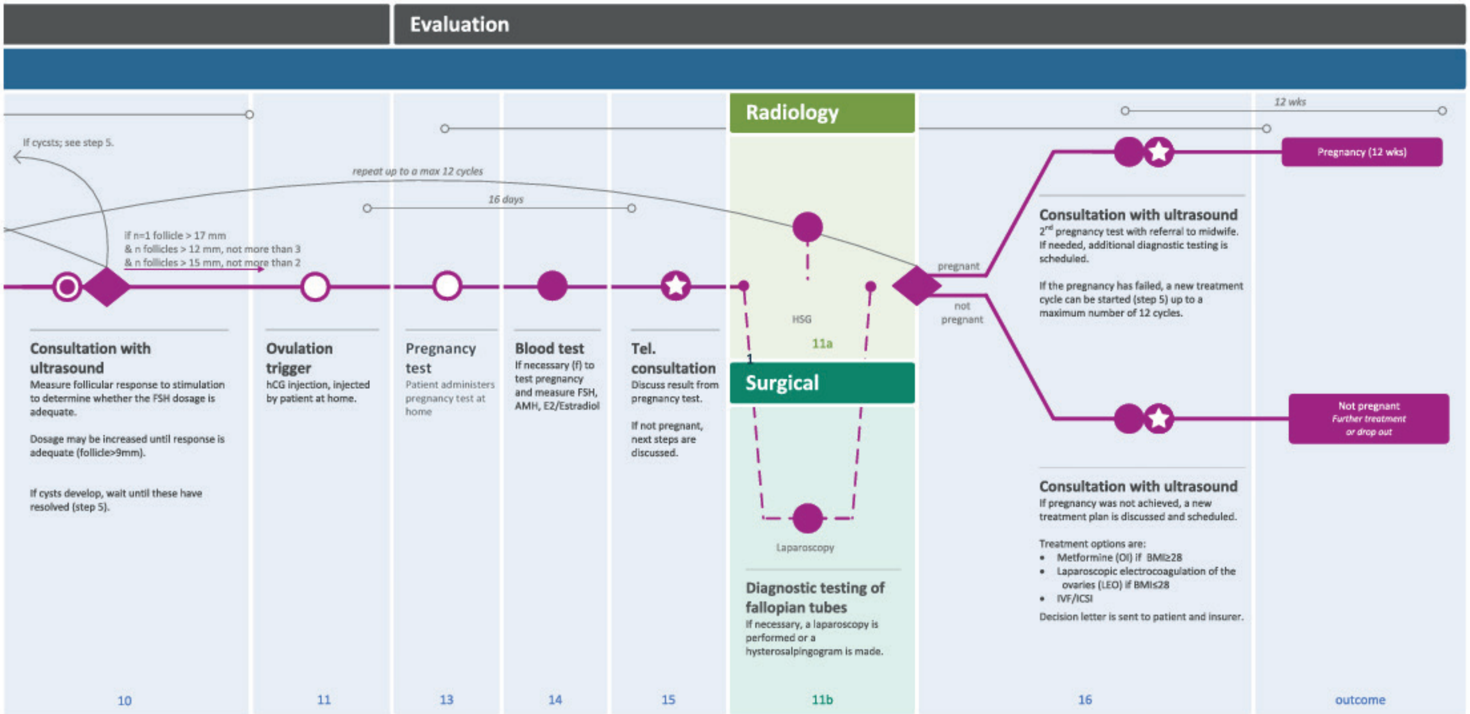


Outcome
Radiology
Clinic
Surgical
0-6 months, 0-6 cycles
12 wks
2-3 wks
30 min
if pregnancy is lost, treatment continuation is possible
In case of poor ovarian response at max. dosage; step 11
if tubal patency is established, treatment can continue (step 8) or end
HSG
11a
Laparoscopy
Pregnancy (12 wks)
Not pregnant
Further treatment or drop out
Blood test
If necessary (f) to measure FSH, AMH, E2/Estradiol
Evaluation consultation with ultrasound
If not pregnant, discuss other treatment options. Schedule diagnostic testing fallopian tubes.
If BMI>28 consider metformine.
Decision letter is sent to patient and insurer.
Diagnostic testing of fallopian tubes
If necessary, a laparoscopy is performed or a hysterosalpingogram is made.
Evaluation consultation with ultrasound
If the treatment was unsuccessful a new treatment plan is discussed and scheduled.
Options are
• Gonadotropins (OI)
• Metformine (OI) if BMI≥28
• Laparoscopic electrocoagulation of the ovaries (LEO) if BMI≤28
• IVF/ICSI
Consultation with ultrasound
2nd pregnancy test
Referral to midwife.
If needed, additional diagnostic testing is scheduled.
If the pregnancy has failed, a new treatment cycle can be started for up to a maximum number of 12 cycles.
9
10
11b
12
13
outcome

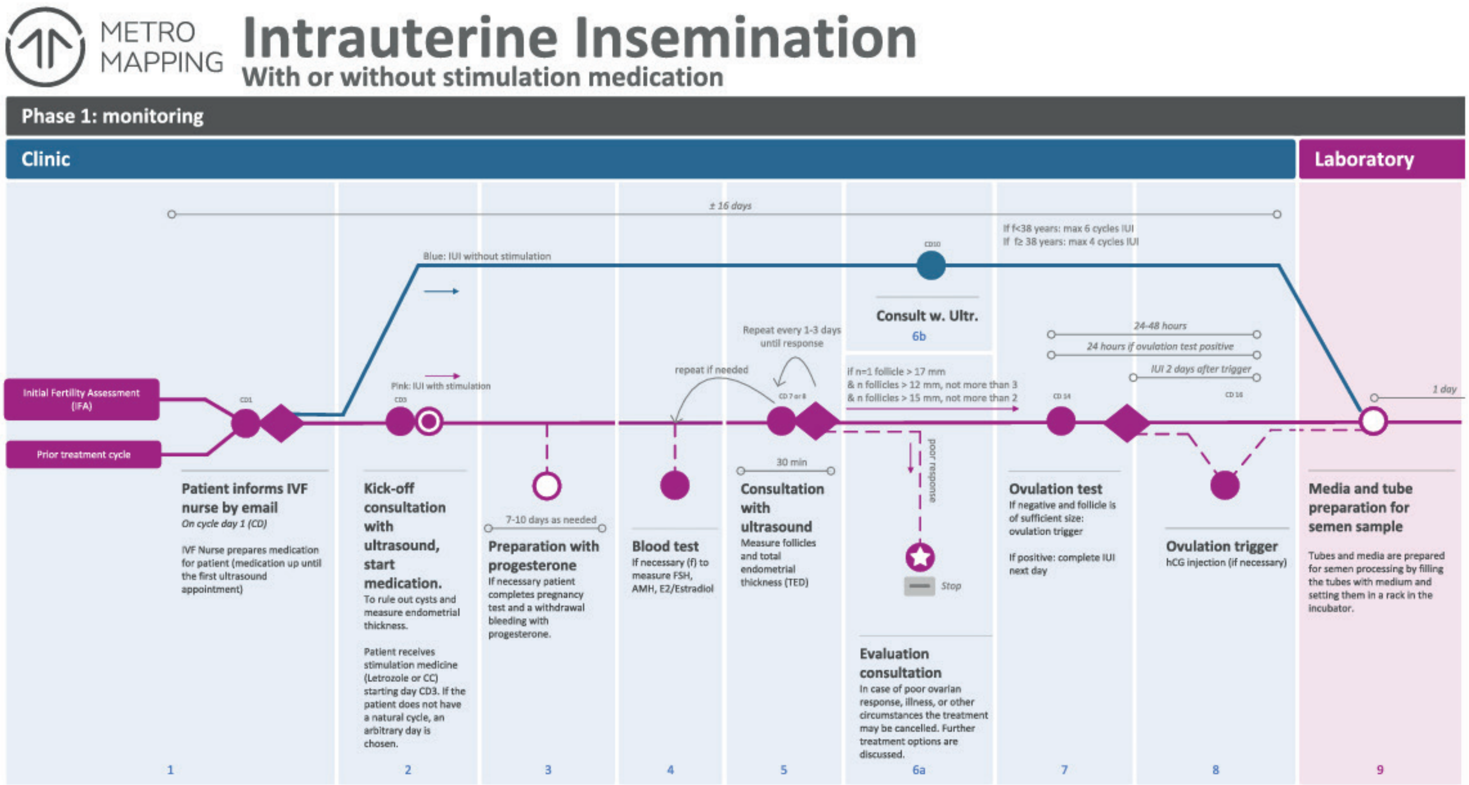
A



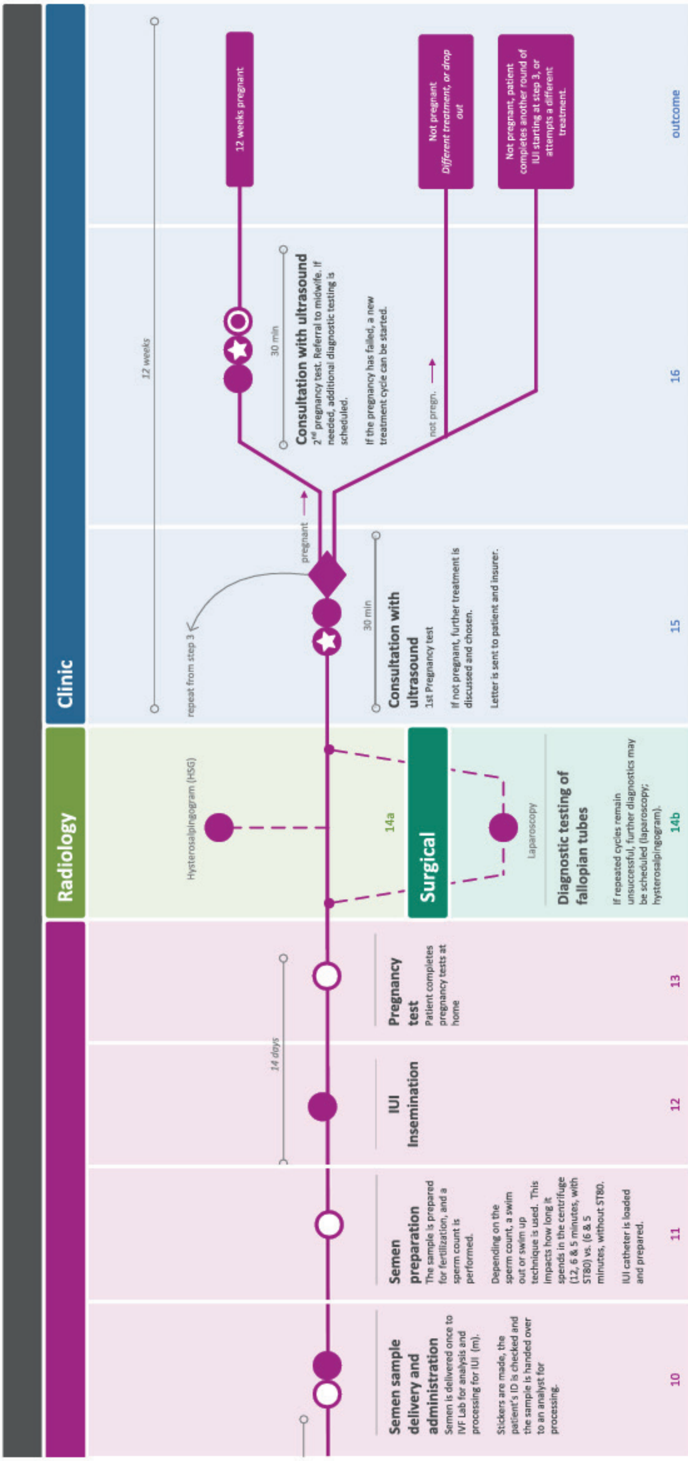
METRO MAPPING
Ovulation Induction
With gonadotropin (FSH) stimulation
Intake
Treatment
Clinic
Initial Fertility Assessment (IFA)
Prior treatment cycle
0-3 wks
0-28 days
14 days
7 days
Repeat until no cysts
Repeat with increasing dosage until response
step-up/down protocol
Intake consultation
Patient receives instructions on how and when to take medication, and picks up the medication.
7-10 days
Preparation with progesterone
If necessary: Pregnancy test, withdrawal bleed with progesterone to cut down waiting time until next menstrual cycle. Medication starts at cycle day (CD) 1.
Consultation and ultrasound
Determine if cysts are present.
Cysts present
28 days
Wait
Until cysts have resolved.
5-7 days
Treatment
Gonadotropin injections at home.
Consultation with ultrasound
Measure follicular response to stimulation to determine whether the FSH dosage is adequate.
Dosage may be increased until response is adequate (follicle>9mm).
If cysts develop, wait until these have resolved.
5-7 days
Treatment
Gonadotropin injections at home
Consultation with ultrasound
Measure follicular response to stimulation to determine whether the FSH dosage is adequate.
Dosage may be increased until response is adequate (follicle>9mm).
If cysts develop, wait until these have resolved.
5-7 days
Treatment
Gonadotropin injections at home, at dosage decided on during previous consultation.
1
2
3
4
5
6
7
8
9


Evaluation
Radiology
Surgical
If cycsts; see step 5.
repeat up to a max 12 cycles
16 days
12 wks
If n=1 follicle > 17 mm
& n follicles > 12 mm, not more than 3
& n follicles > 15 mm, not more than 2
Consultation with ultrasound
Measure follicular response to stimulation to determine whether the FSH dosage is adequate.
Dosage may be increased until response is adequate (follicle>9mm).
If cysts develop, wait until these have resolved (step 5).
Ovulation trigger
hCG injection, injected by patient at home.
Pregnancy test
Patient administers pregnancy test at home
Blood test
If necessary (f) to test pregnancy and measure FSH, AMH, E2/Estradiol
Tel. consultation
Discuss result from pregnancy test.
If not pregnant, next steps are discussed.
HSG
11a
Laparoscopy
Diagnostic testing of fallopian tubes
If necessary, a laparoscopy is performed or a hysterosalpingogram is made.
pregnant
not pregnant
Consultation with ultrasound
2nd pregnancy test with referral to midwife. If needed, additional diagnostic testing is scheduled.
If the pregnancy has failed, a new treatment cycle can be started (step 5) up to a maximum number of 12 cycles.
Consultation with ultrasound
If pregnancy was not achieved, a new treatment plan is discussed and scheduled.
Treatment options are:
• Metformine (OI) if BMI≥28
• Laparoscopic electrocoagulation of the ovaries (LEO) if BMI≤28
• IVF/ICSI
Decision letter is sent to patient and insurer.
Pregnancy (12 wks)
Not pregnant
Further treatment or drop out
10
11
13
14
15
11b
16
outcome

