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FACULTY OF ECONOMICS AND BUSINESS ADMINISTRATION

MANAGING A CHANGING HEALTH CARE ENVIRONMENT

ALIGNING HOSPITAL PROCESSES TO THE NATURE OF CARE

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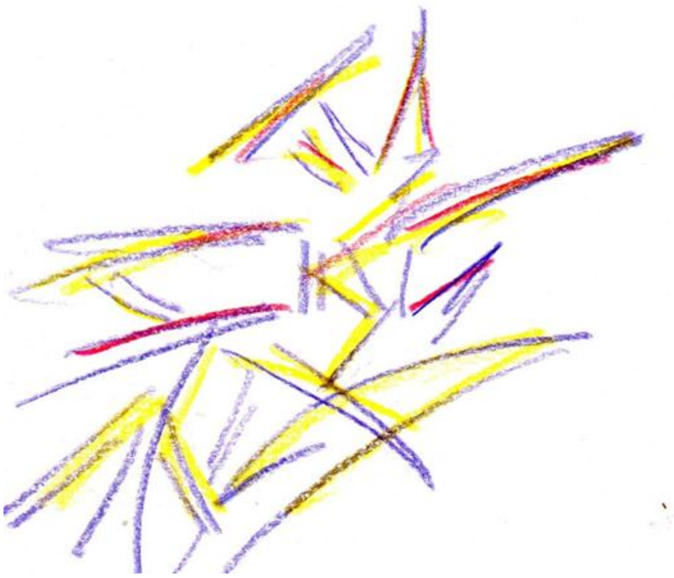
"You don't need eyes to see,
you need a vision"

Faithless, Reverence 1996

Bundled with care,
for the ones I love



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“I wanted to thank you," I said.
She wrinkled her nose and squinted like I'd said something funny.
"Thank me for what?" she said.
"You give me strength I didn't know I had,"; I said. "You make me better.”
Ransom Riggs, Hollow City

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ABBREVIATIONS

AHA:	American Health Association
ASC:	Ambulatory Surgery Center
APR-DRG:	All Patient Refined Diagnosis Related Groups
EBM:	Evidence-based Medicine
FOD:	Federale Overheidsdienst
ICC:	Intraclass correlation
IOM:	Institute of Medicine
LOS:	Length of stay
N:	Number
OM:	Operations Management
OR:	Operating Room
SH:	Specialty Hospital/Specialized hospital
US:	United States
VAP:	Value-added process
WHO:	World Health Organization

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SUMMARY

CONTEXT

Hospitals worldwide face challenging times and are consistently under pressure to control costs and improve quality of care. Research into improving health care should deal with seeking and defining the best methods of organizing and delivering services. In health care, there are two types care processes: sequential (the process is an orderly sequence of steps) and iterative (being composed of multiple cycles of hypothesis propositions and testing, where each cycle builds upon previous ones). These are very different, but both types could benefit if their organization were aligned with a tailored configuration of the operating system adjusted to the specific characteristics of both types of processes. The main purpose of this dissertation is to assess how the design of the operating system impacts efficiency in hospitals. In this dissertation we focus specifically on the sequential care process.

METHODS

The first part (chapter 2), presents a systematic literature review of the effects of specialized hospitals considering these as focused factories. In the second part (chapter 3), an exploratory database analysis of four hospitals was performed. We investigated whether hospital care processes can be assigned to different groups, resulting in better alignment of type and organization of care. In the third part, an empirical study of how the design of the operating system impacts efficiency in hospitals was conducted. Firstly (chapter 4), a multilevel analysis was performed to distinguish factors that influence flow efficiency in a standardized process (i.e. the cataract surgery process), focusing on the role of the organizations, physicians, and case-mix variables of patients. Secondly (chapter 5), a comparative benchmark study with a mixed-method design was conducted to compare sequential care processes between hospitals. We examined how the cataract surgery process operates in hospitals and which design of the operating system is preferable.

RESULTS

Considering the effects of specialized facilities as a strategy for standalone facilities that excel, we found no compelling evidence demonstrating the added value of these specialized facilities in terms of quality or cost. In addition, their corresponding impact on full-service general hospitals remains unclear.

There are groups of patients with inherently different degrees of variation in length-of-stay due to illness and treatment patterns. However, there are significant differences in the distribution of variation groups between the hospitals suggesting that there are clear process differences which led us towards further investigation of the sequential hospital care processes in this dissertation

Investigating a sequential care process (i.e. the cataract surgery) in hospitals, we found (1) controllable and uncontrollable factors influencing flow efficiency and (2) that treating sequential care processes in an operating setting specifically dedicated to such processes enhanced flow- and resource efficiency. In these settings, we not only found higher capacity use, but also shorter turnover times and significantly lower staffing levels, without affecting efficiency and resulting in lower costs.

DISCUSSION

The importance of differentiating distinct processes for health care problem-solving lies in the added value of different approaches to their design and management. Thus, different services and processes require different operating systems. Our results demonstrate that aligning structure and process components with the design of the operating system positively influences operational performance. The sequential care process (e.g., cataract surgery) is designed in line with a standardized process; however, differences in the design of the operating system between the hospitals illustrate the impact on operational performance. We must emphasize the importance of differentiating the types of variation and noting the presence of, as the goal must be to eliminate the unwarranted “artificial” special-cause variation and manage warranted, common-cause variation.

This dissertation provides practitioners and academics with a fresh perspective on the practices of sequential care processes and the factors limiting them. It also serves as a foundation for future initiatives aimed at improving operational performance in hospitals.

SAMENVATTING

INLEIDING

Ziekenhuizen in de westerse samenleving staan voor grote uitdagingen. De vergrijzing van de bevolking, de technologische evolutie, de toename aan chronische aandoeningen, de betaalbaarheid en de toegankelijkheid van onze gezondheidszorg zijn slechts enkele van de uitdagingen waarvoor de ziekenhuizen staan, en dit in een context van beperkte financiële middelen. Daarenboven heeft de ziekenhuissector een groot financieel gewicht in de zorgsector. Het werkingsbudget van de ziekenhuizen vertegenwoordigt de laatste jaren meer dan 20% van het budget van de ziekteverzekering. In 2013 bedroeg de begrotingsdoelstelling voor de ziekenhuizen 7,8 miljard euro. De toenemende besparingsdruk dwingt de ziekenhuizen om efficiënter te werken met minder middelen. Bijgevolg is het van belang dat onderzoek in de gezondheidzorg, en meer specifiek in ziekenhuiszorg, zich oriënteert naar efficiënt werken, o.a. door de hervorming van de organisatie en de financiering.

In dit doctoraat bouwen we op de differentiatie van de soorten zorgprocessen in ziekenhuizen. In de gezondheidszorg onderscheiden we twee verschillende processen: de iteratieve zorg, dat een operationeel systeem vereist georganiseerd rond intuïtieve diagnostische activiteiten, en een sequentiële zorg, dat een operationeel systeem vergt georganiseerd rond het efficiënt uitvoeren van specifieke procedures. Beide processen zijn zeer verschillend en kunnen voordeel halen uit een organisatie dat afgestemd is op de specifieke configuratie van het operationeel systeem, aangepast aan de specifieke kenmerken van beide typen processen. Dit doctoraat heeft als doel om na te gaan hoe de configuratie van het operationeel systeem voor een sequentieel proces een impact heeft op de efficiëntie in het ziekenhuis.

METHODOLOGIE

Dit doctoraat maakt gebruik van een systematisch literatuuronderzoek, een exploratieve database analyse, en twee empirische onderzoeken. De eerste studie (hoofdstuk 2) presenteert de bevindingen van een systematisch literatuur onderzoek naar de effecten van gespecialiseerde (privé) ziekenhuizen. Deze, meestal kleinere, ziekenhuizen kunnen we benaderen als een gefocust bedrijf door de specifieke zorg die geleverd wordt op een sterk afgelijnde groep.

In een tweede studie (hoofdstuk 3) werd een exploratieve database analyse uitgevoerd met All Patient Refined Diagnositic Related Groups (APR-DRG) gegevens[1] van vier Belgische ziekenhuizen. Het onderzoek spitst zich toe op de eventuele mogelijkheid om de zorgprocessen in te delen (sequentiële versus iteratieve zorg). Deze indeling werd geclassificeerd in vier groepen aan de hand van de inherente variatie (zeer laag, laag, hoog en zeer hoog) in het aantal ligdagen.

In de twee laatste studies (hoofdstuk 4 en 5) werd empirisch onderzoek uitgevoerd naar de impact van de configuratie van het operationeel systeem in een sequentieel ziekenhuisproces (het chirurgisch cataract proces) op de operationele efficiëntie van dit proces. In de eerste van deze twee studies werden, aan de hand van multi-level analyses, factoren onderscheiden die de stroomlijn van de zorg beïnvloeden op niveau van de organisatie, de arts en de patiënt. In de laatste studie werd een vergelijkende benchmark studie uitgevoerd tussen vijf ziekenhuizen met een mixed-methode design. We onderzochten hoe het chirurgisch cataract proces verloopt en welke configuratie van operationeel systeem het meest efficiënt is.

RESULTATEN

Toegevoegde waarde van gespecialiseerde ziekenhuizen

Gelet op de effecten van gespecialiseerde ziekenhuizen, als strategie voor faciliteiten die uitblinken, vonden we geen overtuigend bewijs van de toegevoegde waarde van deze gespecialiseerde faciliteiten in termen van kwaliteitsverhoging of kostenverlaging. Uit het onderzoek bleek dat er een onduidelijk effect is van de gespecialiseerde ziekenhuizen op de algemene ziekenhuizen.

Opsplitsen van zorgprocessen

De exploratieve studie toont aan dat er een verschil is in de inherente variatie in het aantal ligdagen van zorgprocessen. Enerzijds zijn er zorgprocessen met inherent weinig variatie en anderzijds zijn er zorgprocessen met inherent veel variatie in het aantal ligdagen. Dit wijst erop dat er wel degelijk verschillende processen bestaan in de ziekenhuizen en ondersteunt het

[1] Via de Diagnosis Related Group kunnen de ziekenhuisdiagnoses worden geclassificeerd in een 500-tal homogene groepen. De basis voor deze groepering vormt de hoofddiagnose in combinatie met chirurgische ingrepen, de leeftijd en het geslacht van de patiënt en het al dan niet voorkomen van complicaties. Afhankelijk van een chirurgische ingreep wordt een indeling gemaakt in chirurgische en medische DRG's. Voorbeelden van DRG's zijn: vaginale bevalling; chemotherapie; ernstige ingrepen op schouder, elleboog en voorarm.

concept om bewust keuzes te maken in de configuratie van het operationeel systeem voor beide zorgprocessen (sequentieel en iteratief). We merkten echter ook op dat er in sommige APR-DRG groepen een verschil was in het niveau van inherente variatie tussen de ziekenhuizen, die niet te wijten was aan de ernst van de ziekte. Dit wijst op een verschil in procesaanpak tussen de ziekenhuizen per ziektegroep, welke tevens de aanleiding was om een sequentieel ziekenhuisproces te analyseren in verdere studies.

Efficiëntie van sequentiële zorgprocessen in het ziekenhuis

In het onderzoek van het chirurgisch cataract proces werden er controleerbare en oncontroleerbare factoren gevonden die de stroom in het proces kunnen beïnvloeden. Het gebruik van een gespecialiseerde verpleegkundige, het toepassen van lokale, maar efficiënte, pijnstilling tijdens de operatie waren factoren die een positieve invloed hebben op de doorstroom in het proces. Vermijdbare variatie werd in elk ziekenhuis vastgesteld en beïnvloedde het proces negatief. Ook het chirurgisch cataract proces organiseren in een setting volledig aangepast aan dit proces (oogkliniek design) verhoogde de operationele efficiëntie. In deze configuratie vonden we niet enkel hoger gebruik van de capaciteit maar ook korte doorlooptijden voor de patiënten en significant minder personeel zonder een invloed te hebben op de operationele efficiëntie en bovendien resulterend in lagere kosten.

Het chirurgisch cataract proces kan benaderd worden als een gestandaardiseerd proces, en hogere standaardisatie van dit proces zorgt voor hogere operationele efficiëntie.

DISCUSSIE

De toegevoegde waarde om iteratieve en sequentiële processen in de gezondheidszorg van elkaar te onderscheiden, ligt in de verschillende benadering van hun configuratie en management. Verschillende diensten en processen vragen immers verschillende operationele systemen. Ons onderzoek toont aan dat het aligneren van structuur- en proces componenten met de configuratie van het operationeel systeem een positieve invloed heeft op de output bij een sequentieel proces. Zo konden we aantonen dat het chirurgisch cataract proces voordeel haalt uit de setting van een gespecialiseerde omgeving (oogziekenhuis setting) en gespecialiseerd personeel.

Ondanks het feit dat het sequentiële zorgproces (i.e., chirurgisch cataract proces) georganiseerd is als een gestandaardiseerd proces in de ziekenhuizen, zijn er toch significante verschillen tussen de ziekenhuizen. Nochtans leent het proces zich tot een hoge graad van standaardisatie met een positief resultaat op de operationele efficiëntie.

Uit het onderzoek werden verschillende vormen van variatie vastgesteld. Ongewenst variatie (zoals technische defecten, foute communicatie,…) had een invloed op de stroomlijn van het proces maar ook niet vermijdbare variatie (voorkeur van de patiënt, ernst van de ziekte) had een invloed op het chirurgisch cataract proces. We benadrukken het belang om de ongewenste variatie te onderscheiden van de onoverkomelijke variatie. Variatie onderscheiden is belangrijk voor het proces met als uiteindelijk doel het voorkomen van ongewenst variatie en managen van onoverkomelijke variatie.

Dit doctoraat verstrekt praktijkbeoefenaars en academici nieuwe inzichten in de organisatie van sequentiële zorgprocessen en de factoren die deze organisatie belemmeren. Dit is echter geen allesomvattend proefschrift en nodigt uit naar verder onderzoek en initiatieven om de operationele output van de zorgprocessen in ziekenhuizen te verhogen.

CHAPTER 1

General Introduction

1. FOCUS OF THE DISSERTATION

This thesis examines the design of the operating system of care processes in hospitals. This is a field of operations management, a crucial discipline that is concerned with creating the services and products upon which we all depend. It involves the design, planning, and control of processes that transfer inputs into products and services (Slack et al., 2009). Effective operations management offers the potential to improve both efficiency and customer services simultaneously (Slack et al., 2009). Operations management originates from research into manufacturing, and is gaining increasing attention in health care. Operations management has a unique set of features that can contribute to substantial improvement over a wide range of medical situations and organizations (Boyer and Pronovost, 2010).

Health care operations management is the analysis, design, planning, and control of all of the steps necessary to provide service to clients (Beech and Vissers, 2005). In other words, it implies identifying the needs of clients, usually patients, and designing and delivering services to meet their needs in the most effective and efficient manner (Beech and Vissers, 2005). Most studies in health care operations management focus on the effects of implementing methods (e.g., lean or six sigma) or projects (e.g., reengineering) to enhance efficiency in organizations over a specific period (Vera and Kuntz, 2007). They therefore do not measure the degree of fit with structure or process elements within the design of the operating system of the organization, but rather the outcome or the success of these methods and projects (Vera and Kuntz, 2007). Empirical research into the design of operating systems in health care seems to be lagging behind. Recently, more attention has been paid to improving the delivery of care, as this is one of the most promising ways to improve efficiency and quality (IOM, 2001; Kohn et al., 1999; Porter and Teisberg, 2006). Research aimed at improving health care should deal with seeking and defining the best methods of organizing and delivering services. Accordingly the research question to be asked is: How should the delivery of care be organized in order to achieve higher quality and greater efficiency? A research question of this kind belongs to the field of operations management.

In the following pages, we aim to sketch the background of health care operations management, and more specifically to consider process choice and the design of the operating system for care processes. We will review the relevant literature and present the theoretical basis and conceptual model that direct the studies. As the dissertation was a process of ongoing learning and growing in conducting research it is important to acknowledge that the reader might find some inconsistencies in the way some key terms were explained and used in each paper (presented as different chapters in this dissertation). Therefore, clear and concise definitions of key terms used throughout the dissertation are also offered in this introduction. Furthermore, we provide an insight into the philosophical positions taken in the research. The chapter ends with the general aim, the research questions, and an outline of the thesis.

2. CONTEXTUAL BACKGROUND

Hospitals are immovable structures whose design is set in stone, usually many years ago. Their configuration often reflects the practice of health care and the patient populations of a bygone area. This has resulted in complex, confused institutions, in which much of the cost is spent on overhead activities. Their incompatibility with present needs ranges from major operational problems (e.g., process failure leading to lower performing institutions) to minor problems (such as unadjusted working space and process failures leading to medication errors). Yet hospitals are a very important element of the health care system (Levit et al., 2002; Strunk et al., 2001). Financially, in the US, they account for about one third of total health care expenditure (32,6%) (American Health Association, 2010). In Belgium similar results are reported (31%) (FOD Sociale Zekerheid, 2012). Organizationally, hospitals dominate the rest of the health care system (McKee and Healy, 2000). Internationally, hospital care is the largest category of health care spending (American Health Association, 2011), so cost control in hospitals remains a challenge, as facilities need to remain competitive by offering cutting-edge services and honoring physicians' suggestions regarding their needs of specialty equipment. This limits their capability to cut spending on capital goods. Hospitals have a particular need to provide quality care while curbing costs by eliminating wasted materials, effort, and time. The cost-cutting that cannot be achieved by eliminating expenditure on capital goods and nonessential services may be gained by boosting efficiency through producing more output without increasing inputs. Organizations that are able to raise production without needing additional inputs (e.g., additional supporting personnel) are operating more efficiently (Cutler, 2010).