A

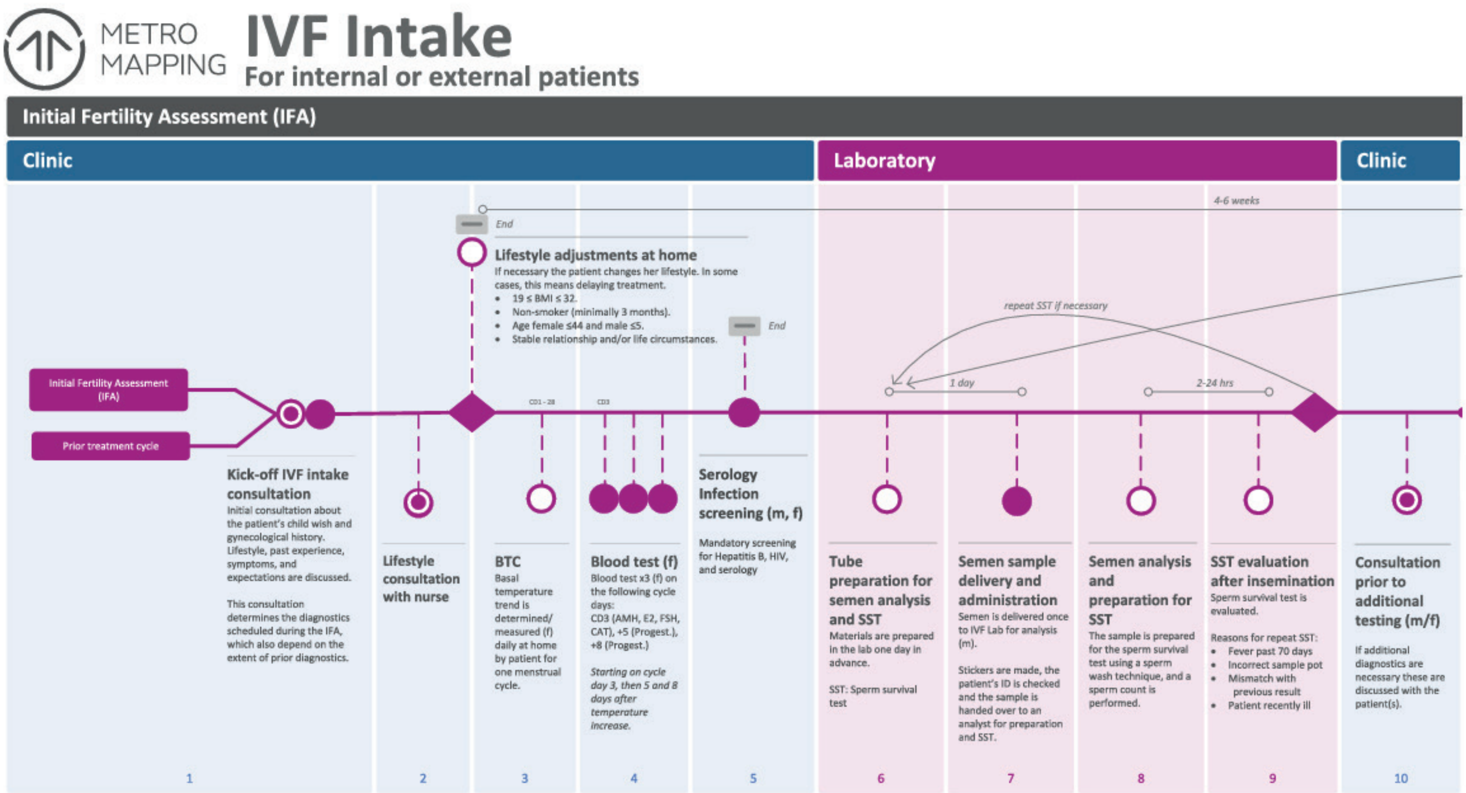


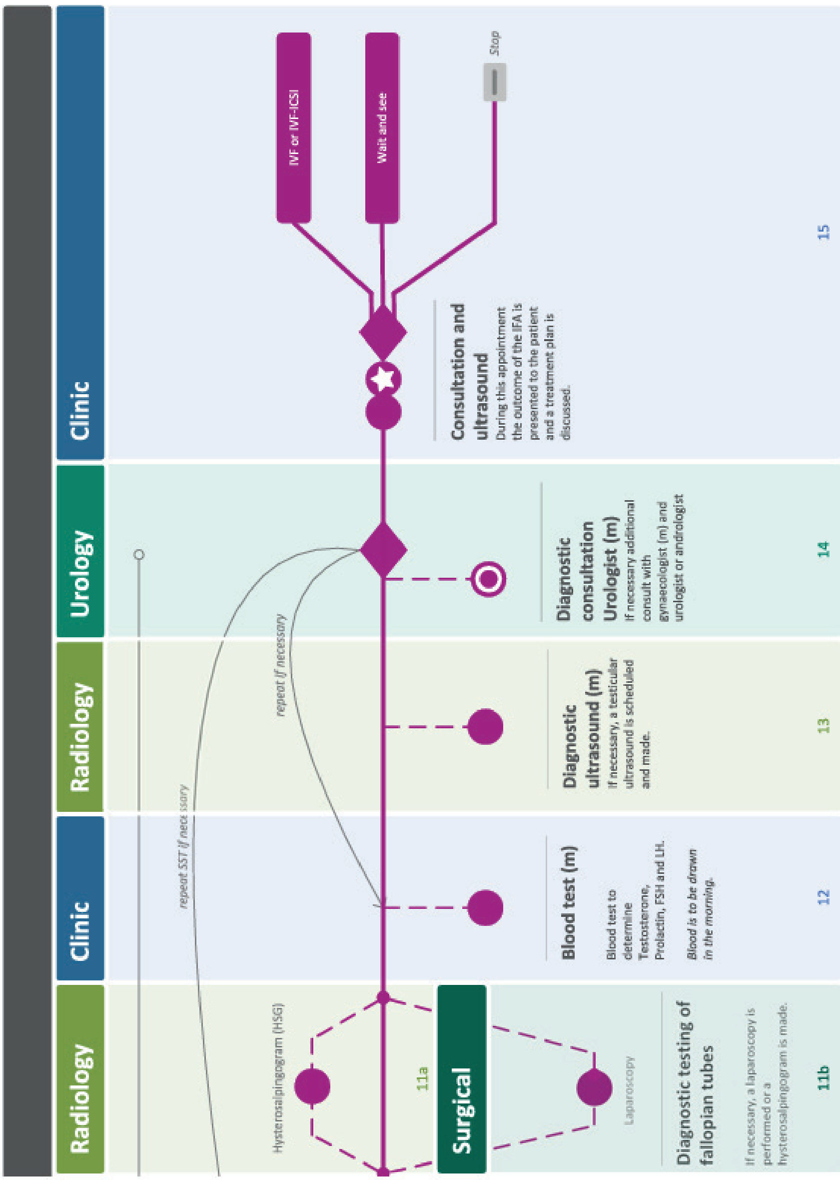
METRO MAPPING
Intrauterine Insemination
With or without stimulation medication
Phase 1: monitoring
Clinic
Laboratory
± 16 days
If f<38 years: max 6 cycles IUI
If f≥ 38 years: max 4 cycles IUI
Blue: IUI without stimulation
Pink: IUI with stimulation
Initial Fertility Assessment (IFA)
Prior treatment cycle
CD1
CD3
CD 7 or 8
CD10
CD 14
CD 16
Consult w. Ultr.
6b
Repeat every 1-3 days until response
repeat if needed
If n=1 follicle > 17 mm
& n follicles > 12 mm, not more than 3
& n follicles > 15 mm, not more than 2
24-48 hours
24 hours if ovulation test positive
IUI 2 days after trigger
1 day
30 min
poor response
Stop
7-10 days as needed
Patient informs IVF nurse by email
On cycle day 1 (CD)
IVF Nurse prepares medication for patient (medication up until the first ultrasound appointment)
Kick-off consultation with ultrasound, start medication.
To rule out cysts and measure endometrial thickness.
Patient receives stimulation medicine (Letrozole or CC) starting day CD3. If the patient does not have a natural cycle, an arbitrary day is chosen.
Preparation with progesterone
If necessary patient completes pregnancy test and a withdrawal bleeding with progesterone.
Blood test
If necessary (f) to measure FSH, AMH, E2/Estradiol
Consultation with ultrasound
Measure follicles and total endometrial thickness (TED)
Evaluation consultation
In case of poor ovarian response, illness, or other circumstances the treatment may be cancelled. Further treatment options are discussed.
Ovulation test
If negative and follicle is of sufficient size: ovulation trigger
If positive: complete IUI next day
Ovulation trigger
hCG injection (if necessary)
Media and tube preparation for semen sample
Tubes and media are prepared for semen processing by filling the tubes with medium and setting them in a rack in the incubator.
1
2
3
4
5
6a
7
8
9

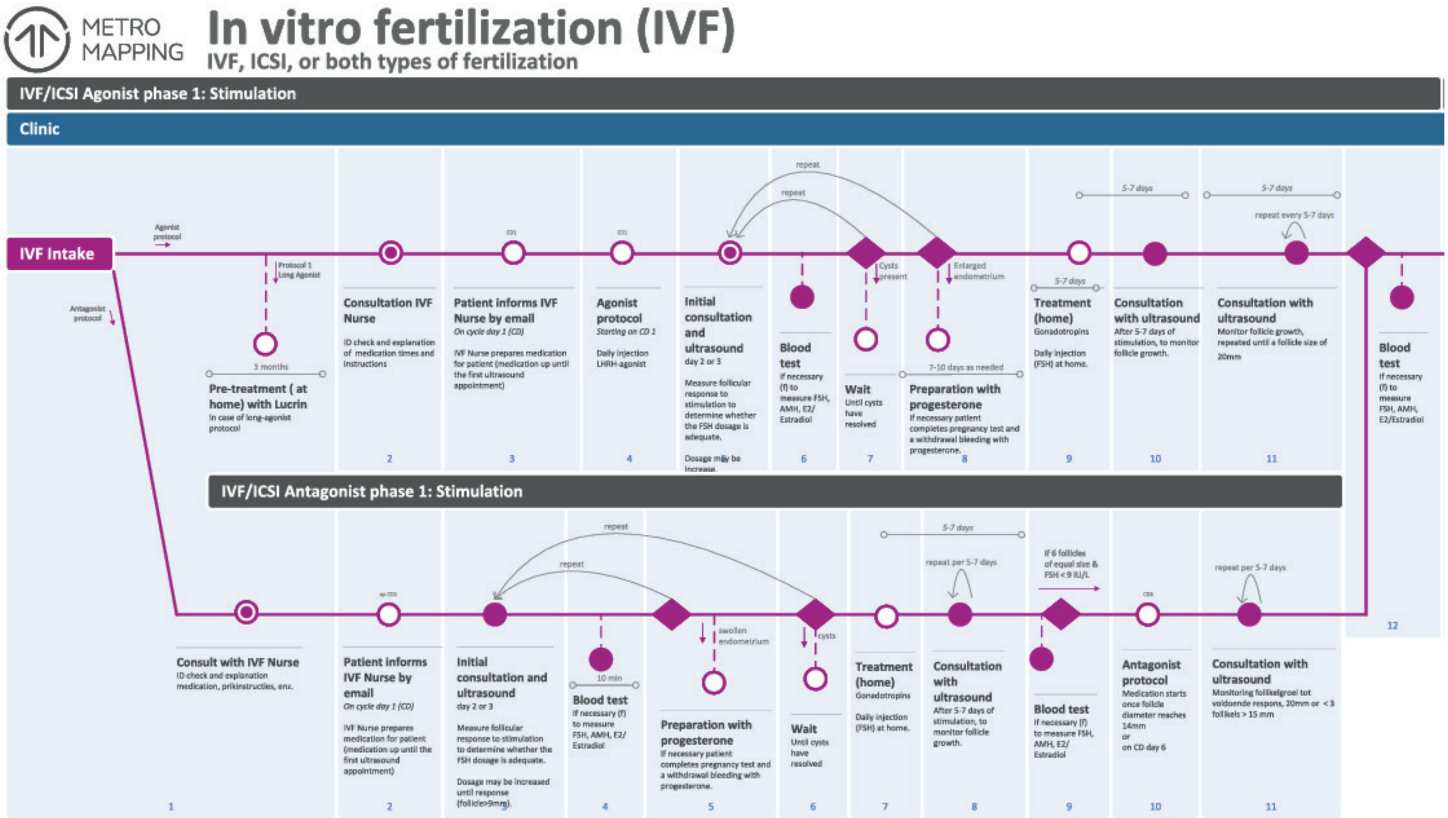


Radiology
Clinic
Semen sample delivery and administration
Semen is delivered once to IVF Lab for analysis and processing for IUI (m).
Stickers are made, the patient's ID is checked and the sample is handed over to an analyst for processing.
10
Semen preparation
The sample is prepared for fertilization, and a sperm count is performed.
Depending on the sperm count, a swim out or swim up technique is used. This impacts how long it spends in the centrifuge (12, 6 & 5 minutes, with ST80) vs. (6 & 5 minutes, without ST80).
IUI catheter is loaded and prepared.
11
14 days
IUI Insemination
12
Pregnancy test
Patient completes pregnancy tests at home
13
Hysterosalpingogram (HSG)
14a
Surgical
Laparoscopy
Diagnostic testing of fallopian tubes
If repeated cycles remain unsuccessful, further diagnostics may be scheduled (laparoscopy; hysterosalpingogram).
14b
repeat from step 3
30 min
Consultation with ultrasound
1st Pregnancy test
If not pregnant, further treatment is discussed and chosen.
Letter is sent to patient and insurer.
15
pregnant
12 weeks
30 min
Consultation with ultrasound
2nd pregnancy test. Referral to midwife. If needed, additional diagnostic testing is scheduled.
If the pregnancy has failed, a new treatment cycle can be started.
not pregn.
16
12 weeks pregnant
Not pregnant
Different treatment, or drop out
Not pregnant, patient completes another round of IUI starting at step 3, or attempts a different treatment.
outcome

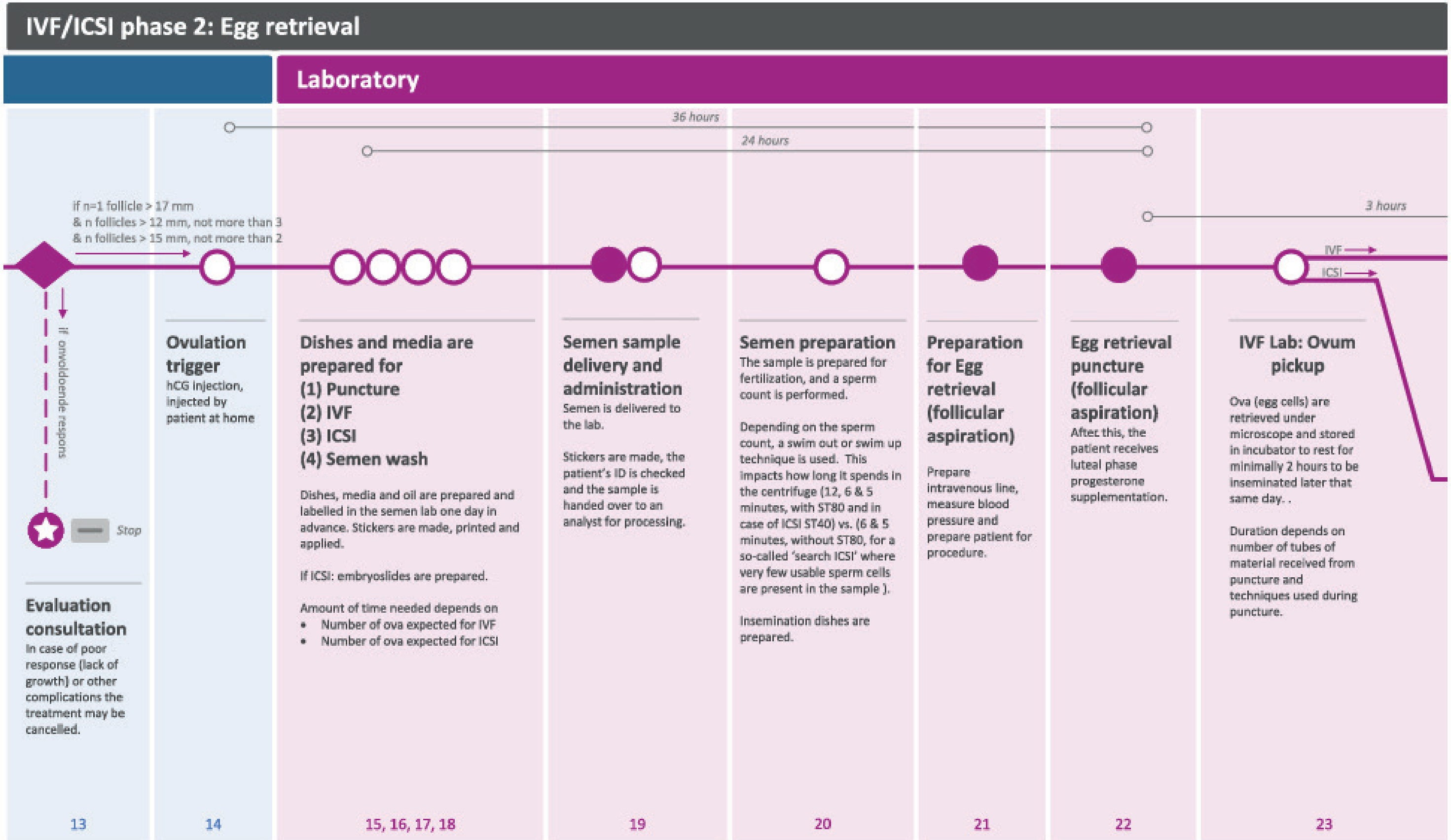
A


METRO MAPPING
IVF Intake
For internal or external patients
Initial Fertility Assessment (IFA)
Clinic
Laboratory
Clinic
Initial Fertility Assessment (IFA)
Prior treatment cycle
Kick-off IVF intake consultation
Initial consultation about the patient's child wish and gynecological history. Lifestyle, past experience, symptoms, and expectations are discussed.
This consultation determines the diagnostics scheduled during the IFA, which also depend on the extent of prior diagnostics.
1
Lifestyle consultation with nurse
2
End
Lifestyle adjustments at home
If necessary the patient changes her lifestyle. In some cases, this means delaying treatment.
• 19 ≤ BMI ≤ 32.
• Non-smoker (minimally 3 months).
• Age female ≤44 and male ≤5.
• Stable relationship and/or life circumstances.
CD1 - 28
BTC
Basal temperature trend is determined/ measured (f) daily at home by patient for one menstrual cycle.
3
CD3
Blood test (f)
Blood test x3 (f) on the following cycle days:
CD3 (AMH, E2, FSH, CAT), +5 (Progest.), +8 (Progest.)
Starting on cycle day 3, then 5 and 8 days after temperature increase.
4
End
Serology Infection screening (m, f)
Mandatory screening for Hepatitis B, HIV, and serology
5
4-6 weeks
repeat SST if necessary
1 day
2-24 hrs
Tube preparation for semen analysis and SST
Materials are prepared in the lab one day in advance.
SST: Sperm survival test
6
Semen sample delivery and administration
Semen is delivered once to IVF Lab for analysis (m).
Stickers are made, the patient's ID is checked and the sample is handed over to an analyst for preparation and SST.
7
Semen analysis and preparation for SST
The sample is prepared for the sperm survival test using a sperm wash technique, and a sperm count is performed.
8
SST evaluation after insemination
Sperm survival test is evaluated.
Reasons for repeat SST:
• Fever past 70 days
• Incorrect sample pot
• Mismatch with previous result
• Patient recently ill
9
Consultation prior to additional testing (m/f)
If additional diagnostics are necessary these are discussed with the patient(s).
10


Radiology
Surgical
Clinic
Radiology
Urology
Clinic
Hysterosalpingogram (HSG)
11a
Laparoscopy
Diagnostic testing of fallopian tubes
If necessary, a laparoscopy is performed or a hysterosalpingogram is made.
11b
repeat SST if necessary
Blood test (m)
Blood test to determine Testosterone, Prolactin, FSH and LH.
Blood is to be drawn in the morning.
12
repeat if necessary
Diagnostic ultrasound (m)
If necessary, a testicular ultrasound is scheduled and made.
13
Diagnostic consultation Urologist (m)
If necessary additional consult with gynaecologist (m) and urologist or andrologist
14
Consultation and ultrasound
During this appointment the outcome of the IFA is presented to the patient and a treatment plan is discussed.
IVF or IVF-ICSI
Wait and see
Stop
15



METRO MAPPING
In vitro fertilization (IVF)
IVF, ICSI, or both types of fertilization
IVF/ICSI Agonist phase 1: Stimulation
Clinic
IVF Intake
Agonist protocol
Antagonist protocol
Protocol 1 Long Agonist
3 months
Pre-treatment (at home) with Lucrin
In case of long-agonist protocol
Consultation IVF Nurse
ID check and explanation of medication times and instructions
Patient informs IVF Nurse by email
On cycle day 1 (CD)
IVF Nurse prepares medication for patient (medication up until the first ultrasound appointment)
Agonist protocol
Starting on CD 1
Daily injection LHRH-agonist
Initial consultation and ultrasound
day 2 or 3
Measure follicular response to stimulation to determine whether the FSH dosage is adequate.
repeat
repeat
Blood test
If necessary (f) to measure FSH, AMH, E2/ Estradiol
Cysts present
Wait
Until cysts have resolved
Enlarged endometrium
7-10 days as needed
Preparation with progesterone
If necessary patient completes pregnancy test and a withdrawal bleeding with progesterone.
5-7 days
Treatment (home)
Gonadotropins
Daily injection (FSH) at home.
Consultation with ultrasound
After 5-7 days of stimulation, to monitor follicle growth.
repeat every 5-7 days
Consultation with ultrasound
Monitor follicle growth, repeated until a follicle size of 20mm
Blood test
If necessary (f) to measure FSH, AMH, E2/Estradiol
IVF/ICSI Antagonist phase 1: Stimulation
Consult with IVF Nurse
ID check and explanation medication, prikinstructies, enz.
Patient informs IVF Nurse by email
On cycle day 1 (CD)
IVF Nurse prepares medication for patient (medication up until the first ultrasound appointment)
Initial consultation and ultrasound
day 2 or 3
Measure follicular response to stimulation to determine whether the FSH dosage is adequate.
Dosage may be increased until response (follicle>9mm).
10 min
Blood test
If necessary (f) to measure FSH, AMH, E2/ Estradiol
swollen endometrium
Preparation with progesterone
If necessary patient completes pregnancy test and a withdrawal bleeding with progesterone.
cysts
Wait
Until cysts have resolved
Treatment (home)
Gonadotropins
Daily injection (FSH) at home.
repeat per 5-7 days
Consultation with ultrasound
After 5-7 days of stimulation, to monitor follicle growth.
If 6 follicles of equal size & FSH < 9 IU/L
Blood test
If necessary (f) to measure FSH, AMH, E2/ Estradiol
Antagonist protocol
Medication starts once follicle diameter reaches 14mm
or
on CD day 6
Consultation with ultrasound
Monitoring follikelgroei tot voldoende respons, 20mm or <3 follikels > 15 mm


IVF/ICSI phase 2: Egg retrieval
Laboratory
36 hours
24 hours
3 hours
if n=1 follicle > 17 mm
& n follicles > 12 mm, not more than 3
& n follicles > 15 mm, not more than 2
if onvoldoende respons
Stop
IVF
ICSI
Evaluation consultation
In case of poor response (lack of growth) or other complications the treatment may be cancelled.
13
Ovulation trigger
hCG injection, injected by patient at home
14
Dishes and media are prepared for
(1) Puncture
(2) IVF
(3) ICSI
(4) Semen wash
Dishes, media and oil are prepared and labelled in the semen lab one day in advance. Stickers are made, printed and applied.
If ICSI: embryoslides are prepared.
Amount of time needed depends on
• Number of ova expected for IVF
• Number of ova expected for ICSI
15, 16, 17, 18
Semen sample delivery and administration
Semen is delivered to the lab.
Stickers are made, the patient's ID is checked and the sample is handed over to an analyst for processing.
19
Semen preparation
The sample is prepared for fertilization, and a sperm count is performed.
Depending on the sperm count, a swim out or swim up technique is used. This impacts how long it spends in the centrifuge (12, 6 & 5 minutes, with ST80 and in case of ICSI ST40) vs. (6 & 5 minutes, without ST80, for a so-called 'search ICSI' where very few usable sperm cells are present in the sample).
Insemination dishes are prepared.
20
Preparation for Egg retrieval (follicular aspiration)
Prepare intravenous line, measure blood pressure and prepare patient for procedure.
21
Egg retrieval puncture (follicular aspiration)
After this, the patient receives luteal phase progesterone supplementation.
22
IVF Lab: Ovum pickup
Ova (egg cells) are retrieved under microscope and stored in incubator to rest for minimally 2 hours to be inseminated later that same day. .
Duration depends on number of tubes of material received from puncture and techniques used during puncture.
23

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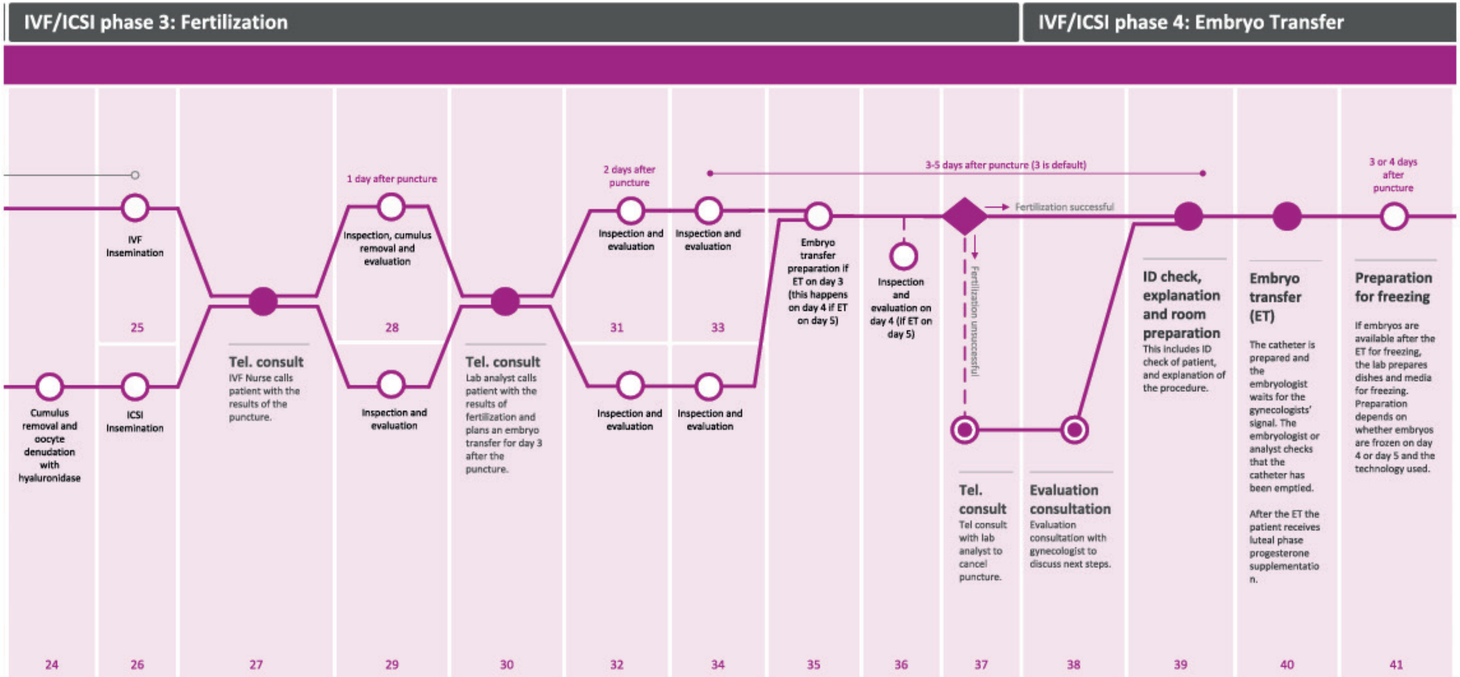
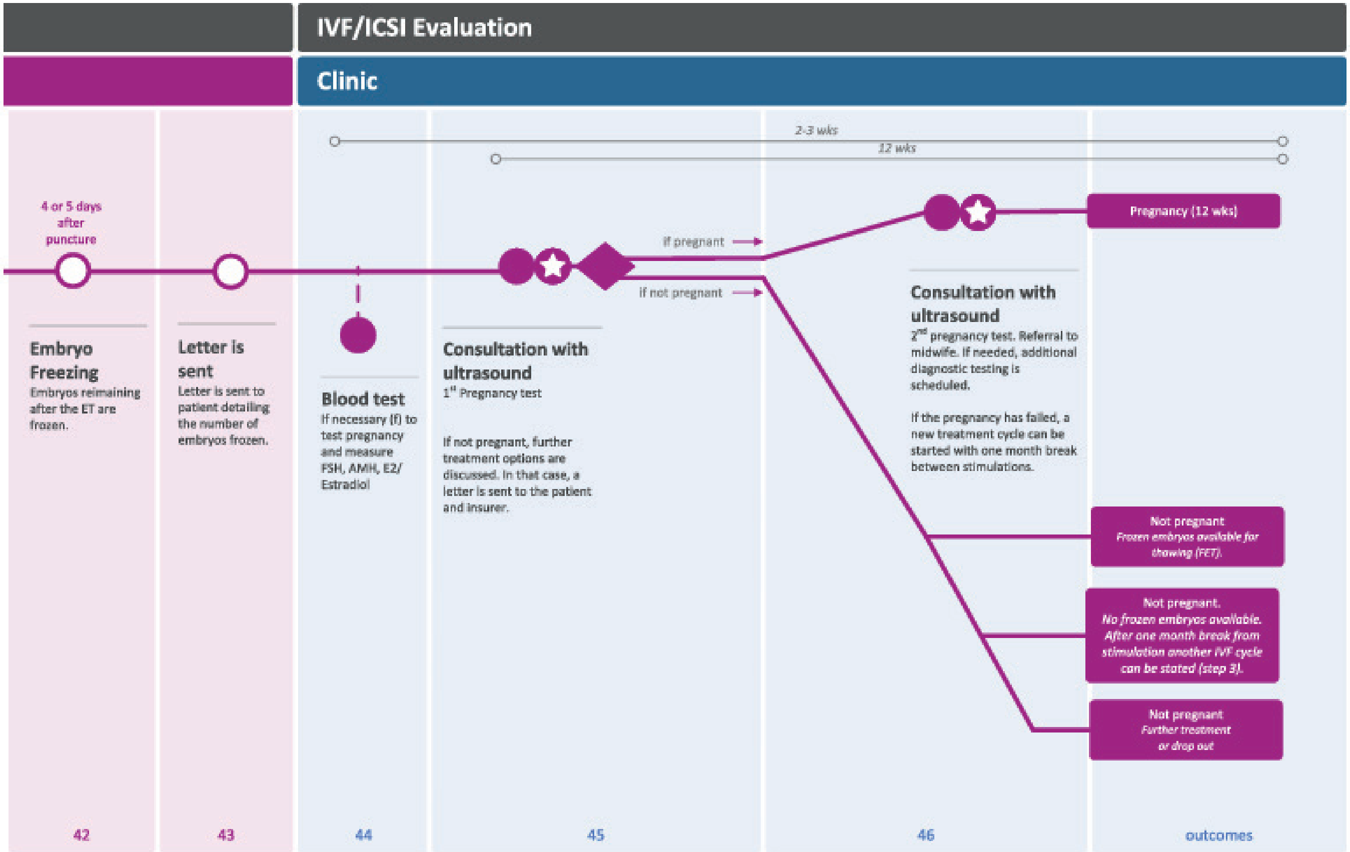
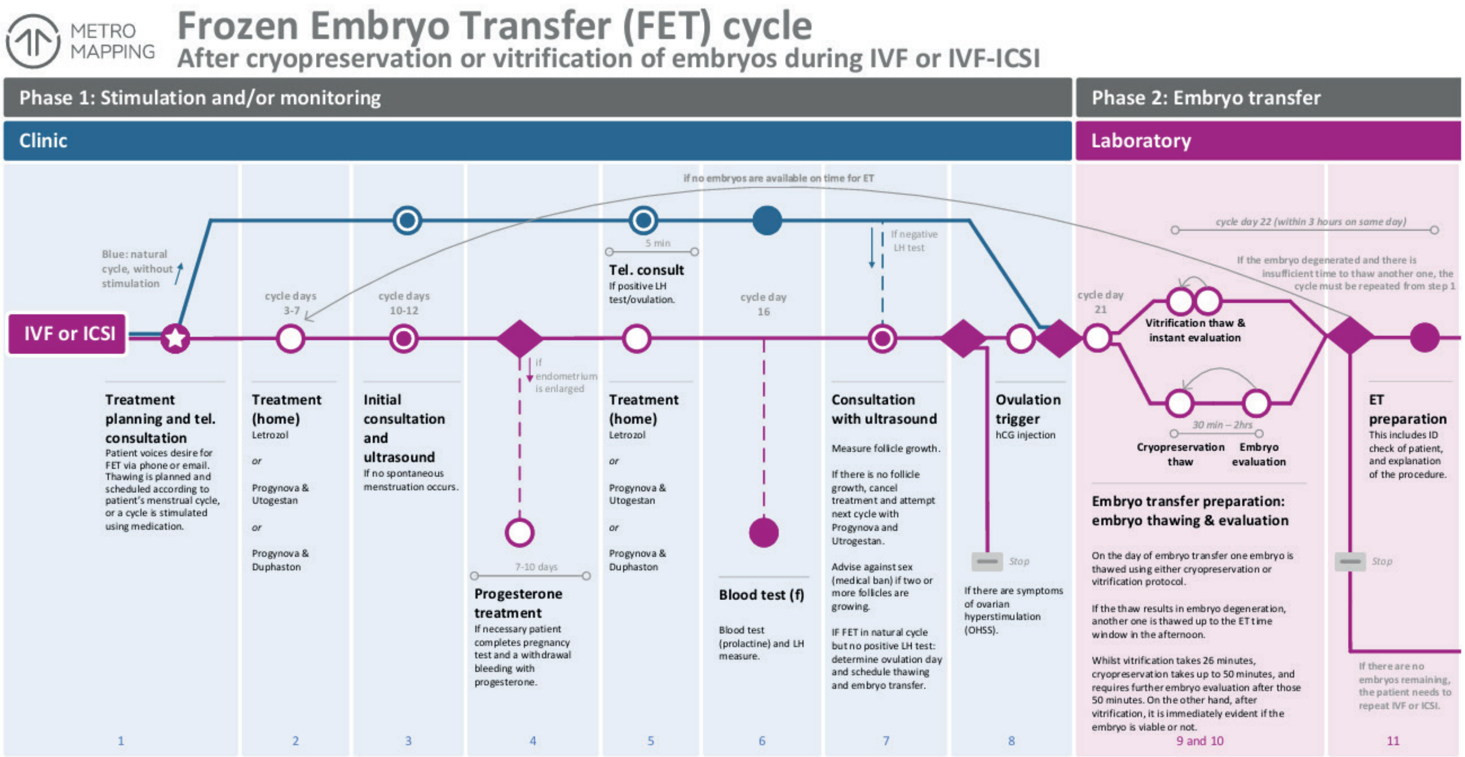
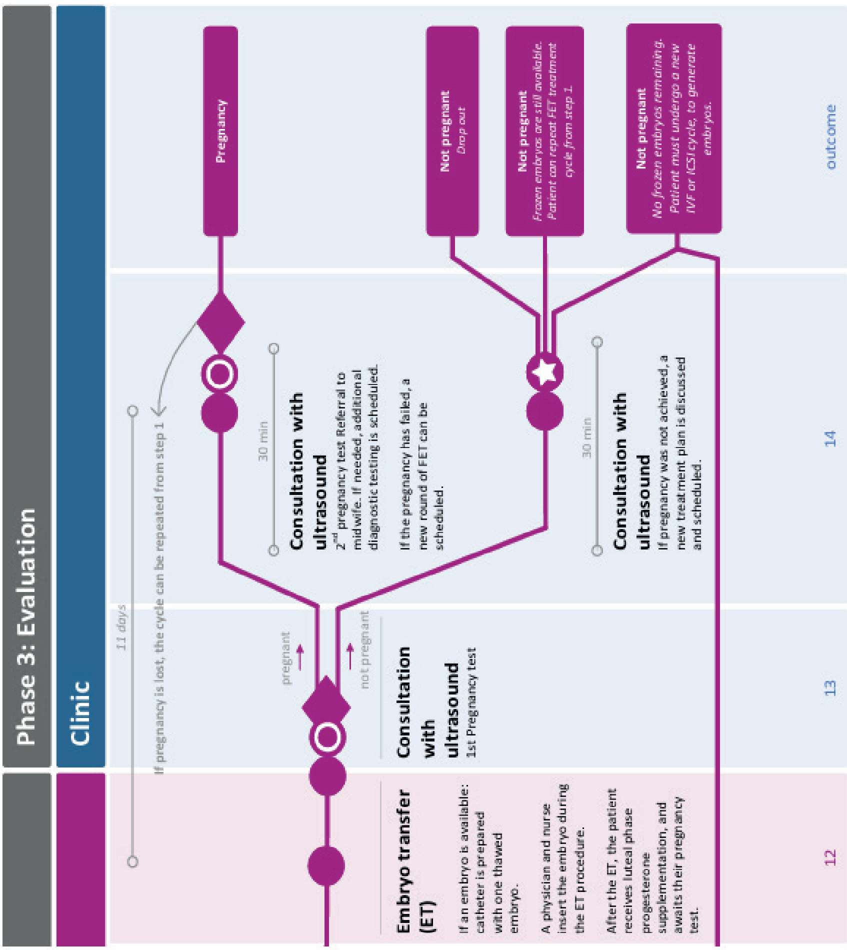

IVF/ICSI phase 3: Fertilization
IVF/ICSI phase 4: Embryo Transfer
Cumulus removal and oocyte denudation with hyaluronidase
24
IVF Insemination
25
ICSI Insemination
26
Tel. consult
IVF Nurse calls patient with the results of the puncture.
27
1 day after puncture
Inspection, cumulus removal and evaluation
28
Inspection and evaluation
29
Tel. consult
Lab analyst calls patient with the results of fertilization and plans an embryo transfer for day 3 after the puncture.
30
2 days after puncture
Inspection and evaluation
31
Inspection and evaluation
32
Inspection and evaluation
33
Inspection and evaluation
34
Embryo transfer preparation if ET on day 3 (this happens on day 4 if ET on day 5)
35
Inspection and evaluation on day 4 (if ET on day 5)
36
3-5 days after puncture (3 is default)
Fertilization successful
Fertilization unsuccessful
Tel. consult
Tel consult with lab analyst to cancel puncture.
37
Evaluation consultation
Evaluation consultation with gynecologist to discuss next steps.
38
ID check, explanation and room preparation
This includes ID check of patient, and explanation of the procedure.
39
Embryo transfer (ET)
The catheter is prepared and the embryologist waits for the gynecologists' signal. The embryologist or analyst checks that the catheter has been emptied.
After the ET the patient receives luteal phase progesterone supplementatio n.
40
3 or 4 days after puncture
Preparation for freezing
If embryos are available after the ET for freezing, the lab prepares dishes and media for freezing. Preparation depends on whether embryos are frozen on day 4 or day 5 and the technology used.
41