In summary, hospitals are critical but costly resources in health care; the challenge is therefore to design processes that on one hand are flexible, but on the other hand work to standards that create consistency (Walley, 2007). Faced with the prospect of rationed care and organizational shake-ups, managers may opt to anticipate an advanced balanced act in managing health care, combining improved quality of care and efficiency. A number of attempts of this nature have been made: not only have hospitals evolved from functional, bureaucratic organizations towards more process-orientated service-line organizations (Gemmel et al., 2008; Vos et al., 2011), additional management techniques originating from industrial practices have, at the same time, begun to diffuse through hospitals (Duclos et al., 1995; Kaluzny et al., 1992; Mazzocato et al., 2010).

The patient—that is, the customer—should be at the center of attention in health care. Customers' needs (i.e., what the customer wants, expects and values) have been the main focus for the business models in other sectors as well. Managing a successful business requires a thorough analysis of the customers' needs. What customers think and feel about a company and its products constitutes a key aspect of business success. It is important to understand customers' needs if goods or services that meet these needs well are to be developed. Additionally, customers have higher expectations and needs of health care, comparing health care organizations not to each other, but to organizations like Disney and Volkswagen (Autostadt) (Herzlinger, 1997). Moreover, one must take into account patient preferences. Of the 10 rules for the redesign of health care from the Institute of Medicine's Crossing the Quality Chasm, four reflect the need to optimize medical decision making and involve patients, including customization based on patients' needs, values and preferences (IOM, 2001). Several researchers have shown that treatment decisions change after populations of patients become well informed. For example, an international Cochrane Review, that included 11 trials involving major elective surgeries, showed that demand declined by 20 per cent after patients became better informed. This systematic review reported consistent evidence that as patients became better informed, they made different decisions and felt more confident (Stacey et al, 2011). The expectation that patients will become increasingly involved in making treatment decisions poses new challenges and must be acknowledged as a warranted form of variation in health care.

Fulfilling different needs requires different operating systems. Moreover, hospitals in particular need to change proactively. It seems impossible for individual hospitals to meet this variety of needs with only one design of the operating system (Christensen et al., 2009). Hence, today's health care is not optimized for the twenty-first century. As Christensen, Grossman and Hwang (2009) have stated in the Innovator's Prescription, *"the delivery of care has been frozen in two business models—the general hospital, and the physician's practice—both of which were designed a century ago, when almost all care was the realm of intuitive medicine"* (Christensen et al., 2009, p. xviii) (Figure 1).

A general hospital is what is known as a job shop (Christensen et al., 2009). This way of organizing is characterized by very low standardization, unstructured problems, and variation in care (Cook et al., 2014), and inextricably leads to lower quality and higher costs (Cook et al., 2014; Kumar et al., 2011). Statistics reveal that general hospitals do not achieve an occupancy rate of 80%, which implies a lack of full efficiency (Kumar et al., 2011).

Besides the general hospitals, as shown in figure 1, in some countries (mainly in the US), we can witness the rise of specialized clinics, with a focus on one specific care process or discipline (e.g., cardiac, orthopedic, and eye clinics).

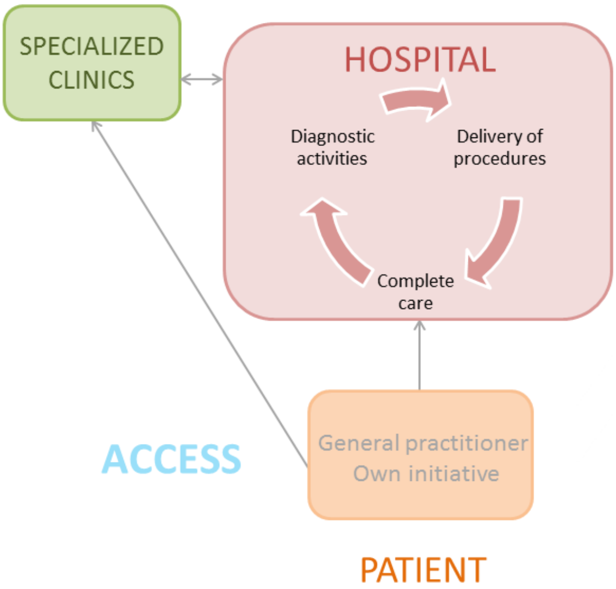

Figure 1 The general hospital, as we know it today

To accommodate the changes and challenges in health care, while paying particular attention to the ever-increasing healthcare spending, we must adjust our current policy on hospitals. The classic hospital that contains everything is obsolete (Bohmer, 2009; Christensen et al., 2009). Cook et al. (2014) recently investigated which problems or populations of patients are best addressed by job shop models and which by focused factory models (therefore claiming that there are two kind of processes in health care). They found that, in hospital surgical care, the universal application of the job shop model contributes to unwarranted variation in care, which leads to lower quality and higher costs. Creating a focused factory model within a job shop—and thus within the general hospital—was found to be very effective in both improving quality and reducing costs. Sixty-seven percent of adult patients could be described as receiving focused factory care (Cook et al., 2014). Porter et al. (2013) proposed a strategy that emphasizes the need to stratify a heterogeneous population into subgroups with different needs; this stratification can then serve as the foundation for differing work models and metrics in health care (Porter et al., 2013).

Health care institutions should focus more on some specific aspects of care and cure. This is also called the *focused factory* concept (Bredenhoff et al., 2010; Cook et al., 2014; Kumar et al., 2011). The idea is to segment patients into homogeneous groups, which leads to more predictable and manageable patterns, both inside and outside the hospital. The focus can be on many different aspects. In health care, this is complicated by the combination of treatments, patient-related characteristics, medical disciplines, and organizational aspects. An appropriate definition of the focused factory in healthcare is also missing (Bredenhoff et al., 2010).

The idea of 'focused factory' is compatible with the fundamental idea that the design of the care process should be in line with the nature of illness and care (Figure 2)—a view that is supported throughout the literature (Bohmer, 2009; Christensen et al., 2009; Cook et al., 2014; Lillrank and Liukko, 2004; Porter et al., 2013; van Merode et al., 2004). This also supports the view of operations management that each kind of service needs a different approach.

3. THEORETICAL BACKGROUND

From an operations point of view, health care proceses are particulary challenging. In the next sections we focus on processes from an operations management perspective and link these views to health care processes.

3.1 The nature of care as key characteristic of health care processes

The process by which patients' health problems are solved is by nature experimental (trial and error), and is operationalized as a function of the problem being solved. Health care professionals are tasked with providing very different types of care depending on the possibility to structure the care problems (Bohmer, 2009). The extent to which a health problem is structured depends on the underlying knowledge, where less-developed knowledge is associated with less well-structured problems and better-developed knowledge with more structure. The process used for unstructured health problems is described as *iterative*, being composed of multiple cycles of hypothesis proposition and testing, where each cycle builds upon the previous. In the case of iterative care, a patient's condition is unknown, and tremendous resources may be required for diagnosis and treatment, often with uncertain outcomes (Bohmer, 2009). This is in contrast for structured health problems, which tend to be more *sequential:* the process is rather an orderly sequence of steps. With sequential care, a patient can be quickly diagnosed and given predictable, reliable, low-cost care. Unstructured problems require an iterative process; structured problems need a sequential process (Bohmer, 2005). The importance of distinguishing the different types of care process lies in the impact that they have on the design of care delivery organizations. Iterative (e.g., complex cancer) and sequential processes (e.g., cataract surgery) require support by very different operating system designs (Bohmer, 2009). This is in line with the view of Christensen et al. (2009) that operating systems need to be designed according to the different values of the customer. This means that we should identify the core drivers that translate the values of the customers into processes. In health care, the values of the customers are related to the 'nature of care and illness' as defined by the extent that the underlying health problem is structured.

In their work, Christensen et al. (2009) also take into account the nature of care. They separate care into three what they define as 'business models' for hospitals with divergent operating systems, namely: 'solution shops', 'value added process (VAP) businesses', and 'facilitated networks'. From their point of view a business model consists of four interlocking elements (customer value proposition, profit formula, key resources and key processes) that, taken together, create and deliver value (Johnson et al., 1996).

Solution shops are defined as "*businesses that are structured to diagnose and solve unstructured problems*" (Christensen et al., 2009, p. xxiv). In this business model, value is delivered by diagnosing complex problems for which there are no standardized procedures. In some cases, medical knowledge remains incomplete, which leads to multiple means of treatment, resulting in a medical problem that requires a cyclical, rather than a linear, process to solve. The process is thus organized to deal with unique cases, such as that of a patient with complex cancer. This care process is characterized by iteration, rework, and repeated modification; it involves large inherent variation (Christensen et al., 2009). In contrast, "*organizations with VAP process business models take in incomplete or broken things and then transform them into more complete outputs of higher value*" (Christensen et al., 2009, p. xxv). In this case, the medical knowledge on the subject is more developed, and many conditions can be treated uniformly in a predictable manner; there is a low level of inherent variation. Most surgical procedures can be considered as VAPs. In a VAP, a fixed set of activities is performed; through repeatability, uniformity, and standardization of procedures, costs are reduced and the quality of care is improved (Christensen et al., 2009). The third model, that of the facilitated network business model, is applicable to "*enterprises in which* *people exchange things with one another*" (Christensen et al., 2009), p. xxvi). For example, chronically ill patients are diagnosed and undergo treatment, but neither a solution shop nor a VAP can completely solve their problems or add value in managing them. In this case, a business model that operates as a network can meet the expectations of chronically ill patients by facilitating the exchange of information for people with different needs (Christensen et al., 2009). These business models differ, as the nature of care in each model shows a different level of inherent variation, leading to greater or lesser standardization.

In these different business models (see Figure 2), processes differ in a number of ways that have a direct consequence on the design of the operating system and its resulting performance.

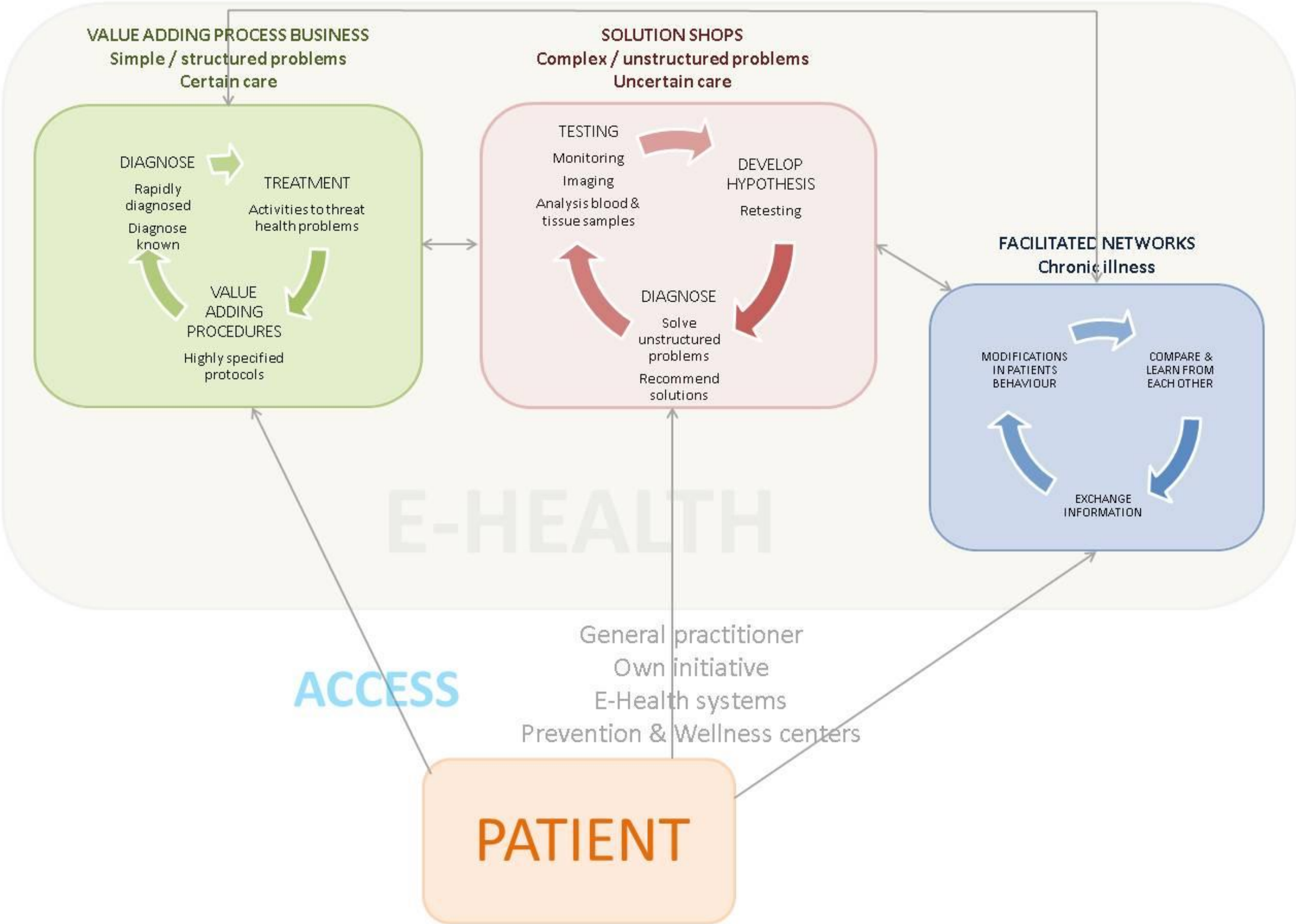

Figure 2 The hospital: How it could be. Adapted from Bohmer, (2009) and Christensen et al., (2009)

3.2 Characteristics of processes

All processes have one thing in common: they take their ‘inputs’—such as raw materials, knowledge, capital, equipment, and time—and transform them into outputs (products and services). They do this in different ways, of which the most significant are the so-called *Four Vs* of operations management: Volume, Variety, Variation, and Visibility (Slack et al., 2009).

3.2.1 Volume (repeatability and systemization)

Volume has important implications for the way in which operations are organized. Producing large volumes has an impact on the repeatability of the tasks and on the systematization of the work, when standard procedures are set down specifying how each part of the job should be carried out. In addition, because tasks are systematized and repeated, it is worth developing specialized equipment for them. The same things are done again and again, and so it is possible to gain a competitive advantage over businesses that have low volumes (Slack et al., 2009).

3.2.2 Variety

Variety relates to the different types of activities that are performed. If there are many fast changeovers between processes, additional operational complexity will be encountered. This implies a wide range of inputs to the process and the additional complexity of matching customer requirements to the products or services. High-variety processes are invariably more costly than low-variety processes (Slack et al., 2009).

3.2.3 Variation in the demand

Processes are always easier to manage when there is predictability of demand. Resources can be more effectively utilized to meet customers’ needs. In a process that possesses a certain level of unpredictability, extra resources will need to be made available to act as a ‘capacity cushion’ against a sudden surge in demand (Slack et al., 2009).

3.2.4 Visibility

How much of the process does the customer actually experience? When there is little interaction between the customer and the process, there is an inevitable lag in communication. When customers’ experience is extremely high, this environment will offer an immediate response to their needs and will have to employ different customer management skills (Slack et al., 2009).

Plotting the processes that exist offers insight into how they should be conducted (Figure 3). Slack et al. (2009) state that it is not uncommon to have separate teams and procedures in place to deal with processes that have varied characteristics (i.e., iterative versus sequential care process).

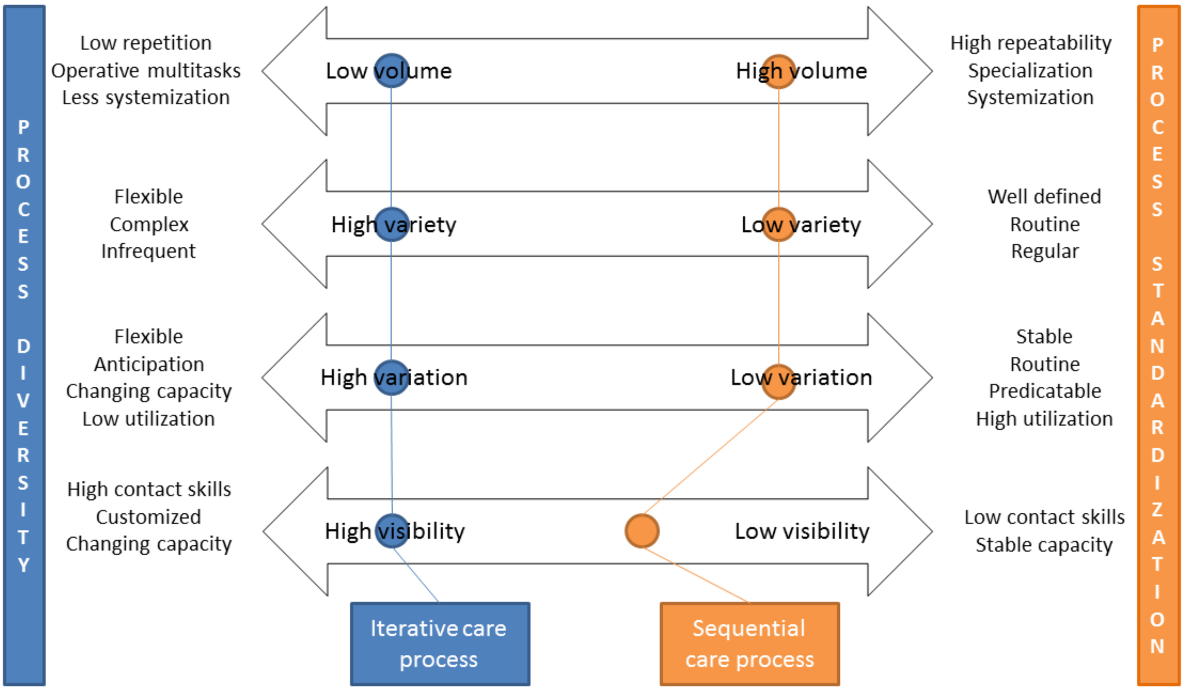

Figure 3 The 4V Process Model of Slack et al., (2009)
applied to the sequential and iterative care process in health care

3.3 Process type

In operations, the design of the process is categorized into types for manufacturing and services. The choice of process design is most dependent on the volume and variety of the product or service that an organization offers. Each manufacturing or service operation can be characterized as one of the following: project, job shop, batch flow, line flow, or continuous flow. The nature of these processes is discussed below and summarized in the manufacturing product–process matrix of Hayes and Wheelwright, 1979 (Hayes and Wheelwright, 1979) (Figure 4).

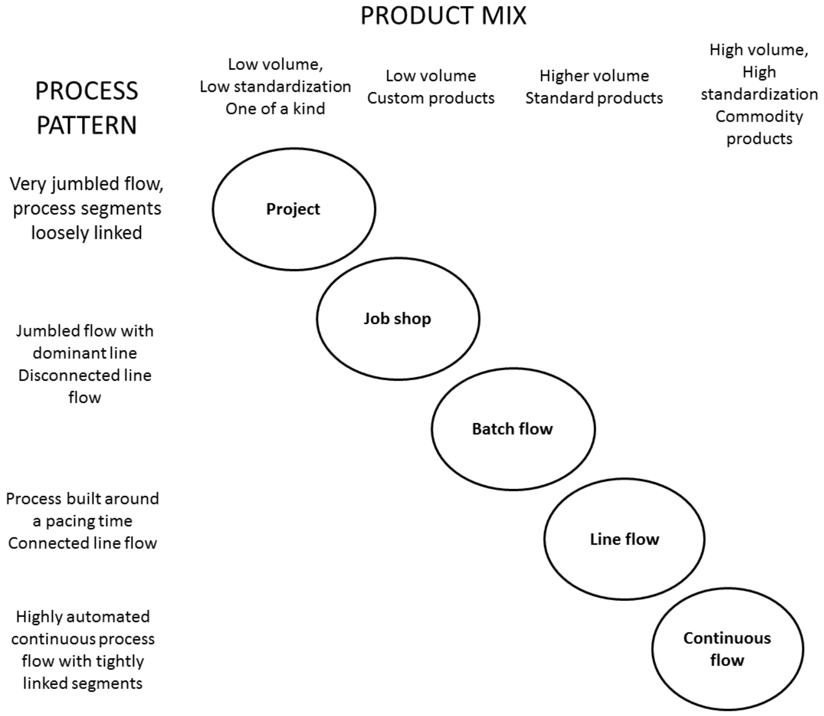

Figure 4 Product-Process Matrix, adapted from Hayes and Wheelwright, (1979)

3.3.1 Project Process

A project process is characterized by a high degree of job customization, a large scope for each project, and the release of substantial resources once a project is completed. Project processes lie at the high-customization, low-volume end of the process-choice continuum. The sequence of operations and the processes involved in each one are unique to each project, creating one-of-a-kind products or services made specifically to customer order. Firms with project processes sell themselves on the basis of their capabilities, rather than on specific products or services. Projects tend to be complex, take a long time, and to be large. Many interrelated tasks must be completed, requiring close coordination. Projects typically make heavy use of certain skills and resources at particular stages, and then have little use for them for the rest of the time. A project process is based on a flexible flow strategy, with work flows redefined for each new project (Hayes and Wheelwright, 1979).

3.3.2 Job Shop Process

Next in the continuum of process choices is the job shop process. This creates the flexibility needed to produce a variety of products or services in significant quantities. Customization is relatively high and the volume for any one product or service is low. The work force and equipment are flexible and can handle various tasks. As with a project process, companies typically make products to order, and do not produce them ahead of time. Each order is handled as a single unit—as a job. A job shop process primarily involves the use of a flexible flow strategy, with resources organized around the process. Most jobs have a different sequence of processing steps (Hayes and Wheelwright, 1979).

3.3.3 Batch Flow Process

A batch flow process differs from the job process with respect to volume, variety, and quantity. The primary difference is that volumes are higher, because the same or similar products or services are provided repeatedly. Another difference is that a narrower range of products or services is provided. Variety is achieved more through an assemble-to-order strategy than through the make-to-order strategy of the job shop. Some of the components for the final product or service may be produced in advance. A third difference is that production lots or customer groups are handled in larger quantities (or batches) than they are with job shop processes. A batch of one product or customer group is processed, and then production is switched to the next one. Eventually, the first product or service is produced again. Batch flow processes have moderate volumes, but their variety is still too great to warrant dedicating substantial resources to each product or service. The flow pattern is jumbled, with no standard sequence of operations throughout the facility. However, more dominant paths emerge than at a job shop, and some segments of the process have a linear flow (Hayes and Wheelwright, 1979).

3.3.4 Line Flow Process

A line flow process lies between the batch and continuous processes: volumes are high and products or services are standardized, which allows resources to be organized around a product or service. Materials move linearly from one operation to the next, according to a fixed sequence, with little inventory held between operations. Each operation performs the same process over and over with little variability in the products or services provided. Production orders are not directly linked to customer orders, as is the case with project and job processes. Manufacturers with line flow processes often follow a make-to-stock strategy, with standard products held in inventory so that they are ready when a customer places an order. This use of a line flow process is sometimes called mass production. However, the assemble-to-order strategy and mass customization are other possibilities that show line flow processes. Product variety is possible through careful control of the addition of standard options to the main product or service. The production may be either machine-paced or worker-paced (Hayes and Wheelwright, 1979).

3.3.5 Continuous Flow Process

A continuous process is the extreme end of high-volume, standardized production. It has rigid line flows and tightly linked process segments. Its name derives from the way materials move through the process. One primary material—such as a liquid, gas, wood fibers, or powder—typically moves without stopping through the facility. The process often is capital-intensive and operates round the clock to maximize utilization and to avoid expensive shutdowns and start-ups (Hayes and Wheelwright, 1979).

These process structures differ in several respects such as flow, flexibility, number of products, capital investment, variable cost, labor content, and skill and volume. Figure 5 illustrates how the process characteristics vary with the structure.

Figure 5 Comparison of process structures and characteristics

The core of the process classification (Figure 4) is the so-called product–process matrix. There is a tight connection between the nature of the product and the type of process used to produce it. This is generally true for health care, too: the nature of the process through which health care is delivered depends on the nature of care in terms of the structure of the problem solving. However, it would be dangerous to apply tools from production and assembly industries, such as the product–process matrix, without modification. Figure 6 shows a modified 'product–process' matrix from health care from Gemmel et al. (2013). As has been indicated, the nature of the service in health care is generally determined by the extent to which the underlying health care problem is structured. The nature of the service (structured versus unstructured health problems) determines the nature of the care process—that is, iterative versus sequential processes.

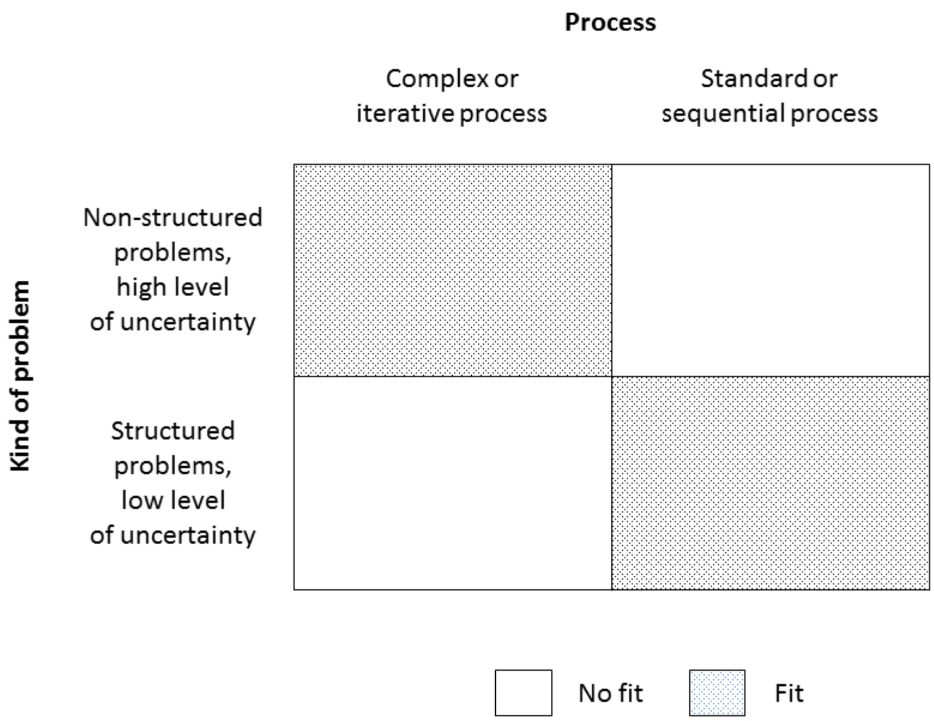

Figure 6 The Product-Process Matrix in health care, adapted from Gemmel et al. (2013)

3.4 Layout

In manufacturing, the facility layout consists of the configuration of the site with lines, buildings, major facilities, work areas, and other pertinent features, such as department boundaries. While the facility layout for services may be broadly similar to that for manufacturing, it also may be somewhat different. Because of its relative permanence, facility layout is probably one of the most crucial elements affecting efficiency. An efficient layout can reduce unnecessary material handling, help to keep costs low, and maintain product flow through the facility (Slack et al., 2009). The three basic types of layout are the product layout, the process layout, and the fixed-position layout. These layouts may be applied to either a single department or an entire facility (group of departments). Therefore, the elements of the layout may be either whole departments or individual pieces of equipment (such as hospital beds or pieces of cafeteria equipment). Understanding the difference between the layouts can give insight that can assist in the structuring of different operations.

3.4.1 Process layouts

Process layouts are found primarily in firms that produce customized, low-volume products that may require different processing requirements and sequences of operations. Process layouts are facility configurations in which operations of a similar nature or function are grouped together, arranging equipment according to its function. As such, they are occasionally referred to as functional layouts. Their purpose is to process goods or to provide services that involve a variety of processing requirements (Slack et al., 2009).

3.4.2 Product layouts

Product layouts are found in flow shops (repetitive assembly and process or continuous flow industries). Flow shops produce high-volume, highly standardized products that require highly standardized, repetitive processes. In a product layout, the resources are arranged sequentially, based on the routing of the products, and work units are moved along a line. In theory, this sequential layout allows the entire process to be laid out in a straight line, which at times may be totally dedicated to the production of only one product or product version. The flow of the line may then be subdivided so that labor and equipment are utilized smoothly throughout the operation (Slack et al., 2009).

3.4.3 Fixed-position layout

A fixed-position layout is appropriate for a product that is too large or too heavy to move. For example, battleships are not produced on an assembly line. For services, other reasons may dictate the fixed position (e.g., a hospital operating room where doctors, nurses, and medical equipment are brought to the patient) (Slack et al., 2009).

3.4.4 Combination layouts

Many situations call for a mixture of the three main layout types. These mixtures are commonly called combination or hybrid layouts (Slack et al., 2009).

As in manufacturing, in health care, too, the basic goals in developing a facility layout should be functionality and cost savings. Functionality includes placing the necessary departments—such as the operating and recovery rooms—close together. Functionality also involves keeping separate those departments that should not be located close together. The actual facility layouts applied to hospitals are almost always a mixture of the three basic types. A hospital may have an overall process layout, with all the departments grouped (intensive care, nursing units, administration). On the department level, there may be some product layouts (cafeteria, labs) and some fixed-position layouts (an operating room). The heterogeneity of the hospitals' input (the iterative and sequential care processes) complicates the identification of the layout, resulting in only a handful of core processes in hospitals being optimized in their layout design—such as the surgery in the one-day clinic or a specialty cardiology department. Again, we claim that identifying and separating the care processes according to their sequential or iterative characteristics can result, for the former, in a product layout and, for the latter, in a process layout, thus enhancing efficiency.

3.5 Performance in health care

Since the publication of the Institute of Medicine's 2001 report *Crossing the Quality Chasm: A New Health System for the 21st Century*, it has become obvious that health care delivery systems are often poorly organized (IOM, 2001).

In that work, a recommendation was made to redesign the health care system. The report's authors also adopted a shared vision of six specific aims for quality improvement (Figure 7). These aims are built around the core needs for health care (IOM, 2001) :

Safe: avoiding injuries to patients from the care that is intended to help them.

Effective: providing services based on scientific understanding to all who can benefit, while refraining from providing services to those not likely to benefit.

Patient-centered: providing care that is respectful of and responsive to individual patient preferences, needs, and values, while ensuring that patient values guide all clinical decisions.

Figure 7 The dimensions of quality of care, adapted from IOM, (2001)

Accessible/Timely: reducing waiting time and sometimes harmful delays for both those who receive care and those who give it.
Efficient: avoiding waste, including the waste of equipment, supplies, ideas, and energy.
Equitable: providing care that does not vary in quality because of personal characteristics, such as gender, ethnicity, geographic location, or socioeconomic status.

The lack of clarity of the Institute of Medicine's quality goals has led to divergent approaches and slow progress in performance improvement (Porter, 2010). According to Porter value should define the framework for performance improvement in health care, as quality is used in so many ways that it has lost its meaning and usefulness. Value depends on results, and must be measured by the outcome achieved, rather than by the volume or by the care processes used. Although value must not be measured by the care process, process measurements are important metrics for improving performance (Porter, 2010).
Today there is a strong focus on the measurement of care processes; however, processes must not be confused with outcomes. Tracking process compliance is less controversial, and can be measured in short term—unlike outcomes. Apart from that, process accountability is attractive to providers, as processes may be measured and controlled internally (Porter, 2010). Process measurement should be largely an internal effort, as all organizations should track their processes and work in order to improve them. Process measurement is useful and should continue, but we believe that these efforts should be supplemented by systematic measurements of patient compliance with care, in order to fully understand the link between process and outcome.

As the focus of this dissertation is that of operations management, and more specifically on the design of the operating system, this research adopts the perspective of *operational efficiency* to measure process performance: optimizing resource utilization without obstructing the flow throughput. One aim of efficiency studies is to minimize waste, or to maximize time savings. In summary, this study focuses on operational care process efficiency (i.e., resource- & flow efficiency). *Resource efficiency* is the most traditional view in the efficiency literature, and focuses on the optimal use of value-adding resources within an organization (Modig and Ahlström, 2012). Efficiency means producing the maximum amount of output for a given amount of input or, alternatively, producing a given output with minimum input quantities (Farell, 1957; Lovell, 1993). This way of looking at efficiency dominates how organizations are organized, controlled, and managed. *Flow efficiency*, however, focuses on the unit processed in the organization. Flow efficiency is not about increasing the speed of value-adding activities, but about maximizing the density of the value transfer and eliminating non-value-adding activities (Modig and Ahlström, 2012).

3.6 Design of the operating system

The impact of design of the operating system on the organizational level is seldom discussed in health care. The few studies that exist have mostly focused on the effects of lean or six sigma projects (Mazzocato et al., 2010; Radnor et al., 2012), and frequently on the level of an individual hospital unit (Andersen et al., 2014). They thereby neglected the degree of fit between the process and the underlying system. Because a good fit will facilitate the creation of value in health care, we believe that the design of the operating system should be studied in greater depth.

In production terms, the care process can be defined as the set of tasks and decisions that takes the input of a sick patient and converts it into a value-added output (Bohmer, 2009). The transformation that makes this happen depends on the input itself—that is, upon whether the problem presented is structured or unstructured. However, the care processes (sequential or iterative) are embedded in a system made up of many structures and processes that allow them to function. Such *processes* include the way supplies are delivered, how information is transferred, the availability of resources, and so on. The *structures* involve the physical environment in which care is delivered, the workforce that organizes and performs the activities, the departmental structure, and so on. The *operating system* expresses the configuration of all the resources and activities (i.e., the structure and processes) that come together to create a service or product (Bohmer, 2009). The structure and process components of the health care operating system all act together to facilitate and constrain the process by which the problem is solved, and will determine the ultimate outcome. In this context, a variety of models in health care have been presented in the literature. One of the best-known examples is Donabedian's conceptual framework with its three dimensions of structure, process, and outcome, on which a facility's quality of care is said to be based. Consequently, to optimize the quality of the delivery of care, structure, process, and outcome should all be considered. The idea that the structure–process–outcome model of Donabedian and Arbor (1980) can be used to study the complex operating system of hospitals has already been recognized in the literature (Gemmel and Van Dierendonck, 1993; Baars et al., 2010).

When evaluating the design of health care processes, we can consider the aspects of volume–variety requirements, process type, and process layout (Figure 8 and Table 1). Optimizing the design of the operating system as a function of process characteristics, type, and layout will result in improved outcomes.

In applying these concepts to sequential and iterative care features, we can differentiate between these two processes, as shown in Table 1.

In summary, sequential and iterative care processes vary greatly in terms of their operating systems and both processes will therefore benefit from aligning the configuration of an adjusted operating system with patient needs and values. This research focuses on the alignment of the operating system with the requirements of sequential care processes.