IVF/ICSI Evaluation
Clinic
2-3 wks
12 wks
4 or 5 days after puncture
Embryo Freezing
Embryos reimaining after the ET are frozen.
Letter is sent
Letter is sent to patient detailing the number of embryos frozen.
Blood test
If necessary (f) to test pregnancy and measure FSH, AMH, E2/ Estradiol
Consultation with ultrasound
1st Pregnancy test
If not pregnant, further treatment options are discussed. In that case, a letter is sent to the patient and insurer.
If pregnant
If not pregnant
Consultation with ultrasound
2nd pregnancy test. Referral to midwife. If needed, additional diagnostic testing is scheduled.
If the pregnancy has failed, a new treatment cycle can be started with one month break between stimulations.
Pregnancy (12 wks)
Not pregnant
Frozen embryos available for thawing (FET).
Not pregnant.
No frozen embryos available. After one month break from stimulation another IVF cycle can be stated (step 3).
Not pregnant
Further treatment or drop out
42
43
44
45
46
outcomes

A


METRO MAPPING
Frozen Embryo Transfer (FET) cycle
After cryopreservation or vitrification of embryos during IVF or IVF-ICSI
Phase 1: Stimulation and/or monitoring
Phase 2: Embryo transfer
Clinic
Laboratory
IVF or ICSI
Blue: natural cycle, without stimulation
If no embryos are available on time for ET
Treatment planning and tel. consultation
Patient voices desire for FET via phone or email. Thawing is planned and scheduled according to patient's menstrual cycle, or a cycle is stimulated using medication.
1
cycle days 3-7
Treatment (home)
Letrozol
or
Progynova & Utogestan
or
Progynova & Duphaston
2
cycle days 10-12
Initial consultation and ultrasound
If no spontaneous menstruation occurs.
3
If endometrium is enlarged
7-10 days
Progesterone treatment
If necessary patient completes pregnancy test and a withdrawal bleeding with progesterone.
4
5 min
Tel. consult
If positive LH test/ovulation.
Treatment (home)
Letrozol
or
Progynova & Utogestan
or
Progynova & Duphaston
5
cycle day 16
Blood test (f)
Blood test (prolactine) and LH measure.
6
If negative LH test
Consultation with ultrasound
Measure follicle growth.
If there is no follicle growth, cancel treatment and attempt next cycle with Progynova and Utrogestan.
Advise against sex (medical ban) if two or more follicles are growing.
IF FET in natural cycle but no positive LH test: determine ovulation day and schedule thawing and embryo transfer.
7
Ovulation trigger
hCG injection
Stop
If there are symptoms of ovarian hyperstimulation (OHSS).
8
cycle day 21
cycle day 22 (within 3 hours on same day)
Vitrification thaw & instant evaluation
30 min – 2hrs
Cryopreservation thaw
Embryo evaluation
Embryo transfer preparation: embryo thawing & evaluation
On the day of embryo transfer one embryo is thawed using either cryopreservation or vitrification protocol.
If the thaw results in embryo degeneration, another one is thawed up to the ET time window in the afternoon.
Whilst vitrification takes 26 minutes, cryopreservation takes up to 50 minutes, and requires further embryo evaluation after those 50 minutes. On the other hand, after vitrification, it is immediately evident if the embryo is viable or not.
9 and 10
If the embryo degenerated and there is insufficient time to thaw another one, the cycle must be repeated from step 1
ET preparation
This includes ID check of patient, and explanation of the procedure.
Stop
If there are no embryos remaining, the patient needs to repeat IVF or ICSI.
11


Phase 3: Evaluation
Clinic
11 days
If pregnancy is lost, the cycle can be repeated from step 1
Embryo transfer (ET)
If an embryo is available: catheter is prepared with one thawed embryo.
A physician and nurse insert the embryo during the ET procedure.
After the ET, the patient receives luteal phase progesterone supplementation, and awaits their pregnancy test.
pregnant
not pregnant
Consultation with ultrasound
1st Pregnancy test
30 min
Consultation with ultrasound
2nd pregnancy test. Referral to midwife. If needed, additional diagnostic testing is scheduled.
If the pregnancy has failed, a new round of FET can be scheduled.
30 min
Consultation with ultrasound
If pregnancy was not achieved, a new treatment plan is discussed and scheduled.
Pregnancy
Not pregnant
Drop out
Not pregnant
Frozen embryos are still available. Patient can repeat FET treatment cycle from step 1.
Not pregnant
No frozen embryos remaining. Patient must undergo a new IVF or ICSI cycle, to generate embryos.
12
13
14
outcome

A

Appendix H: Average and median durations observed

Appendix H table 1: Activity durations measured.

Lab Activity	#	Mean	Mean per k	Med	Range	Other related factors
General lab tasks						
Fill liquid nitrogen tanks (bi-weekly)	3	43,7		44,0	42-45	
Freeze donor sperm	3	36,0		36,0	35-37	
Daily lab clean-up and afternoon checks	3	56,7		55,0	55-60	
Daily lab start-up and morning checks	5	27,6		30,0	21-31	
Medium preparation (Cryopreservation)	3	72,7		70,0	50-98	
Weekly medium preparation (DMSO)	4	10,8		9,5	5-19	
Weekly medium preparation (HTF Hepes)	3	11,3		10,0	10-14	
Weekly medium preparation (HTF/HSA)	3	67,7		37,0	35-131	
Weekly medium preparation (ST80 tubes)	3	27,4		30,0	21-31	
Initial Fertility Assessment (IFA)						
SST tubes and stickers (day in advance)	5	6,1		5,7	4-17	
Semen received and washed for SST or IVF/ICSI	13	47,0		41,0	30-113	Sperm count
using swim-out technique			51,80			
using swim-up technique			42,43			
thawed from frozen			55,00			
SST insemination	4	12,8		13,0	5-20	
SST evaluation	9	5,6		5,0	4-7	
Urologist consultation	3	29,7		30,0	29-30	Case mix
Intra-uterine insemination (IUI)						
IUI: Stickers and administration (day in advance)	4	9,0		9,0	8-10	
IUI: Semen received and washed for IUI	8	37,0		40,0	22-45	Case mix
using swim-out technique			41,33			
thawed from frozen			31,50			
Load catheter	3	5,7		6,0	5-6	
In-vitro fertilization (IVF)						
Phase 2 egg retrieval						

Appendix H table 1: Continued

Lab Activity	#	Mean	Mean per k	Med	Range	Other related factors
IVF: dishes and stickers (day in advance)	4	23,7	1,17 per PO	24,0	12-34,8	HCP's skill
ICSI: dishes and stickers (day in advance)	6	50,3	3,39 per PO	52,5	29-175	HCP's skill
ICSI: Embryoslide preparation (day in advance)	3	14,0	1,20 per PO	16,0	8-18	
ICSI: dishes and stickers (day of)	4	30,0	2,45 per PO	27,5	15-50	HCP's skill
Ovum pickup/Oocyte recovery after puncture	13	34,5	5,22 per tube	36,0	15-66	HCP's skill, case mix
Phase 3 fertilization						
ICSI: Hyaluronic Acid Wash incl preparing dishes	9	28,2	2,51 per oocyte	30,0	6-49	HCP's skill
IVF: Oocyte denudation (day after puncture)	5	30,6	2,89 per oocyte	25,0	18-50	HCP's skill
IVF: Insemination	7	10,4		9,0	4-26	
ICSI: Insemination	10	58,9	9,5 per oocyte	45,0	28-108	HCP's skill, case mix
ICSI: Daily embryo evaluation	7	6,0	1,17 per embryo	5,0	2-8	
IVF: Daily embryo evaluation	7	6,7	1,04 per embryo	5,0	3-12	
Call patient to share results or schedule appointment	8	5,6		5,0	4-10	
Phase 4 embryo transfer						
Embryo transfer: preparation of wash media	3	5,0		5,0	5-5	
Embryo transfer: room preparation and lab work	7	34,9		36,0	27-44	HCP's skill
Preparation for freezing (dishes and media)	4	12,0		12,0	5-19	HCP's skill
Freezing of embryos	9	29,1		30,0	19-33	
using cryopreservation method			31,00	32,6		
using vitrification method			27,60	29,0		
Letter is made and sent to patient	3	5,0		5,0	5-5	
Frozen embryo transfer (FET)						
Preparation for thawing of embryo (dishes)	7	7, 1		8,0	2-11	
using devitrification method			7,00	7,5		HCP's skill

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Appendix H table 1: Continued

Lab Activity	#	Mean	Mean per k	Med	Range	Other related factors
using cryopreservation method			7,33	9,0		HCP's skill
Thawing of embryo in preparation for FET	23	39,9		40,0	17-62	Case mix
using cryopreservation method (blastocyst stage)			43,1	40,0		
using cryopreservation method			46,1	50,0		
using devitrification method			25,2	26,0		
Total observations	**218**					

Note: Average and median time observations, per lab task, and the associated cost predictors per activity based on respondent's statements and the observations. All times are given in minutes. Count refers to the number of times the activity was observed (in total 218 observations). PO: predicted oocyte (refers to the predicted number of oocytes based on ultrasounds prior to the follicular aspiration procedure.

Appendix I: Capacity cost rates (CCRs)

We determined resource pools based on the treatment options offered, and such that no treatment is allocated any costs that are not causally related to it. For example, the laboratory's costs were split into separate sub-departments to prevent allocating lab costs to a treatment trajectory without a causal link. To illustrate, the ICSI-lab is a separate cost pool because only patients undergoing IVF treatment with ICSI insemination require use of this specific set of resources. To account for the constant shifting of tasks between embryologists and analysts in the lab, we created a weighted average CCR that reflects the staffing levels of the clinic, namely that one embryologist is present for every three analysts working. This accounts for the four-eye principle, and the fact that embryologists need to sign off on certain choices or activities typically performed by analysts. Similarly, the gynecologist's CCR is a weighted average of the gynecologist and his/her physician's assistant. The CCRs cover the following costs: building rent, digital infrastructure costs, all medical and support staff salaries, medical and non-medical equipment, disposables, medical waste disposal, and weekly multidisciplinary team meetings.

Appendix I table 1: CCRs constructed and used.

Nr	Name	Description	Rate
CCR 0	Overheads	This rate covers the costs of building rent, IT infrastructure, support staff and weekly team meetings, divided by the practical capacity of all healthcare professionals working at the clinic.	€ 0,109
CCR 1	Gynecologist	This rate covers the costs of gynecologists and their corresponding doctor's assistant, based on their salaries. The practical capacity (denominator) is the total number of hours the Gynecologist is available to handle patients.	€ 1,918
CCR 2	Physicians	This rate covers the costs of the physicians, based on their salaries, relative to their practical capacity.	€ 1,077
CCR 3	Nurses	This rate covers the costs of IVF Nurses, based on their salaries, relative to their practical capacity.	€ 0,837
CCR 4	Clinic	This rate covers clinic's procedure rooms' equipment, disposables and medication stock. The practical capacity (denominator) is the total number of hours a physician or gynecologist is available to treat a patient in a procedure room.	€ 0,207
CCR 5	Urologist	This rate covers the costs of the Urologist, based on their salaries, relative to their practical capacity.	€ 3,333

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Appendix I table 1: Continued

Nr	Name	Description	Rate
CCR 6	Lab staff	This rate covers the costs of the embryologists and laboratory analysts, as a weighted average, based on their salaries and relative to their practical capacity. In this case, one embryologist is present each day, alongside 3 analysts, and work is shared among staff as needed.	€ 2,087
CCR 7	Lab - general	This rate covers the equipment and disposables of the semen lab, including for example the centrifuges and microscopes needed to wash and evaluate semen samples. The practical capacity (denominator) is the total staff time allotted to the semen lab.	€ 0,446
CCR 8	Lab - IVF	This rate covers the equipment and disposables of the IVF lab, including for example the incubators, microscopes, and dishes to complete IVF or ICSI inseminations. The practical capacity (denominator) is the total staff time available to perform IVF related tasks.	€ 1,845
CCR 9	Lab - ICSI	This rate covers the equipment and disposables of the ICSI lab, which is a secluded area of the lab only relevant to ICSI inseminations. The practical capacity (denominator) is the total staff time available to perform ICSI.	€ 1,205
CCR10	Lab - Freezing	This rate covers all media, cryopreservation tanks, and materials required to freeze, store and thaw embryos or other material. The practical capacity (denominator) is the total staff time available to cryopreservation tasks.	€ 0,938
CCR11	Radiology staff	This rate is a weighted average of all staff required to perform a hysterosalpingogram, which occurs in the radiology department. This is a diagnostic image required by a small subset of patients.	€ 2,089
CCR12	Laparoscopy OR staff	This rate is a weighted average of all staff required to perform a laparoscopy, which occurs in the operating room outside of the clinic. This is a diagnostic operation required by a small subset of patients during the initial fertility assessment.	€ 3,193

Note: Cost capacity rates (CCRs) identified and calculated. Disposables costing less than €10 per piece were incorporated into the relevant CCR. Significant disposables greater than €10 per piece were allocated directly to care paths, and not included in CCRs. Note: IFA: Initial Fertility Assessment, IVF: in-vitro fertilization, ICSI: intracytoplasmic sperm injection, FET: Frozen embryo transfer, IUI: intra-uterine insemination, Cryo.: Cryopreservation

Appendix J: Interactive costing tool (Fert Eval)

The interactive costing tool developed throughout the project and referenced in Chapter 4 is available at the following link:

https://doi.org/10.1007/s10198-024-01744-5 supplementary file 5The front-end of the tool allows users to select treatments and to estimate per-trajectory costs and looks as follows:

Fert Eval

Diagnostics	Input		Cost estimate
Initial Fertility Assessment (IFA)			
Number of diagnostic consultations with Gynecologist	2	€	162,15
HSG required?	no (default)	€	-
Urology or Andrology consultation with testicular ultrasound?	0	€	-
Diagnostic operation required?	no (default)	€	-
Number of semen survival tests (SSTs) required?	1	€	195,52
Initial Fertility Assessment (IFA) cost estimate		€	**503**
In-vitro fertilization (IVF) intake			
Number of diagnostic consultations with Gynecologist	0	€	-
HSG required?	no (default)	€	-
Urology or Andrology consultation with testicular ultrasound?	0	€	-
Diagnostic operation required?	no (default)	€	-
Number of semen survival tests (SSTs) required?	0	€	-
IVF intake cost estimate		€	-

Treatment cycles	Input	Cost estimate
Cycle 1	please select	€ 0,00
Cycle 2	please select	€ 0,00
Cycle 3	please select	€ 0,00
Cycle 4	please select	€ 0,00
Cycle 5	please select	€ 0,00
Cycle 6	please select	€ 0,00
Cycle 7	please select	€ 0,00
Cycle 8	please select	€ 0,00
Cycle 9	please select	€ 0,00
Cycle 10	please select	€ 0,00
Cycle 11	please select	€ 0,00
Cycle 12	please select	€ 0,00
Cycle 13	please select	€ 0,00
Cycle 14	please select	€ 0,00
Cycle 15	please select	€ 0,00
Cycle 16	please select	€ 0,00
Cycle 17	please select	€ 0,00
Cycle 18	please select	€ 0,00
Cycle 19	please select	€ 0,00
Cycle 20	please select	€ 0,00
	Total cost estimate	€ 502,96

Appendix J figure 1: Front-end of costing tool.

On a second sheet, users can view and adjust the CCRs used as inputs, and see the corresponding cost estimates per treatment cycle:

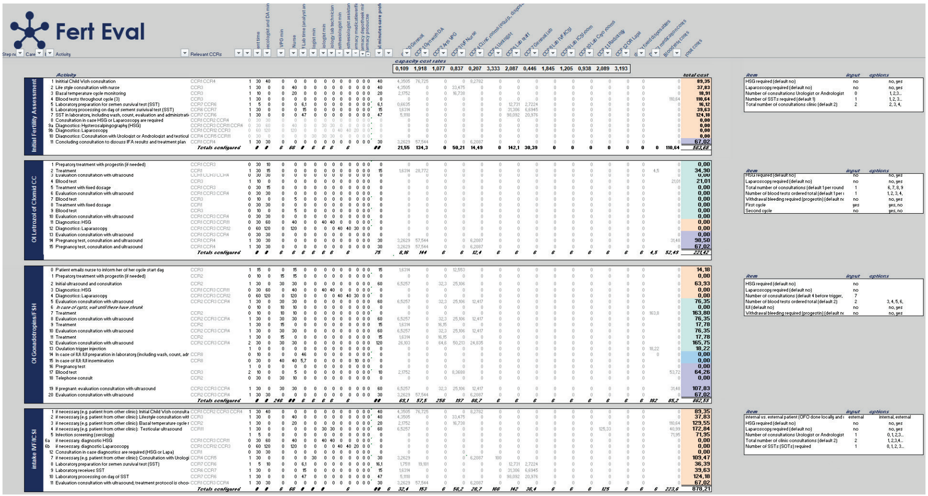
Fert Eval

Item	Type	Cost estimate
Ovulation induction	OI Gonadotropins	€ 963,00
	OI Clomid CC or Letrozole	€ 221,00
Intra-uterine insemination	IUI with stimulation medication	€ 854,00
	IUI with natural cycle	€ 518,00
	IUI with stimulation medication	€ 854,00
In-vitro Fertilisation (IVF)	IVF small	€ 2.479,00
	IVF medium	€ 2.595,00
	IVF large	€ 2.825,00
	IVF/ICSI combination medium	€ 3.010,00
	IVF/ICSI combination large	€ 3.617,00
	ICSI small	€ 2.740,00
	ICSI medium	€ 3.291,00
	ICSI large	€ 4.089,00
Frozen embryo transfer (FET)	FET with natural cycle	€ 940,00
	FET with stimulation medication	€ 1.036,00
Expectant monitoring	Expectant monitoring	€ 0,00

Nr	CCR name	CCR per min
0	CCR0 Building, facilities, support staf	€ 0,1088
1	CCR1 Gyn with DA	€ 1,9181
2	CCR2 Physician	€ 1,0767
3	CCR3 IVF Nurse	€ 0,8369
4	CCR4 Clinic equipment, disposables	€ 0,2070
5	CCR5 Urologist	€ 3,3333
6	CCR6 Staff lab (Embryologist & Ana	€ 2,0871
7	CCR7 General lab incl semen	€ 0,4463
8	CCR8 Lab IVF & ICSI	€ 1,8453
9	CCR9 Lab ICSI	€ 1,2051
10	CCR10 Lab Cryo	€ 0,9381
11	CCR11 Radiology	€ 2,0888
12	CCR12 OK Laparascopie	€ 3,1931

Appendix J figure 2: CCR input sheet of costing tool.

In a third and larger spreadsheet, each activity is programmed in one row and can be adjusted. Making changes here is reflected in the first two interfaces of the tool, and ensures traceability from input information to cost estimate:



Appendix J figure 3: Excerpt of costing tool, depicting each activity as one row that can be adjusted using input fields on the right.

Appendix K: Data linkage in the case of colorectal cancer in Victoria, Australia

To build the longitudinal database described in **figure 1** of the manuscript for CRC in Australia, we integrated data from multiple sources, covering three major hospitals in Melbourne. Data from two clinical registries, ACCORD57F49F[1] and TRACC58F50F[2], were linked with the three hospital's administrative datasets (VAED59F51F[3]) and primary care data (NPS Medicine Insight). The merged data provided a comprehensive view of patient encounters, treatments, and medication usage related to colorectal cancer. Activity costs were derived from VAED (WIES factor60F52F[4]) and NPS Medicine Insight, through cost retrieval of medical services and pharmaceutical prescription item numbers respectively available on MBS61F53F[5] and PBS62F54F[6] websites. The project was part of a larger multi-center research program and had received ethics approval by Royal Melbourne Hospital Ethics Board through the BioGrid application (202003/8).

ACCORD is a comprehensive cancer outcomes and research database that collects information on patients with various tumor types. For this study, patients diagnosed with colorectal cancer were selected. ACCORD contains patients' clinical characteristics, such as tumor type and treatments received, and utilizes an encrypted unique swap identifier (USI) for data linkage. The Victorian Admitted Episodes Dataset (VAED) provides information on hospital admissions, diagnoses, and procedures in Victorian hospitals. The dataset includes encounters with the healthcare system and covers patients admitted to public or private hospitals, extended care facilities, or day procedure centers. The NPS Medicines Insight database consists of de-identified electronic health records from Australian general practices. It includes information on patient encounters, investigations, and prescribed medications. After linking the ACCORD subset from the three hospitals with the NPS MedicineInsights and VAED data, 4336 unique patient records remained. TRACC focuses on the treatment of recurrent and advanced colorectal cancer, enrolling patients from Australian and Hong Kong hospitals. After linking the TRACC data to the ACCORD subset, the linked dataset contained 4246 unique patient records.

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1. ACCORD; Australian Comprehensive Cancer Outcomes and Research Database
2. TRACC; Treatment of Recurrent and Advanced Colorectal Cancer
3. VAED; Victorian Administrative Episodes Data hospital administrative Datasets
4. WIES; Weighted Inlier Equivalent Separation factor
5. MBS; Medicare Benefits Schedule
6. PBS; Pharmaceutical Benefit Scheme

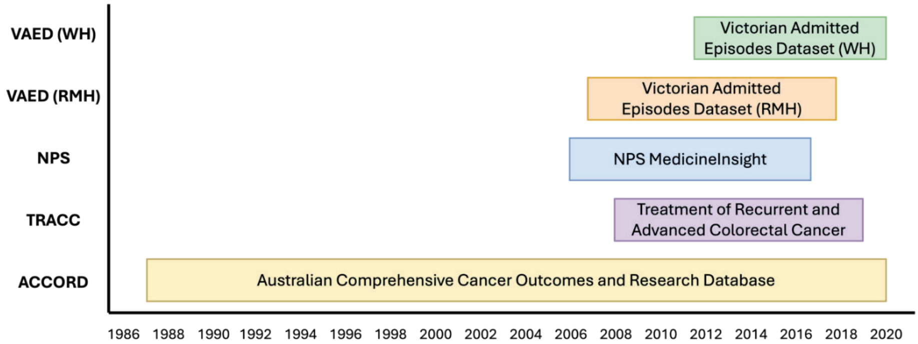
In sum, we linked data from ACCORD, TRACC, VAED, and NPS Medicines Insight to build a longitudinal database of all patient encounters (activities, consults, surgeries, etc.) and medication usage related to CRC. Activity costs were derived from VAED (WIES factor) and NPS MedicineInsights. In NPS MedicineInsights, information related to prescriptions and medical services provided to patients by general practitioners is available. This information corresponds to item numbers that are found in the Pharmaceutical Benefits Scheme (PBS, drugs) and Medicare Benefit Schedule (MBS, medical services). In the linked dataset, there is no cost data available within NPS MedicineInsights, however, it is possible to retrieve individual item number cost online on PBS and MBS websites. Therefore, both websites were scraped to retrieve cost data of all available items and data was uploaded onto the secure server to attribute cost to items found in NPS MedicinesInsight.

In the case of CRC in Australia, we linked five sources of data to meet the requirements discussed above. These data sources are summarized in **appendix K table 1**, per phase of treatment relevant to CRC, and together these data sources cover the data requirements described in the main manuscript. Each row details the data sources, depicted in **appendix K figure 1**. In case of CRC, patients pass through 4 stages of care. Lastly, life event data is required to define an end state to each patient pathway (e.g., survivorship). To be able to link, merge and use such data, ethical approval from the relevant institution(s) should be requested, detailing how the data will be/ is anonymized to ensure privacy [1–3]. It is considered best practice to categorize data that is not needed in direct form, such as age or BMI, which in combination with each other could enable the identification of individuals that fall outside the normal distribution [1]. The combined registry data captures a total economic burden of $ 60,63M AUD, across approximately 4000K/4 million care activities delivered. A noticeable shortcoming of this dataset is that it covers very few patients treated with radiation therapy (about 30) whereas it would be expected that about 15% of patients were treated with radiation [4]. This may have been caused by the data joining process, whereby several patients were excluded if data was incomplete following the merge this or this may be related to inconsistent reimbursement (DRG) coding.

Appendix K table 1: data sources for pathway construction.

General requirements for process mining with cost aggregation			**CRC case data sources**
Pathway	Data	Timestamp data (examples)	Sources
(A) Indication	General practitioner data	GP visit Screening referral Detected in another admission	NPS MedicineInsight,
(B) Diagnosis	Specialist diagnostics data	Imaging techniques (CT/ MRI) Colonoscopy Histology	NPS MedicineInsight,
(C) Admitted Episodes	Hospital data on admitted episodes	Surgeries Admission for chemotherapy Palliative care	VAED, WIES Factor, CPI
(D) Medications	Prescription medication data	Chemotherapy drug during admission Drug prescribed for side effect	NPS MedicineInsight, ACCORD
€ Life events	Life event data from national registries	Diagnosis Death, survivorship Lost to follow-up	TRACC, ACCORD
All	Cost data	Annual standardized service costs DRGs, DBCs, or reference prices Cost estimates derived from activity-based costing techniques	NPS MedicineInsight, VAED (WIES Factor)

Note: VAED: Victorian Admitted Episodes Dataset; ACCORD: Australian Comprehensive Cancer Outcomes and Research Database; TRACC: Treatment of Recurrent and Advanced Colorectal Cancer; PBS: Pharmaceutical Benefit Scheme, MBS: Medicare Benefits Schedule, CPI: Consumer price index



Appendix K figure 1

Note: Summary of data used for colorectal cancer (CRC) case study and timeframes.

Appendix K References

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Appendix L: Patient characteristics per dataset used for CRC case study

Appendix L table 1: Sample characteristics.

	Life events, from ACCORD (N=4246)	Admitted episodes, from VAED (N=3233)	Chemo. Episodes from VAED (N=461)	Diagnostic test (N=50)	GP visits, from NPS (N=163)	Prescriptions from NPS and ACCORD (N=84)
Gender						
F	1792 (42.2%)	1357 (42.0%)	175 (48.9%)	24 (48.0%)	74 (45.4%)	43 (51.2%)
M	2454 (57.8%)	1876 (58.0%)	183 (51.1%)	26 (52.0%)	89 (54.6%)	41 (48.8%)
Age Group						
<30	42 (1.0%)	38 (1.2%)	7 (2.0%)	2 (4.0%)	2 (1.2%)	2 (2.4%)
30-39	113 (2.7%)	84 (2.6%)	16 (4.5%)	1 (2.0%)	6 (3.7%)	2 (2.4%)
40-49	311 (7.3%)	247 (7.6%)	40 (11.2%)	4 (8.0%)	18 (11.0%)	7 (8.3%)
50-59	698 (16.4%)	522 (16.1%)	82 (22.9%)	8 (16.0%)	29 (17.8%)	9 (10.7%)
60-69	1220 (28.7%)	950 (29.4%)	110 (30.7%)	16 (32.0%)	55 (33.7%)	32 (38.1%)
70-79	1181 (27.8%)	902 (27.9%)	70 (19.6%)	11 (22.0%)	30 (18.4%)	19 (22.6%)
80-89	572 (13.5%)	416 (12.9%)	29 (8.1%)	8 (16.0%)	20 (12.3%)	10 (11.9%)
90+	37 (0.9%)	27 (0.8%)	1 (0.3%)	0 (0.0%)	1 (0.6%)	2 (2.4%)
Unknown	72 (1.7%)	47 (1.5%)	3 (0.8%)	0 (0.0%)	2 (1.2%)	1 (1.2%)
Tumor location						
Colon	2580 (60.8%)	1983 (61.3%)	218 (60.9%)	31 (62.0%)	95 (58.3%)	52 (61.9%)
Rectal	1508 (35.5%)	1153 (35.7%)	132 (36.9%)	19 (38.0%)	64 (39.3%)	30 (35.7%)
Other	19 (0.4%)	17 (0.5%)	2 (0.6%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Undefined	139 (3.3%)	80 (2.5%)	6 (1.7%)	0 (0.0%)	4 (2.5%)	2 (2.4%)
Tumour Stage						
A	763 (18.0%)	591 (18.3%)	37 (10.3%)	10 (20.0%)	37 (22.7%)	17 (20.2%)
B	1250 (29.4%)	923 (28.5%)	77 (21.5%)	17 (34.0%)	43 (26.4%)	18 (21.4%)
C	1037 (24.4%)	802 (24.8%)	111 (31.0%)	10 (20.0%)	30 (18.4%)	19 (22.6%)
D	646 (15.2%)	526 (16.3%)	106 (29.6%)	9 (18.0%)	34 (20.9%)	25 (29.8%)
Unknown	550 (13.0%)	391 (12.1%)	27 (7.5%)	4 (8.0%)	19 (11.7%)	5 (6.0%)
Ethnicity/ Indigenous Status						
Aboriginal	507 (12.0%)	297 (9.2%)	18 (3.9%)	10 (20.0%)	18 (11.0%)	9 (10.7%)
Not Ab/TS	3462 (81.6%)	2824 (87.4%)	335 (72.7%)	36 (72.0%)	135 (82.8%)	70 (83.3%)

Appendix L table 1: Continued

	Life events, from ACCORD (N=4246)	Admitted episodes, from VAED (N=3233)	Chemo. Episodes from VAED (N=461)	Diagnostic test (N=50)	GP visits, from NPS (N=163)	Prescriptions from NPS and ACCORD (N=84)
Torres Strait	18 (0.4%)	18 (0.6%)	1 (0.2%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unknown	254 (6.0%)	93 (2.9%)	107 (23.2%)	4 (8.0%)	10 (6.1%)	5 (6.0%)
Remoteness						
Inner Regional	224 (5.3%)	151 (4.7%)	18 (5.0%)	0 (0.0%)	0 (0.0%)	1 (1.2%)
Major City	3959 (93.2%)	3056 (94.5%)	338 (94.4%)	48 (96.0%)	160 (98.2%)	82 (97.6%)
Outer Regional	36 (0.8%)	18 (0.6%)	0 (0.0%)	0 (0.0%)	1 (0.6%)	0 (0.0%)
Remote	1 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unknown	26 (0.6%)	8 (0.2%)	2 (0.6%)	2 (4.0%)	2 (1.2%)	1 (1.2%)

Appendix M: Cost aggregation algorithm

The objective of the algorithm is to enhance the process maps with additional information regarding the costs of each of the executed process steps. Thus, the extension can aggregate the value of a custom defined numeric value, over all aligned traces to a petri net. This function takes in four objects:

1. an event log $\boldsymbol{L}_h$ which contains a set of traces to be aligned to the petri net,

2. the discovered petri net itself,

3. The start- and end markings M_o and M_f

4. an aggregation function, such as the median, the mean, the sum.

The algorithm pseudocode is provided in **appendix C figure 2**. The initialization step of the algorithm initializes an empty list **O** of numeric values, where the current cost value will be stored (step 1). Then first, from the event log $\boldsymbol{L}_h$, the set of traces $\boldsymbol{\Phi}_h$ is stored and a list of all the activities or transition $T_{H,i}$ in the model λ_H. Secondly, For each level of hierarchy evaluated (**H**), each trace σ in $\boldsymbol{\Phi}_h$ is aligned to model λ_H (step 2). Then, for each activity *aj*(*i*) in the trace σ aligned to transition $T_{H,i}$, the associated cost value is aggregated by the specified aggregation function (in this case mean, although minimum, maximum, or median are also possible) and stored in the initialized list **O** (step 3). When all traces have been completed, the list **O** is concatenated to the list of transitions $T_{H,I}$ in the model λ_H, resulting in an annotated model (step 4). This results in a decorated petri net with aggregated costs added to each transition or each activity in the petri net. The costs are then added as an additional attribute, summing all costs of the activities for the included cases (output).

Input: $\boldsymbol{L}_h, \lambda_H, M_0, M_f, \boldsymbol{f}_{aggregation}$ **Output:** $\lambda_{H,annotated}$	
Step 0 Initialise	1 Initialise list ***O*** with k components where k = number of unique transitions T_H in the petrinet λ_H
Step 1. Subset Traces from log	**For** each k in ***O:*** 1. Let $\Phi_H = \{t_H1,, t_H2,\ldots,t_Hi\}$ denote the set of traces in $\boldsymbol{L}_h$ of all case *i* in I on aggregation level H 2. Subset from $\boldsymbol{L}_h$, all $\mathbf{T_{H,i}}$ in Φ_H associated with λ_H.
Step 2. Align traces on each Level	**For** each h in ***H***: 1. Let A_H denote the set of aligned traces of all case *i* in I on aggregation level H 2. A_H = Alignments ($\Phi(V)_H$, λ_H)) 3. Let M_H denote the set of activities in the aligned traces A_H associated with λ_H of all case *i* in I on aggregation level H
Step 3. Aggregate node	**For** each unique T_H in M_H: 1. Let O_k denote the total value of custom attribute on transition T_H 2. $O_k = \boldsymbol{f}_{aggregation}(T_H)$ next T_H
Step 4. End	Next h Next k
Step 5. Add decoration to net	**For** each T_H in λ_H: **For** each M_H in A_H **IF** $T_H = M_H$ $\lambda_{H,annotated} = = \boldsymbol{f}_{add\_to\_net}(O_k, \lambda_H)$ End IF next M_H next T_H
Step 6. Output:	**return** $\lambda_{H,annotated}$

Appendix M figure 1: Pseudocode node aggregation in petri net, which illustrates how the algorithm aggregates costs.

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Appendix N: Enabling costing information items and translations

Appendix N table 1: Items used for "enabling cost information" construct, in Dutch and English.

	English **I feel that the cost system within my organization**	**Dutch** **Ik heb het gevoel dat het kostensysteem binnen mijn organisatie**
Repair 1	enables me to work more efficiently (e.g., by allowing me to compare the costs of alternative processes or technologies).	mij in staat stelt om efficiënter te werken (bijv. door dat ik de kosten van alternatieve processen of technologieën kan vergelijken).
Repair 2	can help me deal with unforeseen work problems.	mij kan helpen bij het omgaan met onvoorziene werkproblemen.
Repair 3	allows me to recognize when things are going wrong (e.g., when certain processes, patients, or clients are being handled inefficiently).	mij in staat stelt om te herkennen wanneer er dingen fout gaan (bijv. wanneer bepaalde processen, patiënten, of cliënten inefficiënt worden afgehandeld).
Repair 4	allows me to revise methods to perform my work more efficiently.	mij in staat stelt om methoden te herzien om mijn werk efficiënter uit te voeren.
Repair 5	allows me to identify opportunities for improvement.	mij in staat stelt om verbetermogelijkheden te identificeren.
Internal transparency 1	gives me useful information about the cost of care (e.g., care pathways, treatments) that was provided.	mij bruikbare informatie geeft over de kosten van de zorg (bijv. zorgtrajecten, behandelingen) die werd geleverd.
Internal transparency 2	gives me useful information about how to do my job.	mij bruikbare informatie geeft over hoe ik mijn werk moet doen.
Global transparency 1	allows me to understand the broader processes within my organization.	mij in staat stelt om de bredere processen binnen mijn zorginstelling te begrijpen.
Flexibility 1	enables me to make decisions to deliver care more effectively.	mij in staat stelt om beslissingen te nemen om de zorg beter te leveren.
Flexibility 2	allows me to make decisions to deliver care more efficiently.	mij in staat stelt om beslissingen te nemen om de zorg efficiënter te leveren.
Flexibility 3	enables me to do my job more flexibly.	mij in staat stelt om mijn werk flexibeler uit te voeren.

Appendix N table 1: Continued

	English **I feel that the cost system within my organization**	**Dutch** **Ik heb het gevoel dat het kostensysteem binnen mijn organisatie**
Coercive 1	is designed to direct people's actions toward the norms and standards of higher (top) management.	is bedoeld om de acties van mensen te sturen in de richting van de normen en standaarden van het hogere (top) management.
Coercive 2	is designed to direct people's actions toward the norms and standards of external agencies (e.g., governments, inspection, health insurers or offices).	is bedoeld om de acties van mensen te sturen in de richting van de normen en standaarden van externe instanties (bv overheden, inspectie, zorgverzekeraars of kantoren).
Coercive 3	is used to limit the authority of executive like me.	wordt gebruikt om zeggenschap van leidinggevende zoals ik te beperken
Coercive 4	is used to limit the authority of healthcare professionals (doctors, nurses, etc.).	wordt gebruikt om de zeggenschap van zorgprofessionals (artsen, verpleegkundigen, enz.) te beperken.
Coercive 5	is used to report to senior (top) management whether employees's actions are conform to what was planned.	wordt gebruikt om aan het hogere (top) management te rapporteren of medewerkers zich aan de planning houden.
Coercive 6	is used to monitor employee adherence to healthcare and/or medical procedures.	wordt gebruikt om te monitoren of medewerkers zich aan zorgprocedures en/of medische procedures houden.
Coercive 7	is used to monitor whether employees adhere to organizational procedures.	wordt gebruikt om te monitoren of medewerkers zich aan organisatorische procedures houden.
Coercive 8	is used to communicate the expectations of upper (top) management, about how employees should act as healthcare professionals.	wordt gebruikt om te communiceren over de verwachtingen van het hogere (top) management, over hoe zorgprofessionals dienen te handelen.
Coercive 9	is used to communicate the expectations of upper (top) management, about how employees should act as managers.	wordt gebruikt om te communiceren over de verwachtingen van het hogere (top) management, over hoe leidinggevende dienen te handelen.