Table 1 Differentiating between sequential and iterative care processes

		Sequential care	**Iterative care**
Process characteristics			
	Volume	High with high repetition	Low, so low repetition and high unit cost
	Variety	Low, so requires well-defined routine standard consistent process	High, which brings flexibility, complexity in the process, and high unit cost
	Variation in demand	Low, so high utilization, stable, and predictable requirements	High, so flexibility and ability to cope with change required
	Visibility	Medium	High
	Standardization	High	Low
	Product	Commodity product	One of a kind, unique
Process type		Line/continuous flow	Project/job shop
	Flow	Continuous	None
	Flexibility	Low	High
	No. of different products	Low	High
	Labor content/skill	Low	High
	Volume	High	Low
Layout		Product	Process

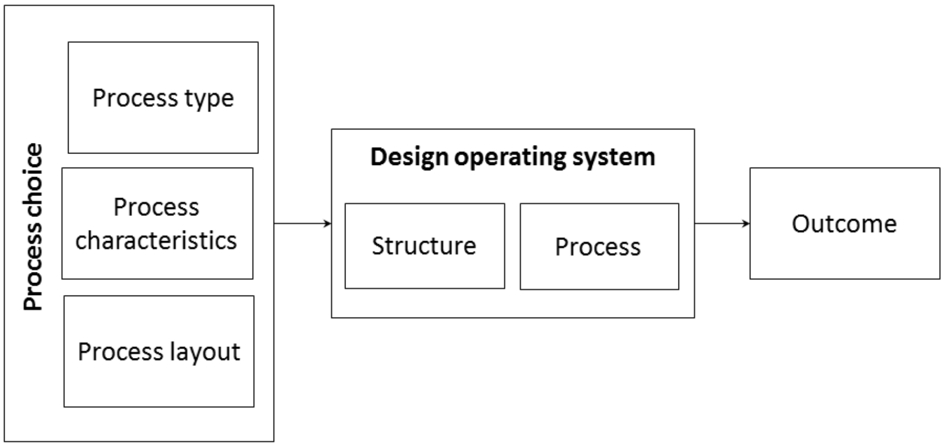

Figure 8 Conceptual framework showing the link between process choice, design of the operating system, and outcome, adapted from Donabedian, (1987)

4. DEFINITIONS OF THE KEY TERMS

This dissertation is built around four separate but interrelated studies. They were performed at different points of time and for various journals. As a result, the dissertation may show some inequalities in definitions of terms throughout the different articles. Therefore we provide clear definitions of the frequently used terms in the dissertation in this first chapter.

4.1 Variety (diversity)

Variety is an assortment or the state of having many different things. This can relate to the different types of activities that are performed, or a number of different types of things, especially in the same general category (e.g. 31 flavors of ice cream, there is something for everyone, that's variety) (Slack et al. 2009).

4.2 Variability (being variable) and variation

As both concepts are often confused we start this paragraph with two general definitions of the concept variability and variation.

The most common given explanation of variability is: the quality, state, or degree of being variable or changeable (e.g., chocolate ice that looks different and tastes different every time you order is an example of undesirable variability) (Wiktionary, 2015).
Variation, on the other hand, is most often described as: the amount by which something changes or something that is different from the usual form or arrangement (e.g., you are more

fond of ice cream in the summer, so you buy more ice creams in the summer than in the winter). (Wiktionary, 2015)

To understand the design and measurement issues related to variations research, it is helpful to reflect on definitions of variability and variations that are grounded in measurement theory (Nunnally, 1978).

Variability- a measure of the extent to which scores on a measure, within a particular sample, differ among themselves. Measures of variability include the range, standard deviation, and variance. The goal of the measure is to capture the variability that exists in patient, provider, and setting variables (Holzemer and Reilly, 1995).

Variation- the degree of variability of the values or scores on measures of variables in a particular group of participants (Holzemer and Reilly, 1995). The causes of variation in health care are complex and inter-related – they may be affected by, for example, differences in geographical patterns of illness, differences in clinicians' behaviour, the effects of incentives in the financing of health care (Appelby et al., 2011).

Variations research extends the concept of naturally occurring variability and labels variability as expected or unexpected or as desired or not desired. Variations research begins with the selection of variables hypothesized to be related to outcomes, it is often difficult to select which variables to include in the study of variations in health care (Holzemer and Reilly, 1995).

4.3 Process variation

Inevitable change in the output or result of a system (process) because all systems vary over time. Two major types of variations are (1) common, which is inherent in a system which we must try to manage (e.g., inappropriate procedures, poor design, poor maintenance of machines), and (2) special, which is caused by changes in the circumstances or environment which we must avoid (e.g., poor adjustment of equipment, operator falls asleep, faulty controllers). (Businessdictionary, 2015). Distinguishing the difference between variation, as well as understanding its causes and predicting behavior, is key to management’s ability to properly remove problems or barriers in the system.

4.4 Business model

Zott et al. (2011) already noticed that despite the overall surge in the literature on business models, scholars do not agree on what a business model is. They observed that researchers frequently adopt idiosyncratic definitions that fit the purposes of their studies and that the business model is often studied without an explicit definition of the concept.

In this dissertation we adopt the point of view of Johnson et al. (1996) to define the term 'business model'. They conceptualize the business model by enumerating its main components. "*A business model, consists of four interlocking elements* (customer value proposition, profit formula, key resources and key processes) *that, taken together, create and deliver value."* Customer value is described as *"a way to help customers get an important job done"*. The profit formula is *"the blueprint that defines how the company creates value for itself while providing value to the customer"*. The key resources are *"assets such as the people, technology, products, facilities, equipment, channels, and brand required to deliver the value proposition to the targeted customer"*; and key processes are *"Operational and managerial processes that allow successful companies to deliver value in a way they can successfully repeat and increase in scale. These may include such recurrent tasks as training, development, manufacturing, budgeting, planning, sales, and service. Key processes also include a company's rules, metrics, and norms."* (Johnson et al., 1996).

4.5 Operating system

"The operating system describes the configuration of all resources and activities that come together to create a service or product with the care process. The components of a health care operating system- the physical plant in which care is delivered, the technology and human resources used, the strategic decisions and managerial policies governing the disposition of these resources, the definition of the nature of the health service being provided and the patient segments being served, the design and sequencing of key tasks, and the positive incentives and negative boundary conditions that shape workers' behavior- all act together to both facilitate and constrain the process by which a patient's health problem is solved. Thus an operating system represents a set of design choices (and inherent trade-offs) about what care to deliver and how to deliver it…" (Bohmer, 2009, p. 117).

5. OUTLINE OF THE THESIS

The chapters in this thesis present research on important blind spots identified in the academic research regarding the design of the operating system and the organization of sequential care processes in hospitals. Each chapter is presented as a standalone paper, which has been published, accepted, or is currently being considered for publication in an international peer-reviewed journal. Therefore, some overlap between the chapters is inevitable. The published and submitted articles have each been adjusted to meet the journal's guidelines. Since the first two studies are already published (chapter 2 and 3) some of the definitions used in these chapters may differ from what is stated here. In the two final studies (chapter 4 and 5) we ensured that the terminology is in line with the definitions used in this introduction.

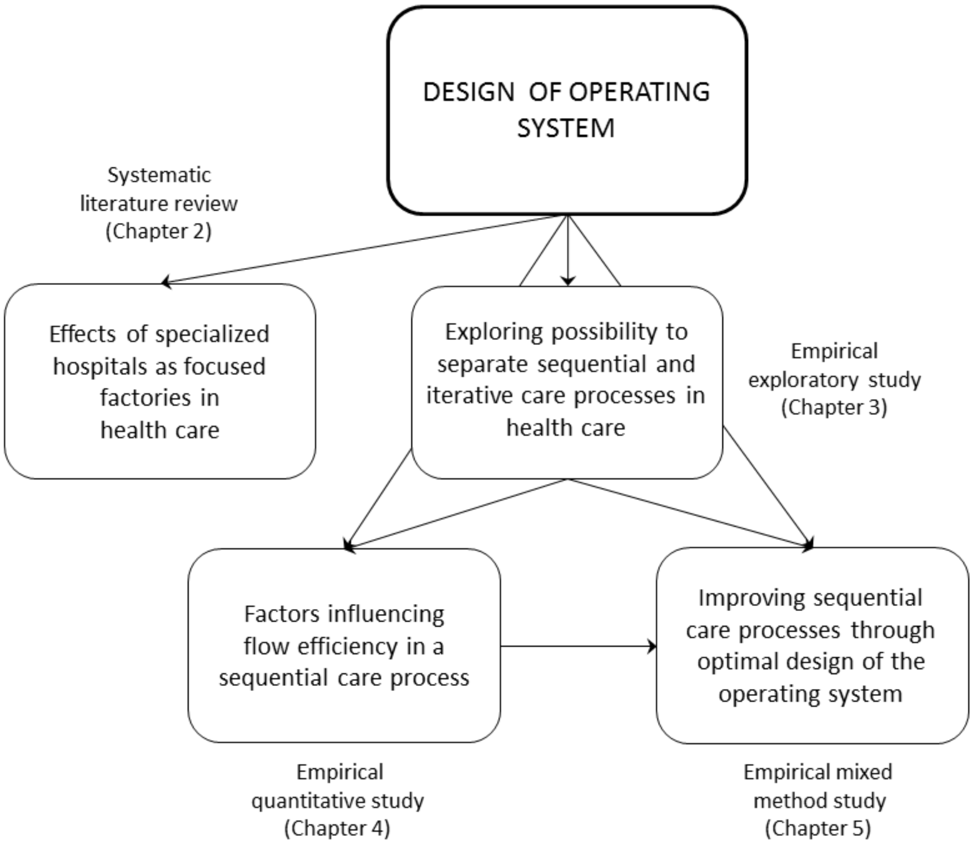

Figure 9 Overview of the described studies

In the theoretical framework we introduced concepts as iterative and sequential care processes, solution shops, VAP's and facilitated networks, each focusing on a different kind of health care processes. However, in this dissertation we limit our research to the sequential care process. The main purpose of this thesis is to assess how the design of the operating system impacts efficiency in sequential care processes in acute care hospitals. More specifically, this dissertation aims (a) to provide knowledge of the effects of specialized hospitals operating as focused factories; (b) to explore the possibilities of assigning hospital care processes to different operations systems; (c) to distinguish factors that are influencing flow efficiency in a sequential care process; and (d) to examine how sequential care operates in hospitals and which operating system design is preferable (Figure 9).

In an ideal research world, researchers would be completely independent when carrying out their research. However, we all have inherent preferences that are likely to shape our research (James and Vinnicombe, 2002). We describe the approach of this dissertation in order to demonstrate an awareness and understanding of the choices made during the research projects. Morais (2014) provides a good overview of the philosophical stances in research (Figure 10), distinguishing on the one hand between objective and subjective (facts versus values), and on the other hand between discovery versus justification (theory development versus theory testing). In line with this framework, we can situate our research on the right-hand side (justification), as we mainly test propositions and hypotheses derived from existing theory (deductive theory testing). In distinguishing between facts and values, we can locate our research on the upper part of the framework, as we concentrate on facts (objective). In summary, our research can be allocated to the upper-right quadrant of 'objective justification'.

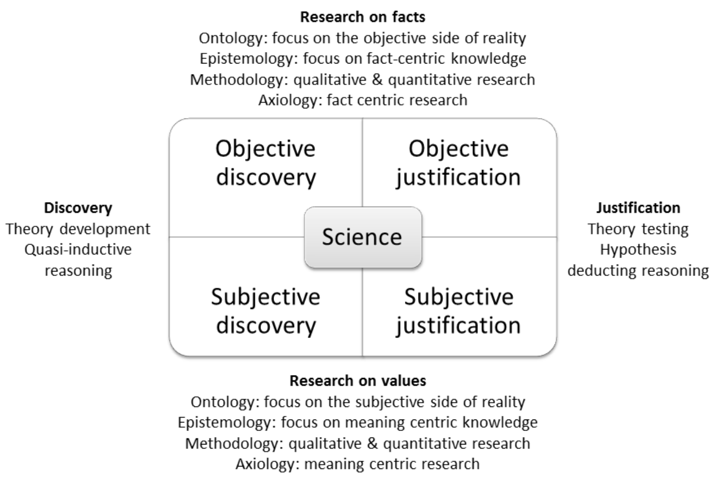

Figure 10 Overview of philosophical stances, adapted from Morais, (2014)

The dissertation is organized as follows: the second chapter focuses on the idea of achieving superior performance in delivering care in a focused factory setting (i.e., the VAP business model of Figure 2). Focused factories are an example of a good fit between the design of the operations system and the nature of care, more specifically in sequential care processes. One could thereby assume that performance, and more specifically efficiency, is better than in the 'one-size-fits-all' hospital. The notion of the focused factory concept has demonstrated great appeal in the health care setting (Bredenhoff et al., 2010; Cook et al., 2014; Herzlinger, 1999). Specialized facilities have emerged beside the traditional full-service general hospital as alternative settings of care delivery. One of the first and well-known example of such a focused factory in health care is the Shouldice Clinic in Ontario, designed specifically to meet the needs of hernia patients. A great deal of research has been published on the theme, but the literature to date lacks an integrated and systematic overview of the extent to which the potential improvements in quality and cost of care are being realized. In addition, the feasibility of the focused factory approach becomes less clear when its corresponding impact on full-service general hospitals is taken into account. In the study of the second chapter, we provide a comprehensive overview of the effects of standalone physician-owned specialized facilities by synthesizing the findings of published empirical studies. The results of this study indicate that there is no compelling evidence available to demonstrate the added value of physician-owned specialized facilities in terms of quality or of the cost of the delivered care. In addition, their corresponding impact on full-service general hospitals remains unclear.

In terms of the centralization of care in hospitals, two important efficiency arguments cannot be ignored: (1) hospitals and clinicians undertaking high volumes of work achieve better outcomes and (2) large hospitals achieve economies of scale (Boyer and Pronovost, 2010). Therefore, the results of the systematic literature review do not imply that the concept of focused factories applied within the hospitals is incapable of improving efficiency. This is also supported by a recent study of Cook et al (2014), demonstrating that creating a focused-factory model within the job shop environment of a hospital is very effective in both improving quality and reducing costs. We further have to take into account that the systematic literature review only discussed studies performed in the US health care setting, with a different type of governmental health care policy maintained than in most European countries. Also, we must bear in mind that most of the specialized facilities are physician-owned, which can induce specific incentives for the owners. In European countries, physician ownership is less common/uncommon.

To better understand the European hospital context and to explore if there are divergent care processes we present, in the third chapter, an exploratory database analysis of four hospitals in Belgium. This chapter investigates whether hospital care processes can be assigned to different groups defined by kind and size of variation in length of stay, to result in a better alignment of type of care and organization of care. Our results show groups with high and low within-group variation; there was, however, a significant difference in the distribution of the variation groups across the different hospitals. These results were one of the triggers to investigate what the causes of variation are, especially in sequential care processes, as we hypothesized that there should be little difference between hospitals in these well-defined processes. As these differences could not be explained exclusively by the severity of illness or by the risk of mortality of the patients—implies that there should be clear differences in the process and the underlying operating system in the hospitals. The reasons behind such differences may vary, but remain complex. Therefore, in the final two studies, we looked into a sequential process—namely, the cataract surgery process. We used a mixed-methods design in a case study, as case studies are the preferred methods when *how* and *why* questions are posed (Yin, 2009), and are therefore suitable for the final research questions. Sequential care organizes care by standardizing the care process, leading to less variation in care and more transparency in how care is performed. One would expect a similar design of the operating system for this process in different hospitals. In the second-last study (Chapter 4), both controllable and uncontrollable factors were found, with clinical and organizational causes influencing flow efficiency in the cataract process. These factors must be taken into account in the management of the health care process. In the final study (Chapter 5), we assessed differences in the organization of sequential care processes and assessed whether care processes with a fully compatible operating system perform better than care processes that are not fully compatible with the operating system.

In the sixth and final chapter, we summarize our findings and state the practical and methodological implications of this dissertation, thereby discussing how the empirical work contributes to the future design of operating systems in hospitals. In particular, we reflect on how the optimal design of the operating system can benefit both hospitals and their patients. We conclude by discussing the limitations of this dissertation and avenues for future research (see chapter 6).

Finally, an appendix is inserted to provide background information on cataract and the cataract surgery procedure.

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CHAPTER 2

Effects of Physician-Owned Specialized Facilities in Health Care: A Systematic Review

Effects of physician-owned specialized facilities in healthcare.

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Health Policy. 2014 Dec;118(3):316-340

ABSTRACT

Background: Multiple studies have investigated physician-owned specialized facilities (specialized hospitals and ambulatory surgery centres). However, the evidence is fragmented and the literature lacks cohesion.

Objectives: To provide a comprehensive overview of the effects of physician-owned specialized facilities by synthesizing the findings of published empirical studies.

Methods: Two reviewers independently researched relevant studies using a standardized search strategy. The Institute of Medicine's quality framework (safe, effective, equitable, efficient, patient-centred, and accessible care) was applied in order to evaluate the performance of such facilities. In addition, the impact on the performance of full-service general hospitals was assessed.

Results: Forty-six studies were included in the systematic review. Overall, the quality of the included studies was satisfactory. Our results show that little evidence exists to confirm the advantages attributed to physician-owned specialized facilities, and their impact on full-service general hospitals remains limited.

Conclusion: Although data is available on a wide variety of effects, the evidence base is surprisingly thin. There is no compelling evidence available demonstrating the added value of physician-owned specialized facilities in terms of quality and cost of the delivered care is available. More research is necessary on the relative merits of physician-owned specialized facilities. In addition, their corresponding impact on full-service general hospitals remains unclear. The development of physician-owned specialized facilities should therefore be monitored carefully.