Note: The items related to coerciveness are listed here but were not used in the analysis reported in chapter 8. These items were chosen based on van der Hauwaert et al. (2022), Mahama and Cheng (2013), and van Beuren and Dos Santos (2019), and are rooted in rooted in Adler and Borys (1996) and Ahrens and Chapman (2004).

Summary

Rising healthcare costs impact us all, regardless of our health. This thesis explores the interdisciplinary challenge of healthcare costs by focusing on how and why co-constructed cost management systems foster cost accountability, aid value-based healthcare (VBHC) strategy implementation, and improve resource efficiency and staff wellbeing in healthcare organizations. Using Practice theory, and by focusing on one specific setting that exemplifies cost and workforce challenges, it explores how changing perceptions of costs, and new cost information, impact daily medical practices as treatments are personalized to patients. By implementing a novel patient-level cost accounting intervention in a fertility clinic delivering medically assisted reproduction (MAR) treatments such as in-vitro fertilization (IVF) over three years, the thesis generated impact through value improvements in the form of cost reductions and outcome improvements. It also extended our understanding of how new treatment pathways stabilize compromises between patients, healthcare providers, and society. By bridging the topics of cost pressure and workforce wellbeing using Self-determination theory, it advances the field by illustrating how and why enabling cost infrastructure is important to sustainable healthcare delivery.

Chapter 1 introduces the topic of healthcare costs from an organizational and managerial perspective, explores why healthcare organizations lack cost measurement or management infrastructure, and presents the research questions and intervention. These research questions center around how cost concerns impact medical decisions and lead to cost variation, how such variation can or should be accounted for, and how or why cost information may contribute to staff's wellbeing and motivation. Answering these questions sheds light on how, from both a technical and social perspective, managerial accounting systems can enable strategies such as VBHC and benefit the workforce.

Chapter 2 focuses on how, when, and why cost information has supported organizational decision-making in prior research. It synthesizes findings from 3874 studies across medical domains to understand if, how, and why cost systems support VBHC. It finds that granular costing methods (e.g., ABC, TDABC) help professionals manage care by identifying cost drivers, enabling before/after comparisons, and supporting process evaluations across groups and time. However, most studies are recent, US-based, and focus on standardized care. True system implementation is rare, and methods often vary so widely that terms like 'ABC' lose meaning. The review identifies three best practices—process mapping, timed observations, and clinician input—as vital to effective cost management system design and

construction. These best practices were applied in the later chapters. Due to a lack of prior studies implementing cost management systems in personalized care settings, where patients require significantly different resources or care, we emphasize the need for future research focused on (a) personalzied care and (b) organiztional implementation rather than one-off economic analyses.

Chapter 3 focuses on the role of costs in daily decisions, when clinicians need to judge what resources are necessary or appropriate for specific patients hoping to become parents. Using Practice Theory and based on two years of ethnographic immersion in a fertility clinic, the chapter examines how accounting practices influence daily resource allocation decisions. It focusses on how clinicians engage in and develop accounting practices, how this shapes their judgements of what resource use is appropriate for individual patients, and reveals that accounting actions are integral to medical practice. The chapter develops the concept of *teleological indeterminacy* to explore how clinicians experience uncertainty during these valuations, because they must anticipate how actions (now) will cause cost and performance outcomes in distant and uncertain futures. In these moments, the costs of using more petri dishes or other materials are weighed against distant outcomes like prengnacy and parenthood. It shows how clinicians face uncertainty when applying standard rules to personalized cases, such as in IVF. Accounting systems shape perceptions of what constitutes "good practice," yet clinicians often lack the practical foresight to predict cost outcomes. This chapter illustrates how cost accountability emerges in practice and the limits of rules in guiding resource use.

Chapter 4, informed by the prior chapters, presents the development of a novel cost estimation method tailored to fertility care (TDABC-PM), which estimates per-patient costs from consultation to pregnancy and birth. It treats each patient's care path as a unique cost object, capturing variation in resource use at the activity level (e.g., number of consultations required, specific diagnostic activities delivered, volume of embryos cultivated). Such cost predictors, when chosen by clinicians, illustrate where and why cost variation occurs in the organization. It may prompt staff to reflect on cost sources and accept new responsibilities by attempting to improve or manage such costs. The method combines management accounting and bioinformatics methods to enable full-cycle cost estimation, making it relevant to other settings. In particular, because the method can capture patient-level variation cross entire treatment pathways, it extends literature on TDABC and VBHC.

Chapter 5 applies this method to a decade of Dutch fertility treatment data (13 203 treatments relating to 4190 pregnancy trajectories and 6822 male and female patients), identifying sources of cost and outcome variation. Informed by the previous chapters, it demonstrates that costs incurred in the laboratory phases of care vary due to six patient-level or organizational factors, such as the number of embryos generated. It identifies key decision-making moments that significantly determine costs and outcomes across entire pregnancy trajectories, and which impact costs in subsequent treatments for that same patient. This informed three care delivery shifts that improved the costs and outcomes of care provided:

1. Vitrification (a new method of embryo freezing and thawing)
2. AI-based embryo selection
3. Combined IVF/ICSI protocols

These shifts reduced costs by between €322 to €4089 per pregnancy trajectory, or €1.3 million in the Dutch setting, while improving time-to-pregnancy. These shifts, by preventing later treatments, made care more sustainable by reducing the total number of treatments needed. This reduced staff workload, resource use, and disposables use per pregnancy trajectory. The empirical results are relevant to European clinics, which follow the same protocols, and which have been facing significant growth in treatment demand (20% growth in demand in 2021; over 368 000 FET treatments we delivered in Europe in 2021). Paradoxically, these improvements caused financial losses for clinics, as shorter treatment durations and fewer repeat cycles reduced revenue. The TDABC model created is included in this chapter as an open-access digital tool, designed to be maintained in the clinic and scaled to other clinics or settings. The analysis reveals that decisions made during treatment impact costs, resource requirements, and outcomes in later treatments – these patterns cannot be identified using current diagnosis-related group prices (DRGs), and allowed us to give concrete advice about how Dutch DRGs could be adjusted to better account for changing technologies and resource consumption patterns. Lastly, the chapter illustrates how and why TDABC systems must account for patient-level variation to support local decision-making.

Chapter 6 extends the methodology to the Australian colorectal cancer setting, which shares personalization challenges with fertility care, but features a more granular reimbursement model. Using data from 4246 patient pathways and over 4 million care activities (2012–2020), the chapter shows that inpatient admissions drive 93% of costs, and that the costs of a treatment depend significantly on the timing of the treatment in the patients' trajectory. For instance, the costly chemotherapy regimen Mflolfox 6 ($35 K AUD), is much more costly during stage C cancer than any other stages. Importantly, this chapter illustrates that future interventions should aim to reduce costs of inpatient episodes, rather than focusing on drug and medication costs as is often suggested. The algorithm developed in this project can be used by practitioners and policymakers in other care settings, and the results reveal that the relative timing of a treatment in the patients' CRC trajectory significantly impacts costs incurred.

Chapter 7 focuses on how new technologies stabilize cost and resource use patterns in organizations through new pathways. It extends the analysis presented in **chapter 5**, and the practice-theoretical perspective developed in **chapter 3**, by exploring how new technologies like vitrification move resource use from later treatments rounds onto earlier treatment rounds within entire pregnancy trajectories. The chapter uses TDABC-PM across one decade of clinical data (4190 pregnancy trajectories, 18 445 care activities), participant observations (430 hrs), and a practice-theoretical lens to identify key patterns in pregnancy trajectories. It illustrates that the value of treatments to patients depend on their relative timing during the pregnancy trajectory. For instance, the chapter finds that the 5th successive IUI treatment offered, as is typically mandated by Dutch fertility care guidelines, has near-zero success chances for patients and should be avoided. Because clinicians allocate resources by considering the patients' trajectory as a total package, rather than individual treatments or products, the chapter shows that early treatment rounds generate losses whereas later treatment rounds in the trajectory recuperate these losses by requiring fewer human and material resources.

By zooming in on the vitrification technology, and by exploring how this care delivery shifts improved value to patients and the health system but generates financial losses for the clinic, the chapter illustrates that these compromises are unpredictable and unfold over time. The chapter extends our understanding of how and why enabling cost management infrastructure must capture costs retrospectively to improve value in healthcare organizations.

Chapter 8 focuses on cost management behavior and workforce wellbeing. It builds on the insights of the previous chapters by conceptualizing when, how and why 'enabling' cost information can empower individuals to manage costs in their daily work. This chapter draws on Self-Determination Theory to empirically investigate the relationships between cost information, psychological wellbeing, motivation, and behavior. Using survey responses from 217 healthcare managers across diverse medical contexts and organizations. The chapter shows that enabling cost information significantly relates to psychological wellbeing (autonomy, competence, relatedness), and that psychological needs satisfaction relates to improved motivation. When cost information is enabling, it contributes to repair practices, internal and global transparency, and offers flexibility by allowing users to customize the system. These findings are relevant, because psychological well-being and motivation are related to lower chances of workplace stress and burnout, and should be prioritized.

Chapter 9 analyses the 'doing of' interdisciplinary research – research between multiple disciplines and sectors as I have engaged in across the previous chapters – to analyze how such work impacts early career researchers, and to analyze what skills and practices are required to do such work. Based on four years of autoethnographic data from three early career researchers and a comparative analysis (50 hrs of transcribed meetings, 600 pages of field notes), the chapter demonstrates that the monodisciplinary organization of scientific institutions (e.g. Universities) limits the generation, dissemination, and understanding of knowledge that does not fit neatly into disciplinary silos. Whilst doing interdisciplinary work, junior researchers must engage in three practices (*condensing, staging, and trespassing*) which can come to feel like 'dirty work' within monodisciplinary spaces. The chapter provides advice to early career scholars seeking to address interdisciplinary societal grand challenges like healthcare costs, and contributes to literature on transdisciplinarity, knowledge production, and researcher wellbeing. The practical recommendations regarding how to organize and make space for transdisciplinarity can inform universities and research teams hoping to generate transdisciplinary knowledge – this is often called for when studying interdisciplinary challenges like healthcare workforce challenges, rising costs, or sustainability.

Finally, in **chapter 10**, the thesis presents overarching contributions and recommendations regarding cost management in healthcare. It discusses how cost estimates may only be experienced as legitimate and actionable by staff for a short period of time and are tied to specific organizations. This is because they are considered outdated and meaningless once care delivery methods have changed and may only facilitate learning and decision-making amongst those staff that contributed to system construction. This leads to the conclusion that to improve the 'value' of care delivered, cost estimates:

1. *Must* reflect local routines and expenses, to be viewed as real, relevant, and actionable by (managing) clinicians.
2. *Should* be traced retroactively as new technologies shift actions, time spent, and materials used in unpredictable ways across different treatments. New technologies and their protocols can shift resource use from one treatment to

another, impacting the entire patient trajectory, and resulting in compromises that unfold over time in unanticipated ways.

3. *Can* improve psychological wellbeing (autonomy, competence, relatedness) and motivation when designed in an enabling way, which requires a high degree of granularity such that different specialists can act on them within their limited scope of autonomy.

These results suggest that undergoing the process of system construction and maintenance is more important to an organization than the actual cost or performance metrics generated. I urge future research to trace how enabling cost management systems are co-created in practice, then implemented and adapted over time, and in doing so come to change managerial and clinical practices. This research must be prioritized over efforts to produce new cost 'averages'; Such averages quickly become outdated, and do not enable individuals to learn what decisions lead to desired outcomes, where and how resources are consumed, or what can be done to improve local routines. During such co-creation processes, attention must be paid to if, when, or how individuals accept new accountabilities for costs, resource use, or care sustainability. This is particularly important, as the relationship between actions (now) and distant but hoped-for outcomes (e.g. patient wellbeing, parenthood, recovery) become increasingly difficult to anticipate for staff. As care is increasingly personalized to patients, such systems will need to account for variation retroactively, to enable local learning and decision-making. This thesis has demonstrated that, although treatments are standardized, the resources required to deliver them are not. In personalized care settings, these standardized protocols generate cost and resource use variation per patient as the protocols are applied in practice. It is precisely within these spaces of difference that economically significant improvements can be found, that co-created managerial cost accounting systems can support local decision-making, and that different forms of value can be discussed, estimated, and strived for.

Samenvatting (Nederlands)

Stijgende zorgkosten en tekorten aan middelen raken ons allemaal op directe en indirecte manieren. Dit proefschrift verkent de interdisciplinaire uitdaging van zorgkosten door te focussen op hoe en waarom gezamenlijk ontwikkelde kostenbeheersingssystemen kostenverantwoording bevorderen, de implementatie van Waardegedreven zorg (WGZ, oftewel value-based healthcare, VBHC) strategieën ondersteunen, en bijdragen aan efficiënter gebruik van middelen en het welzijn van zorgpersoneel binnen zorgorganisaties. Gebruikmakend van Practice Theory, en met een focus op één specifieke setting die exemplarisch is voor stijgende kosten en toenemende vraag, onderzoekt het hoe veranderende percepties van kosten en nieuwe kostinformatie het dagelijks medisch handelen beïnvloeden wanneer behandelingen worden gepersonaliseerd voor patiënten. Door de implementatie van een vernieuwende kostprijsinterventie op patiëntniveau in een fertiliteitskliniek die medisch begeleide voortplantingsbehandelingen (zoals in-vitrofertilisatie, IVF) aanbiedt, genereerde het onderzoek over een periode van drie jaar impact in de vorm van kostenreducties en verbeterde uitkomsten (time-to-pregnancy). Daarnaast breidt het ons begrip uit van hoe nieuwe behandelingen onvoorziene compromissen tussen patiënten, zorgverleners en de maatschappij met zich meebrengen door te onderzoeken hoe en waarom effectievere behandelingen tot financiële verliezen voor de kliniek leidden. Door de thema's kostendruk en personeelwelzijn te verbinden levert het proefschrift een bijdrage aan het vakgebied door te laten zien hoe en waarom een faciliterende kosteninfrastructuur essentieel is voor duurzame zorgverlening.

Hoofdstuk 1 introduceert het thema zorgkosten vanuit een organisatorisch en managementperspectief, onderzoekt waarom zorgorganisaties vaak geen infrastructuur hebben voor kostenmeting of -beheer, en presenteert de onderzoeksvragen en de interventie. Deze onderzoeksvragen richten zich op hoe kostenoverwegingen medische beslissingen beïnvloeden en leiden tot kostenvariatie, hoe met dergelijke variatie kan of zou moeten worden omgegaan, en hoe of waarom kostinformatie kan bijdragen aan het welzijn en de motivatie van zorgpersoneel. Het beantwoorden van deze vragen werpt licht op hoe, zowel vanuit technisch als sociaal perspectief, managementaccountingsystemen strategieën zoals WGZ (VBHC) kunnen ondersteunen en het zorgpersoneel ten goede kunnen komen.

Hoofdstuk 2 richt zich op hoe, wanneer en waarom kostinformatie in eerder onderzoek besluitvorming binnen zorgorganisaties heeft ondersteund. Het synthetiseert bevindingen uit 3874 studies over verschillende medische domeinen om te begrijpen of, hoe en waarom kostensystemen VBHC ondersteunen. De analyse toont aan

dat gedetailleerde kostentoerekeningsmethoden (zoals ABC en TDABC) professionals helpen bij het managen van zorg door kostenveroorzakers te identificeren, voor/na-vergelijkingen mogelijk te maken en procesevaluaties over groepen en tijd te ondersteunen. De meeste studies zijn echter van recente datum, afkomstig uit de VS en richten zich op gestandaardiseerde zorg. Werkelijke systeemimplementaties zijn zeldzaam, en de gebruikte methoden variëren vaak zodanig dat termen als 'ABC' hun betekenis verliezen. De review identificeert drie best practices—procesmapping, tijdsmetingen en input van zorgprofessionals—als essentieel voor een effectief ontwerp en de opbouw van kostenbeheersingssystemen. Deze best practices zijn toegepast in de latere hoofdstukken van dit proefschrift. Vanwege het gebrek aan eerdere studies die kostenbeheersingssystemen implementeren in gepersonaliseerde zorgomgevingen—waar patiënten sterk uiteenlopende middelen of zorg nodig hebben—onderstrepen we de noodzaak van toekomstig onderzoek gericht op (a) gepersonaliseerde zorg en (b) organisatorische implementatie in plaats van eenmalige economische analyses.

Hoofdstuk 3 richt zich op de rol van kosten in dagelijkse beslissingen, wanneer zorgverleners moeten inschatten welke middelen noodzakelijk of passend zijn voor specifieke patiënten met een kinderwens. Vanuit Practice Theory en gebaseerd op twee jaar etnografisch veldwerk in een fertiliteitskliniek onderzoekt dit hoofdstuk hoe accounting praktijken dagelijkse beslissingen over middelengebruik beïnvloeden. Het richt zich op hoe zorgverleners deelnemen aan en zelf boekhoudpraktijken ontwikkelen, hoe dit hun oordelen over passend middelengebruik voor individuele patiënten vormt, en laat zien dat boekhoudkundige handelingen een integraal onderdeel zijn van medisch handelen. Het hoofdstuk ontwikkelt het concept *teleological indeterminacy* om te verkennen hoe zorgverleners onzekerheid ervaren bij deze waarderingen, omdat zij moeten anticiperen op hoe hun handelingen (nu) in de verre en onzekere toekomst kosten en uitkomsten zullen beïnvloeden. In zulke momenten worden de kosten van bijvoorbeeld extra petrischalen of andere materialen afgewogen tegen verre uitkomsten zoals zwangerschap of ouderschap. Het hoofdstuk laat zien hoe zorgverleners onzekerheid ervaren bij het toepassen van standaardregels op specifieke patienten tijdens IVF behandelingen. Accounting systemen beïnvloeden hoe wordt waargenomen wat als "good medical practice" geldt, terwijl zorgverleners vaak het praktische inzicht missen om kostengevolgen goed te voorspellen. Dit hoofdstuk illustreert hoe kostenverantwoording in de praktijk tot stand komt, en waar de grenzen liggen van regels als leidraad voor middelengebruik.