Key words: specialty hospital, ambulatory surgery centre, physician ownership, systematic review

1. INTRODUCTION

In response to pervasive deficits in the quality of care (McGlynn et al., 2003) and skyrocketing health care expenditure OECD (2012), the pressure to provide better and more efficient care continues to shape the health care policy debate. Besides altering payment frameworks and the associated incentives (i.e., pay-for-quality initiatives), policymakers and providers have turned their attention to the way care is delivered. Specifically, care that has historically been delivered in a hospital inpatient setting can increasingly be performed in a more convenient short-stay or even ambulatory setting. Consequently, in the last two decades, specialized facilities have emerged besides the traditional full-service general hospital as alternative settings of care delivery. These specialized facilities are typically defined as hospitals that treat patients with specific medical conditions or those in need of specific medical or surgical procedures—most notably orthopaedic, spine, cardiac, and surgical procedures (Mitchell, 2007; Schneider et al., 2008). Virtually all of these specialized facilities are wholly or partly owned by physicians (Gabel et al., 2008; Lynck and Longley, 2002; Mitchell, 2007; Strope et al., 2009).

The literature on the effects of physician-owned specialized facilities has expanded rapidly over the past decade. A great deal of research has been published on the theme, but the literature lacks an integrated and systematic overview on the extent to which the potential improvements in quality and cost of care are being realized. In addition, the feasibility of the approach becomes less clear when the corresponding impact on full-service general hospitals is taken into account.

Internationally, physician-owned specialized facilities has been the subject of intense policy debate. More precisely, proponents argue that these specialized facilities are 'focused factories' taking advantage of the associated economies of scope. This potentially lowers the cost of health care delivery and possibly enhances quality of care by concentration of the expertise associated with the increased specialization (Casalino et al., 2003). In addition, the ownership by physicians has been argued to improve quality of care by reinforcing the physician's professional role as the primary enforcer of quality of care (Ford and Kaserman, 2000).

On the other hand, critics contend that the physician ownership associated with specialized facilities presents a potential conflict of interest. Since physicians with an ownership stake generate additional revenue besides their professional fees, stronger financial incentives are induced, which could affect physicians' practice patterns. This may lower thresholds for treatment, thus increasing the utilization of procedures (Hollingsworth et al., 2010) and focusing on the most profitable cases (e.g., well-insured patients, low-acuity procedures) (Gable et al., 2008). This potentially undermines the financial health of full-service general hospitals (Carey et al., 2008a).

The aim of this review is to assess and summarize the current evidence and to provide a structured, comprehensive overview of the evidence on physician-owned specialized facilities. We draw on the six dimensions of quality of care described by the Institute of Medicine (Institute of Medicine, 2001). Specifically, we investigate to what extent physician-owned specialized facilities are (1) safe, (2) effective, (3) equitable, (4) efficient, (5) patient-centred, and (6) accessible. In addition, we study (7) the impact on the performance of full-service general hospitals. Supplement 1 provides an overview.

Despite the increasing popularity of these facilities, no systematic evaluation or integration of the current evidence base has yet been conducted. Our results here are intended to inform policymakers of the nature of the evidence base. The next section describes the search strategy employed, as well as the inclusion and exclusion criteria. The results are presented for each dimension separately. The results are then integrated in the discussion, and the implications of our findings for research and policy are covered.

2. MATERIALS AND METHODS

2.1 Data Sources

This study draws upon an analysis of the literature from a systematic review perspective. The Embase, Pubmed, Cinahl, PsychInfo, Web of Science, and Eric databases, along with the Cochrane Library, were searched for relevant studies. The searches were conducted in October 2012 (Week 40). Two reviewers independently searched for relevant studies using a standardized strategy. The concepts of specialized facilities and the different dimensions of quality of care (explained above) were combined into a standardized search string using MeSH and non-MeSH entry terms: "[(ambulatory care center* OR ambulatory surgery center* OR outpatient clinic* OR surgicenter* OR specialty hospital*) AND ("Treatment Outcome" OR "Safety" OR "Health Services Accessibility" OR quality OR outcome* OR error* OR safety* OR access* OR equity OR effectiveness OR continuity OR practice pattern*) AND (ownership* OR Salaries and Fringe Benefits OR Reimbursement OR Incentive OR compensation* OR reimbursement* OR financ* OR bonus* OR remunerat*)]".

The initial search strategy was validated using a selection of key papers known to the authors. Only studies written in English were eligible. Studies published in peer-reviewed journals between January 2000 and October 2012 were included. This time frame was selected because in this period physician-owned speciality hospitals (SH) and Ambulatory surgical centres (ASC) have emerged (Al Amin and Housman, 2010). Only empirical quantitative studies were included. Qualitative research, commentaries, and theoretical analysis were excluded. Finally, since single-centre studies are unable to compare performance, these studies were also excluded.

2.2 Data extraction

Two reviewers searched independently for relevant studies using the standardized search strategy described above. The selection of studies was determined through a two-step procedure. First, the search results were filtered by title and abstract, and then narrowed down according to the formal inclusion and exclusion criteria. These were mainly duplicate records and references to non-empirical studies. The remaining studies were selected for full-text retrieval and underwent critical quality appraisal. In case of non-corresponding results, consensus was sought through consultation with a third reviewer. In addition, the reference lists of relevant publications were screened and a forward citation track was applied. The comparison of the analysis results of the two reviewers identified five noncorresponding primary publications out of 6,108 potentially relevant publications (Cohen's Kappa: 94.1%). We did not perform a meta-analysis, as the selected studies had a high level of heterogeneity in the applied methodology and outcome measurements.

2.3 Quality appraisal

Following Leonard, Stordeur, and Roberfroid (2009), a global unweighted score was assigned to assess the quality of each paper (high (H), medium (M), or low (L) quality). All relevant studies were appraised using ten generic items: clear description of the research question, patient population and setting, intervention, comparison, effects, design, sample size, statistics, generalizability, and the addressing of confounders (Van Herck et al., 2010). Table 2 provides an overview of the applied criteria. More precisely, distinctions were made in the quality scores based on the quality of the data (sources fully clear, quality check performed) and the analyses (methods clearly explained) discriminating low and medium quality scores. The difference between medium and high quality scores were determined by the way potential cofounders were considered and the internal and external validity of the findings. Disagreements between the two raters were solved by a consensus discussion involving the third author (PG).

Table 2 List of criteria used for the quality assessment

Research Question	**Well explained**
Study Design	Appropriate to address the research question
	Cross-sectional or longitudinal
	Size and representativeness of the sample
Data Quality	Source of data mentioned
	Quality check reported
	Addressing confounders
Analysis	Methods clearly explained
	Appropriate statistics
Discussion	Internal Validity
	External Validity
	Conclusions supported by findings

3. RESULTS

3.1 Literature search

Our literature search initially yielded 6,108 unique candidate articles. Their potential relevance was examined based on title and 112 were selected for full-text retrieval (Figure 11). The bibliographical references to these studies were examined in order to collect additional studies that had not been included in the records identified in the database search. In this way, 20 additional studies were included. On the basis of an abstract review, 75 articles (67 of which originated from our database search and eight of which were identified through our search of the included articles' references) did not meet the inclusion criteria and were excluded from further review. After this step, the 61 references that appeared to meet the study eligibility criteria were reviewed thoroughly (as full text). Four papers were not included, after consensus was reached between the authors. A further 11 papers were deemed ineligible (as single-centre case studies and qualitative studies), resulting in a final sample of 46 studies included in the review.

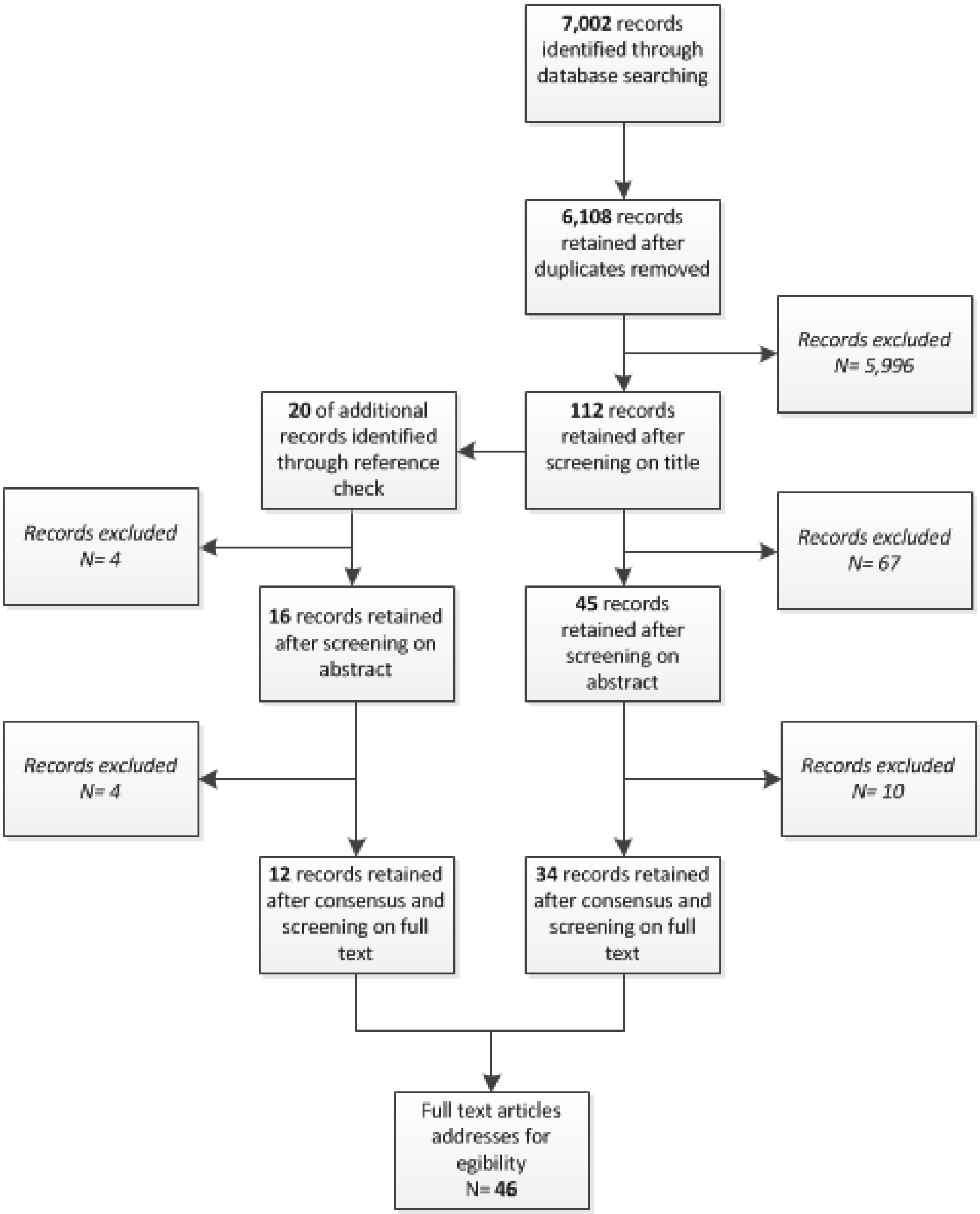

Figure 11 Search strategy flow chart

3.2 Description of studies

All the studies originated in the United States. Surprisingly, not a single European study met the inclusion criteria. A considerable increase in studies meeting the inclusion criteria published can be observed in the past few years. Most of the reviewed articles presented data on ASCs (21 out of 46) or SHs (23 out of 46). One study included both ASCs and SHs. One study referred to 'small private clinics', but addressed the research question under study. Overall, the quality of the studies was appraised as satisfactory. About half of the included studies (23 of 46) were rated high quality, 41% (19 of 46) as medium, and 9% (4 of 46) as low. It should be noted that many of the included studies used convenience samples (such as Medicare data), and the presence of adjustments for confounding factors (like sex, age, and insurance status) varied across the included studies. Studies differed in a number of characteristics. First, the clinical field of the studies varied: whereas the majority of studies focused on orthopaedics (e.g., total hip prosthesis, carpal tunnel release, and arthroscopic surgery of the knee) and on cardiac care (including coronary artery bypass grafting and percutaneous coronary artery intervention), others investigated SHs and ASCs in the clinical areas of oncology, urology, spine surgery, eye surgery, and colonoscopy. In evaluating the results, no notable differences were found between clinical areas (Table 3).

Second, several study designs can be distinguished. The majority of the studies included here applied longitudinal design (31 studies). The remainder (15 studies) applied a cross-sectional design. Three of the included studies were retrospective cohort studies.

Third, multiple outcome measures were used (see Table 4). While most studies focused on the extent to which physician-owned specialized facilities might have an impact on effectiveness (e.g., clear indications), efficiency (e.g., cost), and safety (e.g., mortality) of care, we also found studies that examined the effect on equity (such as adverse selection of poor and uninsured populations). Remarkably, while accessibility and patient-centeredness (such as patient satisfaction) are important quality characteristics of care delivery (IOM, 2001), we did not find a single study focusing on these issues. Finally, the impact of specialized facilities on full-service general hospitals (the effect on the health care value network) was frequently studied.

Table 3 Effect findings of included studies

Reference	Clinical Field	Purpose	Findings
SAFETY			
Barker, Rosenthal & Cram (2011)	Cardiology: cardiac revascularization	To investigate the relationship between procedure volume and mortality at SHs and general hospitals.	After correcting for the simultaneous relationships between procedure volume and mortality, specialty cardiac hospitals have no mortality rate advantage over general hospitals with the same procedure volumes. Evidence was found that mortality rates influence the number of patients a hospital is able to attract.
Barro, Huckman & Kessler (2006)	Cardiology: cardiovascular illness	To determine the effect of cardiac SHs on cost and quality of medical care.	Markets experiencing entry by a cardiac specialty hospital have lower spending for cardiac care without significantly worse clinical outcomes (mortality and readmissions). Specialty hospitals tend to attract healthier patients and provide higher levels of intensive procedures. SHs choose to enter markets with healthier patients, to provide additional intensive treatments of questionable cost-effectiveness, and to treat healthier patients within markets.
Chukmaitov, Devers, Harless, Menachemie & Brooks (2011) [20]	2 common procedures: arthroscopy and colonoscopy	To examine the impact of ASC strategies and structures on their quality performance.	A higher level of specialization and volume of procedures may be associated with a decrease in unplanned hospitalizations at ASCs.[2]

[2] ASC: Ambulatory Surgery Center

Chukmaitov, Menachemi, Brown, Saunders & Brooks (2008)	12 most common surgical procedures (e.g., arthroscopy, biopsy of the liver, cataract removal, colonoscopy, debridement of skin or other tissues)	To compare quality outcomes of ASCs vs. hospital-based outpatient departments.	Neither ASC nor hospital-based outpatient department performed better overall, but important variations for certain procedures were found. When risk-adjustment is applied for both primary and secondary diagnosis, ASCs performed better for upper gastrointestinal endoscopy on 30-day mortality, and hospital outpatient department performed better in all five procedures (colonoscopy, debridement of skin and other tissues, repair of inguinal hernia, laparoscopic occlusion and fulguration of oviducts and spinal injection for myelography and/or computed tomography) for 7-day and 30-day readmissions.
Cram, Bayman, Popescu & Vaughan-Sarrazin (2010)	Cardiology: acute myocardial infarction, coronary artery bypass grafting	To compare characteristics and outcomes of patients hospitalized in specialty cardiac hospitals and general hospitals.	SHs[3] have a lower proportion of women, blacks, and patients with less comorbid illness. In-hospital mortality in specialty hospital was lower than in general hospitals for acute myocardial infarction.
Cram, Vaughan-Sarrazin, Wolf, Katz & Rosenthal (2007)	Orthopaedics: total hip replacement, total knee replacement, and revision of total knee replacement	To compare patient characteristics and outcomes between specialty hospitals and general hospitals.	SHs had a greater mean procedural volume. After adjustment the composite outcome (the six described outcomes occurring within 90 days of surgery) was significant better in SHs compared to general hospitals.
Cram, Rosenthal & Vaughan-Sarrazin (2005)	Cardiology: percutaneous coronary intervention and coronary artery bypass grafting	To compare patients characteristics, hospital procedural volumes and patient outcomes between specialty hospitals and general hospitals.	The mean volumes were higher in SH than general hospitals. After adjusting for patient characteristics, the odds ratio for death after percutaneous coronary intervention was similar in both settings. The odds ratio for death after coronary artery bypass grafting was lower in SH than in general hospitals. After adjusting for procedure volume, no significant differences were found. Specialized hospitals treated healthier patients.

[3] SH: Specialty Hospital/Specialized Hospital

Greenwald, Cromwell, Adamache, Bernard, Drodz, Roor & Devers (2006)	Cardiac, orthopaedic and surgical procedures of circulatory system, musculoskeletal system, connective tissue and surgical DRGs	To compare referral patterns, quality, patient satisfaction, and community benefits of physician-owned specialty versus competitor hospitals.	From the analysis, it was found that ownership by physicians is positively related to the likelihood of referring patients to a specialty hospital. Physicians at physician-owned facilities are more likely than other physicians to refer well-insured patients to their facilities and treat a healthier population. SH provide generally high-quality care to satisfied patients, but provide less uncompensated care in specialty hospitals.
Hollingsworth, Saigal, Lai, Dunn, Strope & Hollenbeck (2012a)	Urological surgery	To evaluate the relationship between surgical quality and the location where care was delivered	Surgical activity at ASCs and the office increased for nearly every procedure with a concomitant decline in hospital utilization. There were significant differences between patients with respect to their gender, race, level of comorbidity, and area of residence when stratified by outpatient surgery setting. Specifically, women and black patients were less likely than men and white patients, respectively, to be treated at an ASC or in the office. Lower acuity cases were concentrated at nonhospital facilities. On multivariable regression, male gender, increasing age, and level of comorbidity were associated with higher odds of an adverse event. Compared with hospitals, rates of postoperative complication were significantly lower at ASCs. However, procedures performed outside the hospital were associated with a higher likelihood of a same-day admission. After adjusting for case mix differences, the probability of an adverse event was low across all ambulatory surgery settings.
Meyerhoefer, Colby & McFetridge (2012)	4 common procedures: colonoscopy, hernia repair, knee arthroscopy, cataract repair	To assess patient selection across ASC and hospital outpatient departments.	ASCs benefit from positive selection. The degree of selection varies by surgery type and patient population. ASCs experienced a significant degree of positive selection among hernia patients, moderate degree on knee arthroscopy and colonoscopy, and a limited degree among cataract patients.

Mitchell (2005)	Cardiac surgery	To compare practice patterns of physician-owners of limited-service cardiac hospitals and physician nonowners at competing full-service community hospitals.	Physician-owners treated higher volumes of profitable cardiac surgical DRGs, higher percentages of low-severity cases and higher percentages of cases with generous insurance compared with physician nonowners.
Winter (2003)	Cataract and eye procedures, colonoscopy, cystoscopy, endoscopy, interventional pain management procedures, arthroscopy, ambulatory musculoskeletal, and ambulatory skin procedures	To compare the medical complexity of patients treated in ASCs and outpatient departments.	In each procedure category, patients in ASCs had lower average risk scores than those treated in outpatient departments.
EFFECTIVENESS			
Cram, House, Messenger, Piana, Horwitz & Spertus (2011)	Cardiology: percutaneous coronary interventions	To investigate inappropriate use of PCI procedures.	Specialty hospitals were found to perform somewhat more PCI for unclear indications. Wide variation existed across hospitals.
Hollenbeck, Hollingsworth, Dunn, Ye & Birkmeyer (2010)	4 common procedures: knee arthroscopy, cystoscopy, cataract removal, colonoscopy	To determine the relationship between ASC market share and rates of procedure.	For all 4 procedures, adjusted rates of procedures performed were significantly higher in hospital service areas with high market share for ASC. The greatest difference was found in patients undergoing cystoscopy. The age-adjusted rate of cystoscopy was nearly 3-fold higher than in areas with low ASC market share.
Hollingsworth, Krein, Ye, Kim & Hollenbeck (2011)	4 common procedures: cataract surgery, colonoscopy, upper gastrointestinal tract endoscopy, cancer-directed breast surgery	To determine the impact of the opening of an ASC in a health market on the rates of procedure performed.	The opening of an ASC is associated with increases in population-based rates of colonoscopy and upper gastrointestinal tract endoscopy. Rates of cancer directed breast surgery remained flat over time. Among hospital service areas where an ASC opened, the relative increases in colonoscopy and upper GI tract endoscopy use were approximately 117% and 93% higher, respectively, 4 years after opening, compared with hospital service areas without ASCs.

Hollingsworth, Ye, Strope, Krein, Hollenbeck & Hollenbeck (2010)	5 common procedures: carpal tunnel release, cataract excision, myringotopy with tympanostomy tube placement, colonoscopy, knee arthroscopy	To determine the association between physician ownership and surgical volume.	A significant association between physician-ownership of surgicenters and greater use of the five common outpatient procedures (carpal tunnel release, cataract excision, myringotopy with tympanostomy tube placement, colonoscopy, knee arthroscopy) was found.
Hollingsworth, Ye, Strope, Krein, Hollenbeck & Hollenbeck (2009)	Urology: urinary stone surgery (percutaneous nephrolithotomy, shockwave litothripsy, ureteroscopy, conventional extraction, ancillary procedures)	To understand how physician ownership of ASCs relates to surgery volume of urinary stones.	A significant association between physician-ownership of ACSs and increased surgery use was apparent. Owners performed a greater proportion of their surgeries in ASCs than nonowners, and their utilization rates were over twofold higher. For every 10 percent increase in the penetration of owners within a urologist's local healthcare market, the annual caseload increased by 3.32.
Mitchell (2012)	Urology: prostate biopsy	To determine how ownership of in-office ancillary services affects the use of surgical pathology services and cancer detection rates.	Self-referring urologists billed more specimens with pathology tissue cores per prostate biopsy than non-self-referring urologists. However, lower cancer detection rate are linked to self-referring urologists.
Mitchell (2010)	Orthopaedics: carpal tunnel repair, rotator cuff repair, arthroscopic knee surgery	To evaluate if financial incentives linked to physician ownership influence frequency of outpatient orthopaedic surgical procedures.	Odds ratios adjusted for age and sex indicate that the likelihood of having carpal tunnel repair was 54% to 129% higher for patients of surgeon owners compared with surgeon nonowners. For rotator cuff repair, the adjusted odds ratios of having surgery were 33% to 100% higher for patients treated by physician owners. The age and sex-adjusted probability of arthroscopic surgery was 27% to 78% higher for patients of surgeon owners compared with surgeon nonowners. Higher use rates by physician owners across time suggest that financial incentives linked to ownership of either specialty hospitals or ambulatory surgery centers influence physicians' practice patterns.
Mitchell (2008)	Back and spine disorders	To compare practice patterns for physician owners and nonowners.	Findings suggest the introduction of financial incentives linked to ownership coincided with a change in the practice patterns of physician owners. These changes were not evident among physician nonowners. The frequency of use of surgery, diagnostic and ancillary services increased significantly after physician established ownership in a SH.

Mitchell (2007)	Spinal fusion procedures (simple and complex)	To compare the utilization rate of spinal fusion in two markets.	The entry of SHs was followed by substantial increases in the market area utilization rates for complex spinal surgery. Such changes did not occur in another region where physician-owned SHs do not exist. For simple spinal surgery, this was not the case.
Nallamothu, Rogers, Chernew, Krumholz, Eagle & Birkmeyer (2007)	Cardiology: coronary artery bypass graft and percutaneous coronary intervention	To determine whether the opening of cardiac hospitals was associated with increased population-based rates of coronary revascularization.	The opening of cardiac hospitals within a hospital referral region is associated with increased population-based rates of coronary revascularization. These findings are consistent when rates for coronary bypass grafting and percutaneous coronary intervention were considered separately. For PCI, this growth appeared largely driven by increased utilization among patients without acute myocardial infarction.
Popescu, Nallamothu, Vaughan-Sarrazin & Cram (2008)	Cardiology: acute myocardial infarction and heart failure	To compare quality of care between specialty cardiac hospitals, competing general hospitals and top-ranked cardiac hospitals.	Compliance to performance indicators in SHs are similar to other hospitals. Quality of care appears to be slightly better for top-ranked cardiac hospitals but the overall performance of all hospitals was relatively high.
Stensland & Winter (2006)	Cardiology: heart hospitals	To determine whether physicians' investment in cardiac hospitals was followed by an increase in the number of relatively profitable cardiac surgeries and/or in a shift towards operating on healthier patients.	Although markets with physician-owned SHs had slightly above-average growth rates in profitable cardiac surgeries, this was only statistically significant for bypass surgery. There was no increase in surgeries performed on healthier patients.
Yee (2011)	Colonoscopy	To investigate physician ownership of ASC on procedure volume and referral behaviour.	Physician board membership had a significant impact on physicians' medical decisions and overall utilization of ASCs. Specifically, physicians who were members of the board had an increased procedure volume and referred and treated more lower risk patients.

EQUITY

Carey, Burgess & Young (2009a)	Cardiology, orthopaedics and general surgery	To determine changes in the provision of uncompensated and charity care in hospitals competing with ASC.	Results indicated that the effects of SHs entry on uncompensated care differed by specialization. No association was found between orthopaedic and surgical hospitals and uncompensated and charity care. Changes in uncompensated and charity cardiac care was characterized by an important downward effect (25.9 and 40.5 percent lower for hospitals in markets with SHs).
Cram, Bayman, Popescu & Vaughan-Sarrazin (2010)	Cardiology: acute myocardial infarction, coronary artery bypass grafting	To compare characteristics and outcomes of patients hospitalized in specialty cardiac hospitals and general hospitals.	SHs have a lower proportion of women and blacks and patients with less comorbid illness. In-hospital mortality in specialty hospital was lower than in general hospitals for acute myocardial infarction.
Cram, Vaughan-Sarrazin & Rosenthal (2007)	Orthopaedic surgery: total hip replacement and revision; total knee replacement and revision	To determine whether physician ownership versus nonownership differ in hospital characteristics and patient population served.	Patients who underwent major joint replacement in physician-owned SHs were less likely to be black than patients in non-physician-owned SHs (although there was a higher proportion of blacks in the neighbourhood of physician-owned SHs). Patients treated in physician-owned SHs had lower rates of most common comorbid conditions (heart failure and obesity). Physician-owned SHs performed fewer major joint replacements on Medicare patients and were less affiliated with medical school.
Gabel, Fahlman, Kang, Wozniak, Kletke & Hay (2008)	General surgery	To investigate the referral patterns by patient insurance (ASCs vs. hospital outpatient department).	Physicians at physician-owned facilities were more likely than other physicians to refer well-insured patients to their facilities and route Medicaid patients to hospital outpatient clinics.
Greenwald, Cromwell, Adamache, Bernard, Drodz, Roor & Devers (2006)	Cardiac, orthopaedic, and surgical procedures of circulatory system, musculoskeletal system, connective tissue and surgical DRGs	To compare referral patterns, quality, patient satisfaction, and community benefits of physician-owned specialty versus competitor hospitals.	From the analysis, it was found that ownership by physicians is positively related to the likelihood of referring patients to a specialty hospital. Physicians at physician-owned facilities are more likely than other physicians to refer well-insured patients to their facilities and to treat a healthier population. SHs provide generally high-quality care to satisfied patients, but provide less uncompensated care.

Hollingsworth, Saigal, Lai, Dunn, Strope & Hollenbeck (2012b)	Urologic surgery (i.e., prostate biopsy, urethra dilation, endoscopic bladder)	To compare quality of surgical care between hospitals and ASCs	A substantial increase in the frequency of non-hospital-based outpatient surgery. Compared to hospitals, ASCs treated more men and healthier patients. Fewer postoperative complications and a higher likelihood of same-day readmission following surgery at ASCs were apparent. The probability of any adverse event was considered low across all ambulatory settings.
Mitchell (2005)	Cardiac surgery	To compare practice patterns of physician-owners of limited-service cardiac hospitals and physician nonowners at competing full-service community hospitals.	Physician-owners treated higher volumes of profitable cardiac surgical DRGs, higher percentages of low-severity cases and higher percentages of cases with generous insurance than did physician nonowners.
Nallamothu, Lu, Vaughan-Sarrazin & Cram (2008)	Cardiology: coronary revascularization (coronary artery bypass grafting, percutaneous coronary intervention)	To examine whether black patients were less likely to undergo coronary revascularization at cardiac hospitals than were white patients.	Black patients were less likely to be admitted at cardiac hospitals for coronary artery bypass grafting and percutaneous coronary intervention. However, this relationship was substantially attenuated if patients lived in close proximity to cardiac hospitals.
Tan, Wolf, Hollenbeck, Ye & Hollingsworth (2011)	Urology: ureteroscopy	To determine whether ureteroscopy rates decreased following the expansion of lithotripter ownership.	The introduction of physician ownership was not associated with increased or decreased rates of ureteroscopy but might have influenced treatment selection among certain patient groups. After ownership expansion, patients who underwent ureteroscopy were older, sicker, and less likely to be white or to have private health insurance.
EFFICIENCY			
Carey, Burgess & Young (2008b)	Cardiology, orthopaedics and general surgery	To perform a comparative cost analysis of full-service hospitals and ASCs.	No evidence was found that SHs were more efficient than full-service hospitals. Orthopaedic and surgical SHs had significantly higher levels of cost-inefficiency. Cardiac hospitals did not appear to be different from their competitors (in terms of cost-inefficiency).

Hair, Hussey & Wynn (2012)	Procedures of the eye and of the nervous, cardiovascular, digestive, musculoskeletal, and integumentary systems; miscellaneous diagnostic and therapeutic procedures	To compare ASCs to hospitals by efficiency measures.	The mean total time was shorter for most categories in free standing ASCs. For the eye, the cardiovascular system, and local excisions this was not the case. The mean time was shorter in freestanding ASCs than hospital-based ASCs across 3 subperiods of time: surgery time, operating time, and postoperative time. No differences in patient age, gender, or symptoms related to the surgery were found.
IMPACT			
Al-Amin & Housman (2010)	Specialized secondary care	To examine competition between ASCs and general hospitals.	No evidence was found that hospitals exit markets with higher levels of competition. No evidence that ASC exit was affected by hospital density. ASC organizational mortality was negatively reflected by competition from another ASC in the market.
Al-Amin, Zin, Rosko & Aaronson (2010)	Cardiology, general surgery, orthopaedics, and oncology	To investigate the relationship between general hospital closure rates and the market rate entry of SH.	Evidence was found that economic, supply, regulatory and financial conditions determined the founding rates of SH. SHs founding rates were related to general hospital closure rates.
Bian & Morrisey (2007)	Specialized secondary care	To determine the association of freestanding ASCs with hospital surgery volume.	ASCs were associated with a decrease in hospital outpatient volume. No effect on hospital inpatient procedures was found. Greater hospital concentration was associated with fewer outpatient and fewer inpatient procedures (limited effect).
Bian & Morrisey (2006)	Specialized secondary care	To determine market effects of health maintenance organization penetration and hospital competition on the growth of freestanding ASCs.	ASC are less likely to enter markets with greater HMO penetration and more likely to enter concentrated hospital markets (corresponding to a higher demand for specialized services).
Barro, Huckman & Kessler (2006)	Cardiology: cardiovascular illness	To determine the effect of cardiac SHs on cost and quality of medical care.	Markets experiencing entry of a cardiac specialty hospital have lower spending for cardiac care without significantly worse clinical outcomes (mortality and readmissions). Specialty hospitals tend to attract healthier patients and provide higher levels of intensive procedures. SHs choose to enter markets with healthier patients, provide additional intensive treatments of questionable cost-effectiveness, and to treat healthier patients within markets.

Carey, Burgess & Young (2008a)	Specialized secondary care	To examine the effects of ASC competition on general hospital financial performance.	The combined effects on revenue, cost, and margin suggest that general hospitals were experiencing competition from ASCs. Cost reductions were insufficient to offset revenue losses, resulting in decreases in margins in hospitals with ASC competition.
Carey, Burgess & Young (2009c)	Cardiology, orthopaedics, and general surgery	To determine the effect of specialty hospital entry on changes in service provision by general hospitals.	General hospitals increase their own offerings of services (cardiac surgery, freestanding outpatient centers) that are in direct competition with those of SHs. The entry of SHs is also associated with a higher growth in high-technology diagnostic imaging services in general hospitals.
Carey, Burgess & Young (2009b)	Specialized secondary care	To determine the effect of SH entry on nurse staffing levels in general hospitals.	SHs were not found to have higher nurse staffing ratios than general hospitals. Hospitals located in markets with the presence of orthopaedic/surgical SHs raised their nurse staffing levels.
Cram, Bayman, Popescu & Vaughan-Sarrazin (2010)	Cardiology: acute myocardial infarction, coronary artery bypass grafting	To compare characteristics and outcomes of patients hospitalized in specialty cardiac hospitals and general hospitals.	SHs have a lower proportion of women and blacks and patients with less comorbid illness. In-hospital mortality in specialty hospitals was lower than in general hospitals for acute myocardial infarction.
Cram, Rosenthal & Vaughan-Sarrazin (2005)	Cardiology: percutaneous coronary intervention and coronary artery bypass grafting	To compare patient characteristics, hospital procedural volumes and patient outcomes between specialty hospitals and general hospitals.	The mean volumes were higher in SHs than general hospitals. After adjusting for patient characteristics, the odds ratio for death after percutaneous coronary intervention was similar in both settings. The odds ratio for death after coronary artery bypass grafting was lower in SHs than in general hospitals. After adjusting for procedure volume, no significant differences were found. Specialized hospitals treated healthier patients.
Chukmaitov, Menachemi, Brown, Saunders & Brooks (2008)	12 most common surgical procedures (e.g., arthroscopy, biopsy of the liver, cataract removal, colonoscopy, debridement of skin or other tissues)	To compare quality outcomes of ASCs vs. hospital-based outpatient departments.	Neither ASC nor hospital-based outpatient department performed better overall, but important variations for certain procedures were found. When risk-adjustment is applied for both primary and secondary diagnosis, ASCs performed better for upper gastrointestinal endoscopy on 30-day mortality, while hospital outpatient departments performed better in all five procedures (colonoscopy, debridement of skin and other tissues, repair of inguinal hernia, laparoscopic occlusion and

			fulguration of oviducts and spinal injection for myelography and/or computed tomography) for 7-day and 30-day readmissions.
Cimasi, Sharamitaro, Haynes & Seiler (2008)	Specialized secondary care	To investigate the effect on profitability of short-term general acute-care hospitals after entry of ambulatory surgical area.	No conclusive evidence was found that SHs negatively impact the profitability of acute-care hospitals.
Courtemanche & Plotzke (2008)	Specialized secondary care	To estimate the effect of ASC entry on hospital outpatient surgical volume.	An influence of ASC entry on hospitals outpatient surgical volume was apparent if facilities were situated within a few miles of each other. This effect is stronger for large ASC and the first ASC to enter the market. The reduction in hospital volume is not nearly large enough to offset the new procedures performed by the entering ASC. No evidence was found that entering ASC reduce hospital inpatient surgical volume.
Hollingsworth, Krein, Birkmeyer, Ye, Kim, Zhang & Hollenbeck (2012b)	Urology: stone surgery	To determine how the opening of ACS impacts stone surgery use in health care market and assess the effects of its opening on the patient mix of nearby hospitals.	No evidence of procedure off-loading from competing hospitals to ASC was found. ASC opening is associated with increased market level stone surgery use. Four years after opening the relative increase in the stone surgery rate was higher (64%) in hospital service areas where a center opened vs. hospital service areas without a center. These market level increases in surgery were not associated with decreased surgical volume at competing hospitals and the absolute change in patient disease severity treated at nearby hospitals was small.
Hollingsworth, Ye, Strope, Krein, Hollenbeck & Hollenbeck (2009)	Urology: urinary stone surgery (percutaneous nephrolithotomy, shockwave litothripsy, ureteroscopy, conventional extraction, ancillary procedures)	To understand how physician ownership of ASCs relates to surgery volume of urinary stones.	A significant association between physician-ownership of ACSs and increased surgery use was apparent. Owners performed a greater proportion of their surgeries in ASCs than nonowners, and their utilization rates were over twofold higher. For every 10 percent increase in the penetration of owners within a urologist's local healthcare market, the annual caseload increased by 3.32.
Lu, Hagen, Vaughan-Sarrazin & Cram (2009)	Orthopaedics: total hip arthroplasty and total knee arthroplasty	To examine the impact of newly opened physician-owned specialty hospitals on competing general hospitals (volume and case complexity)	No clear evidence that entry of physician-owned specialty orthopaedic hospitals resulted in declines in total hip arthroscopy or total knee arthroscopy volume or increases in patient case complexity for the competing general hospital.