Hoofdstuk 4, gebaseerd op de voorgaande hoofdstukken, beschrijft de ontwikkeling van een nieuwe cost estimation methode, specifiek gericht op fertility care (TDABC-

PM). Deze methode berekent de per-patiëntkosten vanaf consult tot zwangerschap en geboorte. Elk patiënttraject wordt gezien als een uniek cost object, waarbij variatie in resource use op activity level wordt vastgelegd (bijv. aantal benodigde consulten, specifieke diagnostische activiteiten, het aantal gekweekte embryos). Dergelijke cost predictors, wanneer gekozen door clinici, maken inzichtelijk waar en waarom cost variation binnen de organisatie optreedt. Dit kan het personeel stimuleren om na te denken over cost sources en nieuwe verantwoordelijkheden te nemen, bijvoorbeeld door pogingen te ondernemen om deze kosten te optimaliseren of te beheersen. Deze aanpak combineert management accounting en bioinformatics methoden om full-cycle cost estimation te realiseren, wat haar relevant maakt voor andere settings. Doordat de methode variatie op patiëntniveau over volledige treatment pathways kan vastleggen, vormt zij bovendien een uitbreiding van de literatuur rondom TDABC en VBHC.

Hoofdstuk 5 past deze methode toe op een decennium aan data over zorgpaden (13 203 behandelingen, 4190 trajecten van 6822 mannelijke en vrouwelijke patienten), waarbij bronnen van kosten- en uitkomstvariatie worden geïdentificeerd. Op basis van de voorgaande hoofdstukken toont het aan dat de kosten in de laboratoriumfasen van de zorg variëren door zes patiënt- of organisatiegebonden factoren, zoals het aantal gegenereerde embryo's. Het beschrijft cruciale beslissingsmomenten die de kosten en uitkomsten over volledige zwangerschapstrajecten aanzienlijk bepalen en van invloed zijn op de kosten in latere behandelingen van die patiënt. Dit leidde tot drie veranderingen in de zorgverlening die de kosten en uitkomsten verbeterden:

1. Vitrificatie (een nieuwe methode voor het invriezen en ontdooien van embryo's)
2. KI-gebaseerde embryoselectie
3. Gecombineerde IVF/ICSI-protocollen

Deze veranderingen verminderden de kosten met €322 tot €4089 per zwangerschapstraject (oftewel €1.3 miljoen in de Nederlandse context) en verkortten de tijd tot zwangerschap. Doordat hierdoor latere behandelingen werden voorkomen, werd de zorg duurzamer, omdat het totale aantal benodigde behandelingen afnam. Dit verlaagde de werklast voor medewerkers, het gebruik van middelen en het gebruik van wegwerpmateriaal per zwangerschapstraject. Paradoxaal genoeg veroorzaakten deze verbeteringen financiële verliezen voor klinieken, omdat kortere behandeltrajecten en minder herhaalde cycli de inkomsten verminderden. Het in dit hoofdstuk ontwikkelde TDABC-model wordt als open-access digitaal hulpmiddel aangeboden, zodat het in de kliniek kan worden onderhouden en in andere klinieken of settings kan worden toegepast. Uit de analyse blijkt dat beslissingen tijdens de behandeling de kosten, middeleninzet en uitkomsten in latere behandelingen beïnvloeden—patronen die met huidige diagnose-related group-prijzen (DRGs) niet zichtbaar zijn. Dit maakte het mogelijk om concreet advies te geven over aanpassingen in de Nederlandse DRGs, zodat deze beter rekening houden met veranderende technologieën en patronen in middelengebruik bij vruchtbaarheidsbehandelingen. Ten slotte laat het hoofdstuk zien hoe en waarom TDABC-systemen rekening moeten houden met variatie op patiëntniveau om lokale besluitvorming te ondersteunen.

Hoofdstuk 6 breidt de methodologie uit naar de Australische context van colorectale kanker, die vergelijkbare personalization-challenges kent als fertility care, maar een meer granulair reimbursement model heeft. Op basis van data van 4.246 patient pathways en meer dan 4 miljoen care activities (2012–2020) laat het hoofdstuk zien dat inpatient admissions 93% van de kosten bepalen, en dat de kosten van een behandeling sterk afhangen van de timing van de behandeling in het traject van de patiënt. Zo blijkt het dure chemotherapy-regime Mflolfox 6 (35K AUD) in stadium C aanzienlijk kostbaarder dan in andere stadia. Van belang is dat dit hoofdstuk aantoont dat toekomstige interventies zich vooral zouden moeten richten op het terugdringen van de kosten van inpatient episodes, in plaats van – zoals vaak wordt verondersteld – de nadruk te leggen op drug- en medicatiekosten. Het in dit project ontwikkelde algoritme kan worden ingezet door zowel practitioners als policymakers in andere care settings. De resultaten tonen aan dat de relatieve timing van een behandeling in het patiëntentraject een significante invloed heeft op de uiteindelijk gemaakte kosten.

Hoofdstuk 7 richt zich op hoe nieuwe technologieën kosten- en middelengebruikspatronen in organisaties stabiliseren. Het breidt de in hoofdstuk 5 gepresenteerde analyse en het in hoofdstuk 3 ontwikkelde practice-theoretical perspectief uit door te onderzoeken hoe nieuwe technologieën, zoals vitrification, het gebruik van middelen van latere behandelrondes verschuiven naar eerdere behandelrondes binnen zwangerschapstrajecten. Het hoofdstuk maakt gebruik van TDABC-PM (4190 zwangerschapstrajecten, 18 445 zorgactiviteiten) en kwalitatieve observaties (430 uur) om de belangrijkste patronen in zwangerschapstrajecten te identificeren. Het illustreert dat de waarde van behandelingen voor patiënten afhangt van de relatieve timing tijdens het zwangerschapstraject. Zo blijkt uit het hoofdstuk dat de vijfde opeenvolgende IUI-behandeling, zoals doorgaans voorgeschreven door de Nederlandse richtlijnen voor vruchtbaarheidszorg, vrijwel geen kans op succes biedt voor patiënten en daarom beter kan worden vermeden. Omdat clinici middelen toewijzen door het patiënttraject als één geheel te beschouwen in plaats van afzonderlijke behandelingen of producten, laat het hoofdstuk zien dat vroege behandelrondes verliezen genereren, terwijl latere behandelrondes deze verliezen compenseren door minder menselijke en materiële middelen te vereisen.

Door in te zoomen op de vitrificationtechnologie en te onderzoeken hoe deze vorm van zorgverlening meer waarde oplevert voor zowel patiënten als het zorgsysteem, maar tegelijkertijd financiële verliezen meebrengt voor de kliniek, illustreert het hoofdstuk dat dergelijke compromissen onvoorspelbaar zijn en zich gaandeweg ontvouwen. Het hoofdstuk vergroot ons inzicht in hoe en waarom een faciliterende kostenmanagementinfrastructuur de waarde in zorgorganisaties kan verbeteren.

Hoofdstuk 8 richt zich op kostenmanagementgedrag en het welzijn van medewerkers. Het bouwt voort op de inzichten uit de voorgaande hoofdstukken door te conceptualiseren wanneer, hoe en waarom 'faciliterende' kosteninformatie individuen kan bekrachtigen om kosten in hun dagelijkse werk te beheren. Dit hoofdstuk baseert zich op Self-Determination Theory om empirisch de relaties te onderzoeken tussen kosteninformatie, psychologisch welzijn, motivatie en gedrag. Op basis van enquête-antwoorden van 217 zorgmanagers Nederland breed (uit verschillende medische contexten en organisaties) laat het hoofdstuk zien dat faciliterende kosteninformatie samenhangt met psychologisch welzijn (autonomie, competentie, verbondenheid), en dat het vervullen van deze psychologische behoeften leidt tot een hogere mate van motivatie. Wanneer kosteninformatie faciliterend is, draagt het bij aan 'repair work', interne en algehele transparantie, en biedt het flexibiliteit door gebruikers de mogelijkheid te geven het systeem aan te passen. Deze bevindingen zijn relevant omdat psychologisch welzijn en motivatie significant samenhangen met een lagere kans op werkgerelateerde stress en burn-out.

Hoofdstuk 9 analyseert het 'doen van' interdisciplinair onderzoek – onderzoek tussen meerdere disciplines en sectoren, zoals ik in de voorgaande hoofdstukken heb gedaan – om te onderzoeken hoe dergelijk werk invloed heeft op beginnende onderzoekers en welke vaardigheden en praktijken nodig zijn om dit werk te kunnen uitvoeren. Op basis van vier jaar auto-etnografische data van drie beginnende onderzoekers en een vergelijkende analyse laat het hoofdstuk zien dat de monodisciplinaire organisatie van wetenschappelijke instellingen (bijv. universiteiten) de totstandkoming, verspreiding en het begrip van kennis die niet precies in disciplinaire silo's past, beperkt. Tijdens het verrichten van interdisciplinair werk moeten junioronderzoekers drie praktijken toepassen (condensing, staging en trespassing), die binnen monodisciplinaire omgevingen kunnen aanvoelen als 'dirty work'. Het hoofdstuk biedt advies aan startende onderzoekers die zich richten op interdisciplinaire maatschappelijke uitdagingen, zoals gezondheidszorgkosten, en draagt bij aan de literatuur over transdisciplinariteit, kennisproductie en het welzijn van onderzoekers. De praktische aanbevelingen over hoe men transdisciplinariteit kan organiseren en hiervoor ruimte kan creëren, kunnen universiteiten en onderzoeksteams helpen die transdisciplinaire kennis willen genereren – iets wat vaak wordt bepleit bij het bestuderen van interdisciplinaire uitdagingen zoals problemen rond het personeel in de zorg, stijgende kosten of duurzaamheid.

Ten slotte presenteert het proefschrift in **hoofdstuk 10** overkoepelende bijdragen en aanbevelingen over kostenmanagement in de gezondheidszorg. Het bespreekt hoe kostenramingen door medewerkers slechts gedurende een beperkte periode als legitiem en bruikbaar worden ervaren, en verbonden zijn aan specifieke organisaties. Dit komt doordat ze verouderd en betekenisloos worden zodra zorgverleningsmethoden veranderen en mogelijk alleen leerprocessen en besluitvorming faciliteren onder medewerkers die hebben bijgedragen aan de constructie van het systeem.

Daaruit volgt de conclusie dat, om de 'waarde' van geleverde zorg te verbeteren, kostenramingen:

1. Lokale routines en uitgaven moeten weerspiegelen, zodat ze als reëel, relevant en legitiem worden gezien.
2. Achteraf moeten worden getraceerd, omdat nieuwe technologieën de handelingen, de bestede tijd en de gebruikte materialen op onvoorspelbare wijze kunnen verschuiven tussen verschillende behandelingen. Nieuwe technologieën en hun protocollen kunnen het gebruik van middelen van de ene behandeling naar de andere verleggen, wat gevolgen heeft voor het volledige patiënttraject en resulteert in compromissen die zich in de loop van de tijd op onverwachte manieren ontvouwen.
3. Het psychologisch welzijn (autonomie, competentie, verbondenheid) en de motivatie kunnen verbeteren wanneer ze op een faciliterende manier zijn ontworpen, wat een hoog detailniveau vereist zodat verschillende specialisten ermee kunnen werken binnen hun beperkte mate van autonomie.

Uit deze resultaten blijkt dat het doorlopen van het proces van systeemconstructie en -onderhoud voor een organisatie belangrijker kan zijn dan de feitelijke kosten- of prestatiecijfers die eruit voortkomen. Ik benadruk het belang van vervolgonderzoek naar hoe faciliterende kostenmanagementsystemen in de praktijk samen met gebruikers worden gecreëerd, vervolgens worden geïmplementeerd en gaandeweg worden aangepast, en hoe ze daarbij de management- en klinische praktijken veranderen. Dergelijk onderzoek is van hogere prioriteit dan het produceren van nieuwe 'gemiddelde' kosten; zulke gemiddelden raken snel verouderd en bieden medewerkers niet de mogelijkheid om te leren welke beslissingen leiden tot gewenste uitkomsten, waar en hoe middelen worden verbruikt en wat kan worden gedaan om lokale routines te verbeteren.

Tijdens deze co-creatieprocessen is het bovendien van belang te onderzoeken of, wanneer en hoe individuen nieuwe verantwoordelijkheden accepteren voor kosten, middelengebruik of de duurzaamheid van zorg. Dit is vooral cruciaal aangezien de relatie tussen huidige acties en toekomstige, gewenste uitkomsten (bijv. welzijn van de patiënt, ouderschap, herstel) voor het personeel steeds moeilijker te voorspellen is. Naarmate zorg steeds meer gepersonaliseerd wordt, zullen dergelijke systemen achteraf rekening moeten houden met variatie, om lokaal leren en besluitvorming mogelijk te maken. Dit proefschrift heeft laten zien dat, hoewel behandelingen gestandaardiseerd worden aangeboden, de middelen die nodig zijn voor de uitvoering ervan dat niet zijn. In gepersonaliseerde zorgcontexten genereren deze gestandaardiseerde protocollen variatie in kosten en middelengebruik per patiënt wanneer ze in de praktijk worden toegepast. Precies in deze 'verschilruimtes' zijn economische verbeteringen van betekenis te vinden, kunnen co-gecreëerde managementsystemen voor kostenverantwoording lokale besluitvorming ondersteunen en kunnen verschillende vormen van waarde worden besproken, geschat en nagestreefd.

Acknowledgement

Many others have contributed to this research over the past four years. First and foremost, Will, thank you for understanding why this project was so important to me. Thank you for being the kind of man that encourages me to dream bigger and shout louder, because we both know that life and joy grow in relation to our courage. Life has handed me (us) so many lemons, and yet we laugh, debate, and travel the world together. When I said goodbye to my mother, we mourned my losses and prayed for my brother. When my estranged father died not long ago, we stood there together in this stranger's home, staring at the blood smeared across the floor and the pile of medical debt I stood to inherit. And yet, our discussions, debates and laughter give me joy and confidence in life and research every day. You, more than anyone else, know how many unarticulated remainders were left out of this work. Mieke, Evert, thank you for supporting me (and Will) throughout this journey, and for taking care of many practicalities whilst I stayed abroad during my research visits. Thank you, also, for your assistance in organizing our wedding during my research visit in Australia.

Kees Ahaus, Carina Hilders, Hilco van Elten, thank you for your mentorship and support during this project. Kees, thank you for always encouraging me to pursue my own academic interests, for offering invaluable feedback on various chapters, and for supporting and guiding the project at the heart of this dissertation. Carina, you have created many opportunities for me, and your medical and regulatory knowledge and awareness have contributed to the specificity and practical relevance of my work, for which I am very grateful. Hilco, thank you for introducing me to likeminded friends and colleagues, for teaching me about the art of survey research and structural equation modelling, and for providing invaluable feedback and suggestions throughout the four years.

Evert van Santbrink, your enthusiasm for this project and my work gave me a lot of energy and purpose, thank you for that. I admire your ability to jump from one role to another: one day you're seeing patients, the next you're investing in the latest technological breakthroughs for your laboratory. Your passion for your profession and patients is inspirational, and I am looking forward to future collaboration as we continue to use and study the dashboard built in this project.

Ivo De Loo, you taught me how to make theory work for me, and how to say more with less. Thank you for teaching me so much about organizational ethnography, and for introducing me to countless like-minded scholars, communities, and philosophers. You continue to open many doors for me, for which I am very grateful.

Erik van Raaij, I thoroughly enjoyed teaching alongside you over the past few years. Thank you for many thought-provoking discussions about teaching and research, and for introducing me to the 'garbage can' model for solving (research) problems. This approach has changed how I tackled some of the challenges I faced throughout this project. We share a love for gin & tonics (with fresh orange peel and star anise, please!) and the 'doing of' art as a means to clear the mind. I admire the multidisciplinarity of your work, and your ability to juggle so many roles in research and beyond. You make it look easy and effortless, which is an art in and of itself.

Dominic Detzen, Isabelle Fabbricotti, Jérémy Morales, Martina Buljac, Alan Lowe, Welmoed van Deen - thank you for the advice or mentorship each of you has, in one way or another, given me through passionate discussions or feedback on ideas and proposals. Dominic, thank you for introducing me to the concept of editing backwards, from discussion to introduction. Jérémy, thank you for our lengthy discussion about valuations, invisible practices, and 'dirty work' – I admire the breadth of your research and learned a lot from the feedback you gave me on chapters during discussions at the IPA conference. Martina, thank you for your feedback on several chapters, particularly on chapter 8, and for the feedback you provided during various presentations in our internal seminars. Welmoed, thank you for our discussions on digital technologies like dashboards, and for your advice regarding personal grants. Isabelle, thank you for our lengthy discussions on pragmatism in research, and TDABC and process mining in particular – I admire your ability to balance quantitative and qualitative research.

Marleen de Mul, Sandra Sülz – I thoroughly enjoyed teaching with you over the past few years. I enjoyed redesigning elements of both our BSc. And MSc. programs with your input, doing everything from making exam questions to redesigning courses and giving lectures (in both Dutch and English, no less). I am very proud of the high student evaluations we achieved.

Renée Michels, Sydney Howe, Milou Silkens, Thomas Reindersma – thank you for providing me with a wonderful community within which to conduct (and reflect on) interdisciplinary research. Milou, thank you for our many critical discussions concerning mixed methods research, and the advice you have offered me over the past two years. Thomas, thank you for our many inspiring conversations in Oslo and at the office. Renée, Sydney, thank you for our many MMA meetings, dinners, and inspirational conversations. On that note, I would also like to thank the fantastic PhD community at Erasmus University Rotterdam, and in particular Veerle, Gigi, Ellen, Bora, Maud, Aino, Alina, Ilaria, Jitse and Michael for the many thought-provoking discussions and afternoon coffee breaks throughout our PhDs.

Maarten IJzerman, thank you for hosting me at the University of Melbourne, my academic visit in Australia was a real highlight for me. I am looking forward to collaborating again very soon. On that note, I want to thank the entire Cancer Health Services Research (CHSR) team for being fantastic hosts and co-authors during my academic visit in Melbourne – thank you Sven Relijveld, Fanny Franchini, Hadi Khorshidi, Karen Trapani, Jennifer Soon, and Martin Vu and many others for making my visit so pleasant. I felt very welcome, made many memories, and was sorry to say goodbye.