Meyerhoefer, Colby & McFetridge (2012)	4 common procedures: colonoscopy, hernia repair, knee arthroscopy, cataract repair	To assess patient selection across ASC and hospital outpatient departments.	ASC benefit from positive selection. The degree of selection varies by surgery type and patient population. ASC experienced a significant degree of positive selection among hernia patients, s moderate degree for knee arthroscopy and colonoscopy, and a limited degree among cataract patients.
Mitchell (2005)	Cardiac surgery	To compare practice patterns of physician-owners of limited-service cardiac hospitals and physician nonowners at competing full-service community hospitals.	Physician-owners treated higher volumes of profitable cardiac surgical DRGs, higher percentages of low-severity cases and higher percentages of cases with generous insurance than did physician nonowners.
Plotzke & Courtemanche (2011)	General outpatient surgery (13 categories: nervous system, eye, ear, nose/mouth, respiratory system, cardiovascular system, digestive system, urinary system, male and female genital system, musculoskeletal system, integumentary system, and miscellaneous procedures)	To investigate whether the profitability of patients has an impact on the setting where the surgery is performed by a physician.	Higher profit surgeries have a higher probability of being performed at an ASC compared to a hospital. After controlling for surgery type, a 10% increase in the surgery's profitability is associated with a 1.2 to 1.4 percentage point increase in the probability that the surgery is performed at an ASC.
Schneider, Ohsfeldt, Morrisey, Li, Miller & Zelner (2007)	General surgery, orthopaedic surgery, cardiac surgery	To determine if the presence of SHs in the market affects general hospitals' financial performance.	Presence of SHs is associated with higher general hospital patient care margins and lower patient care operating costs. No difference was found for hospital patient care revenue.
Strope, Diagnault, Hollingsworth, ye, Wei & Hollenbeck (2009)	87 procedures of the genitourinary system (e.g. cystoscopy)	To evaluate the relationship between ownership and use of ASCs (procedure volume and share of financially lucrative procedures).	In general, rates of ambulatory surgery increased. This was primarily the case in ASCs (in contrast to hospitals). Physician ownership was associated with this increased use. The share of financially lucrative procedures increased more when ownership was present.

3.3 Effect findings

3.3.1 Safety

A total of 12 publications that assessed safety of care were identified. Mortality and readmission rates were the most frequently studied safety outcomes. Several studies found lower mortality rates (Chukmaitov et al., 2008; Cram et al., 2005; Cram et al., 2010; Greenwald et al., 2006) and readmission rates at specialized facilities (Chukmaitov et al., 2011; Cram et al., 2007; Hollingsworth et al., 2012a). However, in case of readmissions, the results of Greenwald et al. (2006) showed that this is not always the case. Although they found that patients treated at orthopaedic SHs had lower readmission rates among moderate-severity cases, readmissions were higher among patients treated at cardiac specialty hospitals—in particular for the severe category. Apart from mortality and readmission rates, Cram et al. (2007) and Hollingsworth et al. (2012a) investigated the occurrence of postoperative complications. Both studies concluded that patients experienced fewer postoperative complications (such as postoperative sepsis and postoperative haemorrhage) at ASCs and specialized hospitals.

However, it is important to note that the safety advantages in favour of specialized facilities seem to disappear when these outcomes are adjusted for patient characteristics and procedural volume. The former is clearly important, as the cases treated in general hospitals have been found to have higher average risk scores (Cram et al., 2007; Meyerhoefer et al., 2012; Mitchell, 2005; Winter, 2003), higher medical complexity (Chukmaitov et al., 2008; Cram et al., 2010), and less healthy patients (Barro et al., 2006; Cram et al., 2005; Hollingsworth, 2012a). Furthermore, evidence was found in support of volume-safety relationships (Barker et al., 2011; Chukmaitov et al., 2011; Cram et al., 2005) demonstrating that treating higher volumes of cases can sometimes improve safety of care.

3.3.2 Effectiveness

Our review identified 13 articles addressing effectiveness of care, from which two subthemes emerged. On the one hand, adherence to clinical guidelines and evidence-based quality measures was investigated. Popescu et al. (2008) found that compliance to evidence-based treatment guidelines in cardiac SHs was similar to that in other top-ranked hospitals. This contrasts with the finding of Cram et al. (2011), who showed that SHs perform more percutaneous coronary interventions for unclear indications.

On the other hand, several studies focused specifically on the financial incentives introduced by physician ownership of SHs and the impact of these on effectiveness. Several studies showed that the incentives linked to ownership coincided with an increase in procedures on a hospital level (Cram et al., 2011; Hollingsworth et al., 2009; Hollingsworth et al., 2010; Hollingsworth et al., 2011; Mitchell, 2008; Mitchell 2010;Mitchell, 2012; Yee 2011). In addition, evidence is available to show that adjusted population-based rates of procedures performed in areas with high market share for ASCs were manifest (Hollenbeck et al., 2010), growth rates were also higher (Stensland and Winter, 2006), and the entry of SHs in a region substantially increased market utilization rates (Mitchell, 2007; Hollingsworth et al., 2011; Nallamothu, 2007).

3.3.3 Equity

Equity was studied in nine articles. Gabel et al. (2008) and Greenwald et al. (2006) studied the insurance status of patients referred to ASCs. They found that physician-owners refer well-insured patients to their facilities and less insured patients (such as those on Medicaid) to general hospital facilities. Furthermore, Mitchell (2005) and Tan et al. (2011) found that specialty hospitals treated higher percentages of cases with generous or private insurance. In addition, black patients (Cram et al., 2010; Nallamothu et al., 2008) and women (Cram et al., 2007; Cram et al., 2010) were less likely to be cared for in ACSs and SHs.

Specialty hospitals provide less uncompensated care (Greenwald et al., 2006). Similarly, uncompensated and charity care in general hospitals was negatively affected after the entry of cardiac SHs. This was, however, not the case for orthopaedic or surgical specialty hospitals (Hollingsworth et al., 2012b; Carey et al, 2009a).

3.3.4 Efficiency

Efficiency was addressed by only two studies. Carey, Burgess, and Young (2008b) studied the costs of full-service general hospitals and physician-owned cardiac, orthopaedic, and surgical specialty hospitals. They found no lower costs, and thus no evidence for increased efficiency, in the case of specialty hospitals. On the contrary, in the case of orthopaedic and surgical specialized facilities, it was found that they exhibit higher levels of overall cost inefficiency. This can be explained by the argument that competition is in part driven by increasing cost-raising services and technology. In the case of cardiac care, this difference was not present.

In addition, Hair, Hussey, and Wynn (2012) assessed potential differences in operational performance. Their main outcomes were perioperative times as a proxy for hospital efficiency. Surgery time, operating room time and postoperative time were significantly shorter in ASCs. However, it is important to note that clinical outcomes were not considered in this study, and an unequal basis of comparison could be present.

3.3.5 Impact of SHs on full-service hospitals

The corresponding effect of specialized facilities on full-service general hospitals emerged as a frequently studied topic. We identified 21 articles focusing on this aspect.

Competitive effects

A central argument in the debate about SHs is the potential effect of promoting healthy competition with full-service general hospitals, thus enhancing performance. Previous studies indicate that hospitals located in markets with orthopaedic or surgical specialty hospitals raise their nursing staffing levels (Carey et al., 2009b). Furthermore, Schneider et al. ((2007) found that the entry of specialized hospitals encourages greater cost efficiency at the existing hospitals. Hospital operating margins were improved by reducing the costs of the full-service general hospital.

Finally, while it has been shown that SHs are more likely to enter markets with lower levels of interhospital competition (Bain and Morrisey, 2006), empirical results suggest that general hospitals, when confronted with competition from specialized facilities, increase the standard of their own services. This was found by Carey, Burgess, and Young (2009c) for the case of cardiac services and high-technology diagnostic imaging. These researchers also examined the differences in the offerings of safety-net services, but found mixed results. While trauma centres and burn units were positively associated with competition, this was not the case for emergency care and crisis prevention.

Patient volume and characteristics

Research indicates that the shift of volume from full-service general hospitals to physician-owned specialized facilities occurred only to a limited degree (Bian and Morrisey, 2007; Courtemanche and Plotzke, 2008; Hollingsworth et al., 2012a). Furthermore, this shift concentrated primarily on low-severity cases that correspond to more profitable diagnostic-related groups (Mitchell, 2005; Plotzke and Courtemanche, 2011; Strope et al., 2009) and lower cost risk (Meyerhoefer et al., 2012). Cohesively, evidence was found that SHs treat a greater share of healthier patients (Barro et al., 2006; Cram et al., 2005, Hollingsworth et al., 2009) with less comorbid illness (Chukmaitov et al., 2008, Cram et al., 2005). However, since the market of secondary care as a whole has grown, clear evidence of a decline in volume or of an increase in case complexity for general hospitals is absent (Hollingsworth et al., 2012a; Lu et al., 2009). Whereas the studies of Courtemanche and Plotzke (2008) and of Bian and Morrisey (2007) depicted similar results for inpatient procedures, they did find a decrease in hospital outpatient volume.

Financial effects

The effects of increased competition, changes in patient volume and patient characteristics could possibly have a negative financial effect on full service-general hospitals. Carey, Burgess, and Young (2008a) found that specialized facilities have indeed led to revenue losses and decreases in margins. Furthermore, it has been shown that hospitals in the long run tend to exit markets with a high density of SHs (Al-Amin and Housman, 2010), and the rate of founding specialized facilities is related to the rate of closure of general hospitals (Al-Amin et al, 2010). This contrasts with the findings of Cimasi et al. (2008) and Schneider et al. (2008), who did not find conclusive evidence of the negative impact of specialized facilities on overall hospital profitability. Their findings question the contention that competition from specialized facilities harms general hospitals financially. Moreover, in case of the study of Schneider et al. (2007), hospital operating margins were improved by a reduction in costs at the general hospital. Finally, while SHs tend to focus more on cases with generous insurance (Mitchell, 2005) and financially lucrative procedures (Strope et al., 2009), there is no evidence of a negative financial impact on full-service general hospitals.

Table 4 Methodological overview of included studies

Reference	Design	Outcome	Control / Secondary Measures	Quality appraisal
SAFETY				
Barker, Rosenthal & Cram (2011)	Cross-sectional Medicare patients who underwent coronary artery bypass graft in 2000 and 2001. Two-stage least squares with hospital quality alliance scores and estimated market size as instruments for mortality and volume, to control for positive simultaneity.	Mortality (predicted from patient health)	Procedure volume, hospital quality score (conformance to clinical guidelines), staffing rate, for-profit status, race, number of hospitals, 65+ population, expected hospital volume based on geographic distribution of patients	M
Barro, Huckman & Kessler (2006)	Longitudinal data on cohorts of Medicare recipients who were hospitalized with cardiovascular illness in 1993, 1996, and 1999 Three principal sources: Medicare provider analysis and review files, agency for health care administration survey, and the Dartmouth atlas of health care. The procedures included cardiac catheterization or angiography, which may be followed by coronary artery bypass graft or percutaneous transluminal coronary angioplasty. Readmissions and mortality rate were used.	Hospital expenditures, use of intensive procedures, health outcomes (mortality and readmission)	Patient characteristics (age, gender, race, diagnosis, 180-day prior expenditure)	H
Chukmaitov, Devers, Harless, Menachemie & Brooks (2011)	Longitudinal and cross-sectional hospital inpatient discharge data from 1997–2004. Data from the Florida AHCA. The two most common procedures (arthroscopy and colonoscopy) were included. Several key independent variables were constructed, and numeric counts, averages, and percentages of binary variables were included. All analytical models used the same set of independent variables. Specialization was measured using several distinct continuous and time-varying measures. A severity measure was included.	30-day unplanned readmissions	Number of practicing physicians, volume of services, percentage of specialization, ownership type, payer mix, severity of illness, overall market competition, race, gender, age year	H

Chukmaitov, Menachemi, Brown, Saunders & Brooks (2008)	Pooled cross-sectional design (1997–2004) on organizational level. Ambulatory patient discharge and inpatient discharge data from Florida (AHCA) from 12 most common procedures. Morality and unexpected hospitalization was measured by 7 and 30-day binary variables. Hospital-based outpatient departments served as the reference. Risk-adjustments for demographic characteristics of patients and severity of illness were calculated using diagnostic cost groups/hierarchical condition categories methodology.	Risk-adjustment 7-day and 30-day mortality and 7-day and 30-day unexpected readmissions	Severity of illness, comorbidity	H
Cram, Bayman, Popescu & Vaughan-Sarrazin (2010)	Cross-sectional study (2000–2005) on an organizational level. Payer administrative data from Arizona, California, Texas, and Wisconsin. Acute myocardial infarction and coronary artery bypass grafting are studied. Data was stratified into patients insured by Medicare and those with other types of insurance (private insurance, Medicaid or uninsured/other); secondary diagnoses, identified by ICD-9-CM codes, were considered as comorbid conditions.	Differences in patient demographics, comorbidity, risk-standardized mortality	Race, gender	H
Cram, Vaughan-Sarrazin, Wolf, Katz & Rosenthal (2007)	Descriptive study using national Medicare data of beneficiaries who underwent total hip replacement and total knee replacement in 29 physician-owned and 8 non-physician-owned specialty orthopaedic hospitals from 1999 to 2003. Comparison of hospital characteristics of physician-owned and non-physician-owned (procedural volumes, teaching status, for-profit status) and demographics, comorbid conditions.	Outcomes occurring within 90 days of surgery (sepsis, haemorrhage, pulmonary embolism, deep vein thrombosis, wound infections requiring readmission or death), Length Of Stay, and the proportion of patients requiring transfer to another acute care hospital.	Demographic characteristics (age, gender, race, and socioeconomic status), comorbidity, high-risk conditions, and admission source	H
Cram, Rosenthal & Vaughan-Sarrazin (2005)	Retrospective cohort study of Medicare beneficiaries who underwent coronary artery bypass graft or percutaneous transluminal coronary angioplasty during 2000 and 2001 in	Mortality rate	Demographic characteristics (age, gender, race), socioeconomic status, comorbidity, admission source, surgical priority, age,	H

	specialty cardiac hospitals and general hospitals. Administrative data were used to compare patient characteristics, hospital procedure volume, and patient outcomes. Multivariate models were made.		volumes.	
Greenwald, Cromwell, Adamache, Bernard, Drodz, Roor & Devers (2006)	Cross-sectional study on the level of hospital type using 2003 data. National sample of specialty hospitals' Medicare claims in 2003. Hospital outpatient departments and ASCs were excluded. Specialized facilities were identified using the MedPAC definition in which at least 47% of discharges were in one of three clinical groups: diseases and disorders of the circulatory system, musculoskeletal system, and connective tissue or surgical diagnosis related groups. Physician ownership was determined in two stages. First, a potential specialty hospital was identified through an internet search and listings. Second, Medicare claims data from January to June 2004 were used to determine specialization.	Referral volume, patients preferences and service needs, severity of illness, mortality rates, readmissions and patient safety indicators	Participation in taking emergency calls with competing community hospitals,	M
Hollingsworth, Saigal, Lai, Dunn, Strope & Hollenbeck (2012a)	National sample of Medicare claims (1998–2006) identifying elderly beneficiaries who underwent one of 22 common outpatient urological procedures. Developed a three-level categorical variable, specifying the location of care: (i.e., hospital, ASC, or office), using appropriate place of service codes from Medicare's carrier file.	30-day mortality, unexpected admissions, and postoperative complications	Case-mix adjustment; differences between patients with respect to their age, gender, race (white, black, or other), comorbid status (assessed using an adaptation of the Charlson index12), and area of residence (Northeast, Midwest, South, or West).	M
Meyerhoefer, Colby & McFetridge (2012)	Longitudinal data from 4 years (2004–2008) on the hospital level. Medicare data from Florida. Sources are data collected by the Florida Agency for Health Care Administration. Procedures included those most common in Florida (knee arthroscopy, hernia surgery, and colonoscopy, and cataract surgery).	Patient illness severity, cost risk	Age, gender, ethnicity, payer type, procedure volume (physician and facility), market conditions (ASC market penetration) and patient demographics	H