Albrecht Becker, thank you for hosting me at the University of Innsbruck, and thank you for your comments and feedback on various articles since meeting at the IPA conference in 2024. I would like to thank the Management Accounting research group at the University of Innsbruck for being excellent hosts, and both the Management Accounting and Management Control groups for many inspirational discussions – thank you, Benjamin Falch, Rebekka Fleischmann, Bettina Jaekel, Silvia Jordan, Martin Messner and others for great discussions, and for being so welcoming. My visit was a wonderful way to end my fourth year.

Hans van Oosterhout, working as a teaching assistant in your “philosophy of science” course at RSM inspired me to embrace a career in research, and to consider alternative ways to think about ‘knowing’ in practice. Our discussions shaped this research project and motivated me to write chapter 9 – thank you.

Beyond this, I want to thank the members of the “Accounting Reading Community” for our ongoing meetings and discussions within the critical and/or social accounting research. Our joint reading projects and meetings gave me energy and many fresh ideas for future research.

Additionally, I would like to thank my research participants, who graciously gave their time and input to various chapters. Further, I would like to thank the many members of the Dutch Value-Based Fertility Care Consortium (consisting of 6 fertility clinics in the Netherlands – Reinier De Graaf in Voorburg, UMCG in Groningen, Elisabeth-TweeSteden in Tilburg, Erasmus MC in Rotterdam, Isala in Zwolle, TFP Medisch Centrum Kinderwens in Leiderdorp) for their enthusiasm and/or collaboration over the past years.

Finally, my thanks are due to my department (HSMO) at the Erasmus School of Health Policy & Management (Erasmus University Rotterdam) for enabling me to travel the world and present my research at so many conferences, seminars, and academic visits worldwide. This generous support has not only contributed to my development and research but has also greatly enriched my experience.

Maura Leusder
January 2025, Rotterdam

Portfolio

International conference presentations

- AOM, *Academy of Management* (Copenhagen, 2025)
- AOM, *Academy of Management*, symposium panel speaker (Copenhagen, 2025)
- EURAM, *European Academy of Management* (Florence, 2025)
- EAA, *European Accounting Association* annual congress (Rome, 2025)
- 4S/EASST, *Making and doing transformation* (Amsterdam, 2024)
- IPA, *Interdisciplinary Perspectives on Accounting* (London, 2024)
- IPA, *Interdisciplinary Perspectives on Accounting*, doctoral colloquium (London, 2024)
- OBHC, *Organizational Behavior in Healthcare*, panel speaker (Oslo, 2024)
- OBHC, *Organizational Behavior in Healthcare*, doctoral colloquium (Oslo, 2024)
- INFORMS *Healthcare* (Toronto, Canada, 2023)
- ISPOR *Impacting Innovation, Value, and Healthcare Decision Making* (Boston, US, 2023)
- EHMA, *European Health Management Association* (Brussels, 2022)
- TDABC *Time-driven activity-based costing conference* (Lisbon, 2022)
- EHMA, *European Health Management Association* (Rotterdam, 2021)
- IFERA, *International Family Enterprise Research Academy* (Zwolle, 2018)
- SMS, *Strategic Management Society* (Paris, 2018, best paper award nomination)
- FB&CC, *Corporate control conference hosted by Bocconi University* (Milan, 2018)
- AOM, *Academy of Management* annual conference (Atlanta, US, 2017)

International academic visits

- 2025 (Q1), University of Innsbruck (Management Accounting research group), Austria
- 2023 (Q2), University of Melbourne (School of Public Health), Melbourne, Australia

Recognition

- Finalist “Best article 2024” at EGSH PhD Excellence awards ceremony 2025
- Finalist “Best Ph.D. Colleague” at EGSH PhD Excellence awards ceremony 2025
- “Best paper” nomination (SMS, Paris, 2018)

Qualifications

- Risbo University Teaching Qualification (BKO/UTQ, 2025).

Invited research seminars

- 2025, Accounting Research Seminar Series, University of Innsbruck, Austria
- 2024, Accounting Research Seminar Series, Rijksuniversiteit Groningen, NL

- 2024, Centre for Public Health in Economics and Business, Rijksuniversiteit Groningen, The Netherlands
- 2023, School of Global Population Health, University of Melbourne, Australia
- 2023, Nyenrode Business University, Breukelen, The Netherlands

Invited research presentations

- 2025, Costs and outcomes in fertility care: analyzing one decade of patient trajectories, Reinier De Graaf (Delft)
- 2025, Towards Value-Based Fertility Care, Annual Meeting of Dutch Gynecology
- 2024, Improving the costs and performance of fertility treatments, Reinier De Graaf (Delft)
- 2024, Costs and outcomes in fertility care: analyzing one decade of patient trajectories, Erasmus School of Health Policy & Management (Rotterdam)
- 2024, Costs and performance of subfertility treatments, Value-Based Fertility Care Consortium Netherlands (Isala Zwolle, Reinier de Graaf Voorburg, Erasmus MC Rotterdam, UMCG Groningen, TFP Leiderdorp, Elisabeth-TweeSteden, Brabant)
- 2023, Research presentation with funding body (DSW), Reinier de Graaf Hospital (Delft)
- 2023, Improving the value of fertility treatments through practice changes. Presentation for the Rector Magnificus, Erasmus University Rotterdam.
- 2022, Costs and cost drivers of subfertility patient pathways. Internal seminar presentation at Erasmus School of Health Policy & Management (Rotterdam)
- 2022, How are costs measured in VBHC? Internal seminar presentation at Erasmus School of Health Policy & Management (Rotterdam)
- Two internal seminar presentation, Rotterdam School of Management, Rotterdam

Media

- Linnean webcast presentation on cost measurement in value-based healthcare (available online)
- Linnean interview on time-driven activity-based costing in healthcare (available online)

Doctoral courses completed

- Statistical Methods, *Erasmus Research Institute of Management*
- Applied Econometrics, *Erasmus Research Institute of Management*
- Skill Course Publishing Strategy, *Erasmus Research Institute of Management*
- Skill Course Scientific Integrity, *Erasmus Research Institute of Management*
- Skill Course Introduction to data analysis with R, *Erasmus Research Institute of Management*

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- Skill Course Advanced Data analysis with R, *Erasmus Research Institute of Management*
- Developing Theory and Theoretical Contributions, *Erasmus Research Institute of Management*
- Foundations of Int. Business Strategy, *Erasmus Research Institute of Management (Brussels)*
- Advanced topics in Organizational Theory, *Erasmus Research Institute of Management*
- Topics in Fintech by David Yermack, *ERIM Summer School*
- Executive Compensation and other Managerial Incentives by David Yermack, *ERIM Summer School*
- Empirical Corporate Finance, *Erasmus Research Institute of Management*
- Longitudinal data analysis with Stata, *Statistical Horizons* (Philadelphia, US)
- Multilevel Modeling: A second course, *Statistical Horizons* (Stockholm)

The courses listed above represent 40 European Credits (ECs), and exclude self-study coursework, conference attendance, or workshops. One ECTS corresponds to a workload of 28 hours. The entire portfolio including conferences and other activities was estimated at 173 ECs.

Other coursework

- Self-study of Wil van de Aalst' work on data and process mining in R.
- Self-study of Theodore Schatzki's works on practice theory (1996, 2002, 2005, 2006, 2010).
- Self-study of Bernard Stiegler' works on technics (1998, 2008, 2010).
- "Bernard Stiegler's Thoughts on Technics", taught by *The New Centre for Research & Practice.*

Teaching – course development and coordination

- 2024-2025, 2023-2024, Technology and Innovation. (Bachelor, Dutch & English) *I redesigned a large part of this course concerning cost and performance management in healthcare organizations, which included designing new materials, learning objectives, exercises, and exams following the principles of constructive alignment as part of my University Teaching Qualification.*
- 2018-2019, 2019-2020 Corporate Governance, course coordinator and lecturer (Pre-Master, English)
- 2018-2019, Business Strategies in Family Business, course development from scratch together with one colleague (Master, English)

Teaching – Lecturer

- *I taught these courses in the role of lecturer ('Kerndocent' in Dutch). I taught lectures, made and updated teaching materials, designed and graded exams, and was involved in all course*

*evaluation and improvement processes.*2024-2025,2023-2024,2022-2023 Technology and Innovation (Bachelor, Dutch & English)
- 2023-2024, 2022-2023, 2021-2022 Market regulation in healthcare (Bachelor, Dutch)
- 2022-2023 Introduction to Financial Management in Healthcare (Pre-master, Dutch)
- 2018-2019, 2019-2020 Corporate Governance (Pre-master, English)
- 2018-2019 Business Strategies in Family Business (Master, English)
- 2018-2019 Advanced Strategy (MBA, English)

Teaching - Invited guest lectures
- 2024-2025, Guest lecture on cost management in healthcare organizations for value improvements (Bachelor, Dutch, taught at Vrije Universiteit Amsterdam)
- 2023-2024, Guest lecture on time-driven activity-based costing for healthcare (Master, English)
- 2023-2024, Guest lecture on time-driven activity-based costing for healthcare (Bachelor, English)
- 2023-2024, Guest lecture on management accounting in healthcare (Pre-master, Dutch)
- 2022-2023, Guest lecture on data-driven business models in healthcare (Master, English)
- 2022-2023, Guest lecture on cost management in healthcare (Master, English)
- 2018-2019, 2019-2020, Guest lecture on corporate governance (Pre-Master, English)

Teaching – Thesis Supervision
- MSc. Thesis supervision, Healthcare Management, 2023-2024 (5 students)
- BSc. Thesis supervision, Healthcare Management, 2021-2022 (6 students)
- MSc. Thesis supervision at Rotterdam School of Management, 2018-2020 (12 students)

Peer reviews completed
- 2025, BMC Health Services Research
- 2025, Cost Effectiveness and Resource Allocation
- 2025, Academy of Management (AOM, 2 reviews)
- 2025, European Academy of Management (EURAM, 2 reviews)
- 2025, The British Accounting Review
- 2024, British Medical Journal (BMJ) Open
- 2024, Interdisciplinary Perspectives on Accounting (IPA 2024, 2 reviews)
- 2024, The British Accounting Review (2 reviews)
- 2023, British Medical Journal (BMJ) Open

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- 2023, Health Services Management Research
- 2023, The British Accounting Review (2 reviews)
- 2023, European Academy of Management (EURAM, 3 reviews)
- 2023, Information Systems and Operational Research

Other activities

Co-founder & organizer of "Mixed Methods Anonymous", an ongoing empowerment initiative for PhD. Students engaging in interdisciplinary and/or interparadigmatic research.

Peer-reviewed publications and selected work in progress

This thesis

Chapter 2 - Leusder, M., Porte, P., Ahaus, K., & van Elten, H. (2022). Cost measurement in value-based healthcare: a systematic review. *BMJ Open*, *12*(12), e066568. https://doi.org/10.1136/bmjopen-2022-066568

Chapter 3 - Leusder, M., van Elten, HJ, De Loo, I. *(under review, revision)* Valuing care at the intersection of accounting and medical practices. *Accounting, Auditing & Accountability Journal.*

Chapter 4 - Leusder, M., van Elten, H. J., Ahaus, K., Hilders, C. G. J. M., & van Santbrink, E. J. P. (2023). Protocol for improving the costs and outcomes of assistive reproductive technology fertility care pathways: a study using cost measurement and process mining. *BMJ Open*, *13*(6), e067792. https://doi.org/10.1136/bmjopen-2022-067792

Chapter 5 - Leusder, M., van Elten, H. J., Ahaus, K., Hilders, C. G. J. M., & van Santbrink, E. J. P. (2024). Patient-level cost analysis of subfertility pathways in the Dutch healthcare system. *The European Journal of Health Economics*. https://doi.org/10.1007/s10198-024-01744-5

Chapter 6 - Leusder, M*., Relijveld, S*., Demirtas, D., Emery, J., Tew, M., Gibbs, P., Millar, J., White, V., Jefford, M., Franchini, F†., & IJzerman, M†. (2024). Toward value-based care using cost mining: cost aggregation and visualization across the entire colorectal cancer patient pathway. *BMC Medical Research Methodology*, *24*(1), 321. https://doi.org/10.1186/s12874-024-02446-5

* Authors contributed equally.
† Authors contributed equally.

Chapter 7 - Leusder M. *(under review)* Standardized hope, personalized losses: Improving the value of 'pregnancy trajectories' through compromises.

Chapter 8 - Leusder, M, & van Elten, HJ. (*under review*) Designing organizations to foster motivation, wellbeing, and cost management practices. *Public Management Review.*

Chapter 9 - Howe, S*., Michels, R*., and Leusder, M*. (*under review, revision*). Mixed Methods Anonymous: The Invisible Work of Early Career Transdisciplinary and Interparadigmatic Researchers. *Research Policy.*

**Authors contributed equally.*

Publications (other)

Leusder, M., van Elten, H., Ahaus, K., Hilders, C.G.J.M., van Santbrink, E.J.P.: Determining Costs, Cost Predictors, and Resource Requirements in Assisted Reproductive Technology Care Pathways: A Value-Based Fertility Care Costing Tool Using Time-Driven Activity-Based Costing. **Value in Health**. 26, S248 (2023). https://doi.org/10.1016/j.jval.2023.03.1367

Leusder, M., Porte, P., Ahaus, K., & van Elten, H. Literatuurstudie: Costing in value-based healthcare – science or fiction? A systematic review (2022). **Kennisplatform Uitkomstgerichte Zorg.** *Available online* https://www.linnean.nl/nieuws+linnean/2146517.aspx?t=Linnean-webcast-Wat-werkt-in-de-implementatie-van-WGZ-en-waarom-Resultaten-uit-literatuuronderzoek

& https://www.platformuitkomstgerichtezorg.nl/aan+de+slag/documenten/HandlerDownloadFiles.ashx?idnv=217496

Selected work in progress not included in thesis

Health services research

Silkens, M., Leusder, M., Woznitza, N., & Scarbrough, H. (*under review*). Mind the gap! Overcoming the lack of evidence to support the innovation journey of AI in healthcare.

Leusder, M., Zwart, B., Sulz, S., IJzerman, M. Towards a desirable future: A cost and capacity analysis of the Nanospresso platform technology for point-of-care mRNA-based gene therapy production in Europe.

- Submitted to and accepted at ISPOR Europe 2025

Zwart, B., Verwey, J., Leusder, M., Sulz, S., IJzerman, M. Systems-Level Modelling Approaches for Complex Health Technologies: A Systematic Review.

- Submitted to and accepted at ISPOR Europe 2025

Organizational and/or accounting research

Leusder, M. From organizational to field-level change: Autonomizing work in the co-construction of an ABC system with professionals. Aimed at *Accounting, Organizations and Society*.

- Full paper presented at a seminar at Rijksuniversiteit Groningen (2024).
- Full paper presented at AOM conference (2025).

Leusder, M. Dashboard construction as a process of responsibilization: Engineering cost and performance accountabilities in medically assisted reproduction.

- Full paper presented at IPA conference in London (2024).

Leusder, M. Redistributing accountability: A process study of implementing AI-mediated embryo ranking and selection. Aimed at *Administrative Science Quarterly*.

Leusder, M. Time-driven activity-based costing as a "learning machine" to problematize the present and make the future. Aimed at *Organization Studies*.

About the author

Maura Leusder was a PhD candidate at the Erasmus School of Health Policy & Management, Erasmus University Rotterdam. Maura was born in Germany, grew up in Thailand and New Zealand, and now lives in Brielle with her husband. She speaks three languages and teaches in both Dutch and English. She received both her Bachelor of Science and Master of Science from the Rotterdam School of Management, graduating cum laude and with honors.

Her doctoral project was supervised by Prof. dr. Kees Ahaus, Prof. dr. Carina Hilders, and Dr. Hilco van Elten. During her doctoral studies, Maura led a cost and performance improvement project at a large Dutch hospital during which she implemented a time-driven activity-based costing system (TDABC) and traced the development of a performance dashboard from ideation to daily use in a fertility clinic. The infrastructure developed in this project, as part of a "value-based healthcare" initiative, is now being scaled to other clinics. Maura spent time as a visiting scholar at both the University of Melbourne (School of Global Health) and the University of Innsbruck (Management Accounting Research group). During her time as PhD candidate, she also redesigned teaching materials and independently taught courses on the topics of financial and managerial accounting, workforce pressures, technology, and strategy.

Maura's research interests lie at the intersection of management accounting, workforce wellbeing and technology in healthcare. She is passionate about ethnographic and interventionist research, wherein she uses data-driven interventions to research how medical and managerial or accounting practices change over time, and how users shape dashboards or other systems to suit their needs. She pays particular attention to how technologies like dashboards and/or new calculations (e.g. cost estimations) change the actions, perceptions and practices of individuals including clinicians, managers, and patients. She continues to research these topics as a research fellow in the European NANOSPRESSO consortium focused on personalized gene therapies and gene editing. In her free time, she enjoys reading, weightlifting, and painting in watercolor. Her artworks have sold worldwide.

Rising healthcare costs are a major societal concern, yet little is known about how cost awareness and accounting systems shape medical practice, or how cost accounting systems can improve value.
This dissertation investigates the co-creation and implementation of a cost management system in a fertility clinic as part of a value-based healthcare (VBHC) strategy, focusing on how clinicians use and shape accounting. It explores (1) how cost concerns influence clinical decisions and accountability in fertility treatments, (2) how cost variation can be estimated and managed in personalized care, and (3) how enabling cost information supports workforce wellbeing across medical domains and contexts.
Using a predominantly interventionist research design and a practice-theoretical lens, the research combines ethnographic and quantitative methods across eight studies to develop and evaluate a tailored system—time-driven activity-based costing with process mining (TDABC-PM). Drawing on a decade of fertility care data (4190 pregnancy trajectories, 18 445 activities and treatments), it shows how three care delivery shifts reduced costs and improved time-to-pregnancy (i.e. improved "value"). A national survey across medical domains further reveals how and why enabling cost information enhances managers' psychological wellbeing and motivation.
The research introduces the concept of teleological indeterminacy to examine how manager's and clinician's engagement with accounting practices impacts their situational judgments of what resource use is appropriate for specific patients. It advances understanding of how cost management systems—when designed with and for users—can improve care value, financial sustainability, and workforce wellbeing. It offers practical and theoretical contributions to tackling cost containment and workforce issues.

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