Mitchell (2005)	Longitudinal data of 6 years (1998–2003) on the physician level. Data from Arizona inpatient discharge data. Sources are the Arizona Department of Health Services and Physician directory information from the Arizona Medical Board. The clinical field is cardiac hospitals. Physician-owners are defined as referring and treating patients at the facility. Sensitivity analyses were performed. Severity-of-illness and multiple comorbid conditions were included in the analyses.	Volumes of cases and severity of illness of case mix	Payer mix (DRG cases treated each year with different types of insurance coverage)	H
Winter (2003)	Cross-sectional study (1999) on organizational level. Medicare US claims data 1998 (Beneficiaries' diagnoses) and 1999 enrolment data (demographic information). The clinical field covers several domains such as eye procedures, gastrointestinal procedures, cystoscopy, musculoskeletal, and skin procedures. A comparison is made between ASCs and outpatient departments. Patient risk scores were applied (Berenson–Eggers type of service classification).	Medical complexity (risk score)	Age, gender, diagnosis, setting (inpatient, outpatient, and physician visits)	M
EFFECTIVENESS				
Cram, House, Messenger, Piana, Horwitz & Spertus (2011)	Retrospective cohort study on the hospital level. Medicare provider and analysis review and CathPCI registry data. A comparison is made between not-for-profit hospitals, major teaching hospitals, for-profit hospitals, and physician-owned specialty hospitals. Cardiovascular risk factors and comorbidities are included in the analyses.	Unclear indications of PCI (adherence to guidelines: without documented angina, typical of atypical chest pain or a positive stress test)	Type of hospital (not-for-profit, teaching, for-profit or specialty), geographic location, bed size, PCI volume, patient demographics (gender, race, admission source, insurance status, inpatient status), comorbidity (i.e., congestive heart failure, diabetes), clinical characteristics (i.e., ejection fraction, New York heart association class)	H
Hollenbeck, Hollingsworth, Dunn, Ye & Birkmeyer (2010)	Data from the healthcare costs and utilization project's state ambulatory surgery databases for Florida for 2006 were collected on patients undergoing ambulatory surgery to determine the relationship between ASC market share and rates of procedure on the market level. Health care markets were defined by using the boundaries of the hospital service area as described by the Dartmouth atlas. For each procedure (knee arthroscopy, cystoscopy, cataract removal,	Procedures rate (number of patients)	Age, gender, race, insurance status, socioeconomic status, comorbidity, ASC market share	H

	colonoscopy) generalized linear models and Mantel-Hanszel tests were used. The Herfindahl-Hirschman index was used for measurement of competition within a given market. Data were adjusted for age, gender, race, insurance status, socioeconomic status, comorbidity, and ASC market share.			
Hollingsworth, Krein, Ye, Kim & Hollenbeck (2011)	Longitudinal study on the level of the hospital service area. Florida data from the state ambulatory surgery databases (1998–2006). Medicare-eligible persons 65 years or older. Cataract surgery, colonoscopy, upper gastrointestinal endoscopy. The incidence of breast cancer was used as a proxy to measure hospital market capacity. A Charleston score of 0 was used to measure comorbidity.	Annual surgical volumes	Age, gender, race, year, presence of multiple ASCs within hospital service area, comorbidity, socioeconomic status, insurance status	H
Hollingsworth, Ye, Strope, Krein, Hollenbeck & Hollenbeck (2010)	Cross-sectional study with data from the Healthcare Cost and Utilization Project SASD between 1998 and 2006 from Florida on the market level. Ambulatory stone surgery was studied, because it includes procedures done at hospitals, freestanding ASCs, and lithotripsy centers. Hospital service area boundaries were used to assign each hospital and ASC to one health care market where stone surgery was performed. The primary outcome was the annual HSA level rate of stone surgery, standardized to the 2000 US population by age and gender. Data were compared for patient characteristics (age, gender, race, year, presence of multiple ASCs within hospital service area, comorbidity using an adaption of Charleston index, socioeconomic status, and insurance status)	Surgical volume (differences in annual case loads and changes in annual case load)	Differences in patient mix, patients by treatment site, insurance status, comorbidity	H
Hollingsworth, Ye, Strope, Krein, Hollenbeck & Hollenbeck (2009)	Cross-sectional study on the physician level. Healthcare cost and utilization project's state ambulatory surgery databases for Florida (1998–2002). Patients undergoing outpatient surgery for urinary stone disease were included. Urologists were considered owners when they performed 30% or more of ambulatory surgery cases in a year at a given ASC. Patient comorbidity status was determined by a constructed indicator variable identifying those cases for which there were 0–5 comorbid conditions on the discharge record.	Procedural volume of urologist (in ASC and total)	Patient age, gender, race, primary payer, socioeconomic status, level of comorbidity, year	M

Mitchell (2012)	Data was collected from 2005 to 2007, from a sample of male Medicare beneficiaries who were potential candidates for prostate biopsies, listed on the international statistical classification of diseases and related health problems. This study examines Medicare claims for men in a set of geographically dispersed counties to determine how the in-office ancillary services exception affected the use of surgical pathology services and cancer detection rates associated with prostate biopsies. Data were compared to practice types. A targeted-market-area case-study design was used to identify men who met the selection criteria and resided in a geographically dispersed set of counties across the United States. Data were adjusted for year, region, gender, comorbid conditions, and race.	Billing for specimen per biopsy, cancer detection rate	Year, region, gender, comorbid conditions, and race	L
Mitchell (2010)	Longitudinal data (5 years of claim data, 2003–2007), from a large private insurer in Idaho and states records, to compare frequency by orthopaedic surgeon owners and nonowners of surgical procedures (carpal tunnel repair, rotator cuff repair, arthroscopic knee surgery). Analysis on the level of physician ownership status to evaluate if financial incentives linked to physician ownership influence frequency of outpatient surgical procedures, by comparing frequency by orthopaedic surgeon owners and nonowners of surgical procedures that could be performed by in ASCs or hospital outpatient surgery departments. Age, year, physician ownership, and sex-adjusted odds ratio.	Frequency of use (number of patients treated by procedure/number of patients with such diagnosis)	Age, gender, year, physician ownership	M
Mitchell (2008)	The study analyses medical claims for services rendered from 2001 to 2004 for the largest worker's compensation insurer in Oklahoma. This study compares practice patterns of physician owners of specialty hospitals before and after ownership, and practice patterns of physician nonowners who treated similar cases over the same time period in markets without physician-owned specialty hospitals. Using the methodology developed by MEDPac, the relative profitability of complex and simple spinal fusion surgeries was calculated. No variables were used for adjustment.	Practice patterns: frequency of use of surgery, diagnostic and ancillary services (i.e. simple and complex spinal fusion, MRI, Epidurals, physical therapy...)	None	L

Mitchell (2007)	The study examines trends in utilization rates for complex and simple spinal fusion procedures performed on injured workers with back/spine disorders from 2000 through 2004 from the largest worker's compensation insurer in Oklahoma. Data from Medicare documents the use of back surgery in four states (Oklahoma, Kansas, South Dakota, and Arizona) and a control group of states located in the Northeast were used as a comparison group. Descriptive analysis was used to compare the utilization rate of spinal fusion in two markets. No variables were used for adjustment.	Utilization rate (complex and simple) spinal fusion per 1000 back-spine cases in treatment.	None	M
Nallamothu, Rogers, Chernew, Krumholz, Eagle & Birkmeyer (2007)	Data from Medicare beneficiaries aged 65 years or older enrolled in fee-for-service programs were collected from the centers for Medicare & Medicaid services, Medicare provider and Analysis Review (MEDPAR) from 1995 through 2003 to determine whether the opening of cardiac hospitals was associated with increasing population-based rates of cardiovascular revascularization. Hospital referral regions from the Dartmouth atlas of cardiovascular health care were used to identify health care markets. Population-based rates for coronary artery bypass graft and percutaneous coronary angioplasty were calculated in each of the hospital referral regions during each year of the study. Rates were adjusted for differences in age, sex, and race across hospital referral regions and years using direct standardization.	Rates of change in population based weights of revascularization (year).	Age, gender, race, US region, baseline year, presence of multiple new programs within hospital referral region, socioeconomic status of hospital referral region	H
Popescu, Nallamothu, Vaughan-Sarrazin & Cram (2008)	Cross-sectional study on the hospital level. Data reported to Medicare and Medicaid service centers in 2005–2006. Hospital compliance with CMS guidelines: the percentage of eligible patients with acute myocardial infarction and heart failure who received guideline-based treatment. Specialty cardiac hospitals were identified by calculating the ratio of cardiac admissions to total admissions for each hospital (2003 MedPAR data) and compared with general hospitals and a list of America's best cardiac hospitals. No correction for the severity of the treated pathology was applied.	Compliance to treatment guidelines (evidence based quality measures: administrating aspirin, β-blockers, angiotensin-converting enzyme inhibitor; left ventricular function and composite measures)	None	M

Stensland & Winter (2006)	Data analysis (1996–2002) regarding utilization changes in markets with physician-owned cardiac hospitals and markets lacking such hospitals. Document analyses of Medicare. No variables were used for adjustment.	Number of high-margin services (coronary bypass grafting), moderate margin surgery (acute myocardial infarction) and low margin surgery (implantation of cardio defibrillators) performed and severity of patients treated at both types of hospitals	None	L
Yee (2011)	Longitudinal study on the physician level. Outpatient records from the Florida Agency for Health Care Administration and corporate filings from the Florida Division of Corporations. Data from 1997–2004. Physician owners were identified through board membership of an ASC. Colonoscopy was chosen as clinical field. The risk profile of patients was measured by the median health risk score. Medical severity was determined by the Charleston comorbidity index.	Physician procedure volume, referrals	Patient health-risk score	H
EQUITY				
Carey, Burgess & Young (2009a)	Data analysis from the hospital annual financial data obtained from the California office of statewide health planning and development for the period 1997–2006 on the hospital level. A longitudinal model of hospitals' provision of uncompensated and charity care for orthopaedic/surgical and cardiac care. The Herfindahl index was used to calculate the market concentration of hospitals. The total number of beds, number of hospitals, number of ASC, overall market competition, per capita income, unemployment rates, occupancy rate, and hospital ownership status were used as control variables.	Costs of uncompensated care and charity care	Total number of beds, number of hospitals, number of ASC, overall market competition, per capita income, unemployment rates, occupancy rate, hospital ownership status	M

Cram, Bayman, Popescu & Vaughan-Sarrazin (2010)	Cross-sectional study (2000–2005) on an organizational level. Payer administrative data from Arizona, California, Texas, and Wisconsin. Acute myocardial infarction and coronary artery bypass grafting were studied. Data was stratified into patients insured by Medicare and those with other insurance (private insurance, Medicaid, and uninsured/other); secondary diagnoses, identified by ICD-9-CM codes, were considered as comorbid conditions.	Differences in patient demographics, comorbidity, risk-standardized mortality	Race, gender	H
Cram, Vaughan-Sarrazin & Rosenthal (2007)	Retrospective cohort study between 1999 and 2003. National sample of Medicare beneficiaries who underwent total hip replacement and total knee replacement. Specialty orthopaedic hospitals were identified by the use of a ratio of orthopaedic admissions to total admissions. Patient safety indicators developed by the agency for healthcare research and quality most relevant to surgical quality. Six outcomes occurring within 90 days of surgery: sepsis, haemorrhage, pulmonary embolism, deep vein thrombosis, wound infection requiring readmission, or death. Secondary outcomes were length of hospital stay and proportion of patients requiring transfer to another acute care hospital, as a potential measure of complications that could not be managed in the primary hospital.	Race (black or white patients), insurance status.	Procedural volumes, hospital teaching status, for-profit status, severity, comorbid conditions, nurse staffing ratios	H
Gabel, Fahlman, Kang, Wozniak, Kletke & Hay (2008)	Cross-sectional study (2003) on hospital type level (physician-owned surgery centers vs. hospital outpatient departments and other ASCs) Discharge data of the Pennsylvania health care cost containment commission. Facilities that provided a broad range of services to all patients were studied. Paediatric, women's hospitals, cancer, cosmetic, and eye surgery were thus excluded.	Referral patterns of physicians by patient insurance status	Facility type, physician ownership status, patient characteristics (gender, age, and race), discharge status (i.e., home), diagnosis, procedure, source of admission, referring physician, payer mix (self-pay, Medicaid, Medicare, commercial)	M

Greenwald, Cromwell, Adamache, Bernard, Drodz, Roor & Devers (2006)	Cross-sectional study on the level of hospital type using 2003 data. National sample of specialty hospitals, Medicare claims 2003. Hospital outpatient departments and ASCs were excluded. Specialized facilities were identified using the MedPAC definition in which at least 47% of discharges were in one of three clinical groups: diseases and disorders of the circulatory system, musculoskeletal system, and connective tissue or surgical diagnosis related groups. Physician ownership was determined in two stages. First, a potential specialty hospital was identified through an internet search and listings. Second, Medicare claims data from January–June 2004 were used to determine specialization.	Referral volume, patients preferences and service needs, severity of illness, mortality rates, readmissions and patient safety indicators	Participation in taking emergency calls with competing community hospitals	M
Hollingsworth, Saigal, Lai, Dunn, Strope & Hollenbeck (2012b)	5% national sample of Medicare data of 1998–2006. Claims data of 22 common outpatient urological procedures (endoscopic bladder, urethral and ureteral surgery, prostate biopsy, urodynamic procedures, ...). Mortality was defined as death within 30 days of surgery or death during hospitalization that began within 30 days of surgery. Unexpected hospitalization means same day admission and subsequent admissions within 30 days of the procedure. Postoperative complications within 30 days were identified by ICD-9 CM diagnosis codes. Comorbidity status was assessed using an adapted Charleston index.	Adverse events: 30-day mortality, unexpected readmission rate (same day and 30 days), postoperative complications	Case mix, age, gender, race, comorbid status, area of residence	H
Mitchell (2005)	Longitudinal data from 6 years (1998–2003) on the physician level. Data from Arizona inpatient discharge data. Sources are the Arizona Department of Health Services and Physician directory information from the Arizona Medical Board. The clinical field is cardiac hospitals. Physician-owners are defined as referring and treating patients at the facility. Sensitivity analyses were performed. Severity-of-illness and multiple comorbid conditions were included in the analyses.	Volumes of cases and severity of illness of case mix	Payer mix (DRG cases treated each year with different types of insurance coverage)	H

Nallamothu, Lu, Vaughan-Sarrazin & Cram (2008)	Cross-sectional study on the level of hospital referral regions (2002–2005). Medicare provider and analysis review part A and provider-of-service files. Black and white patients 65 or more who underwent coronary revascularization with coronary artery bypass grafting or percutaneous coronary intervention. To identify specialty hospitals, a cardiac specialty index was used, based on the percentage of cardiac to total admissions among Medicare beneficiaries in 2002–2003. In addition, a selection was made of corporate-owned facilities (excluding obstetric or paediatrics) identified by Centers for Medicare and Medicaid services as 'physician-owned specialty hospitals'.	Patient characteristics (gender, race, age)	Geographic proximity to the nearest hospital, procedural acuity, comorbidities, admission type (elective, urgent, emergent) and admission source.	H
Tan, Wolf, Hollenbeck, Ye & Hollingsworth (2011)	Longitudinal study (2004–2007) on the level of hospital type (urologist ownership). Healthcare cost and use of project's state ambulatory surgery database. Patients who underwent ureteroscopy were selected.	Use of ureteroscopy (number of procedures/population)	Comorbidity, age, gender, race, socioeconomic status and primary payer	M
EFFICIENCY				
Carey, Burgess & Young (2008b)	Longitudinal data (1998–2004) from Medicare cost reports and hospital inpatient discharge data for Texas, California, and Arizona. Additional data came from the American Hospital Association annual survey database on level of organizations (full service hospital versus physician-owned cardiac, orthopaedic, and surgical specialty hospitals) and the Dartmouth Atlas of Health Care. A hospital cost function was estimated using stochastic frontier regression analysis and generated hospital inefficiency measures. The key outpatient variables were number of discharges and number of outpatient visits. Secondary measures included the number of discharges, number of outpatient visits, average length of stay, input price, case mix, patient safety indicators (infections due to medical care, postoperative haemorrhage or hematoma, accidental puncture or laceration), competition, ownership, system (multihospital system), teaching status, hospital size.	Hospital total costs	Number of discharges, number of outpatient visits, average length of stay, input price, case mix, patient safety indicators (infections due to medical care, postoperative haemorrhage or hematoma, accidental puncture or laceration), competition, ownership, system (multihospital system), teaching status, hospital size	H

Hair, Hussey & Wynn (2012)	Data from discharged patients after a single procedure with Medicare as the principal payer in 2011. Ambulatory surgical visits of Medicare beneficiaries were compared for hospital-based and freestanding ambulatory surgical centers, with time in surgery, time in operating room, time in postoperative care and perioperative time as main outcomes. Descriptive statistics were used to compare the hospital-based and freestanding ASC visits by age distribution, sex, number of diagnoses reported at the time of visit, number of symptoms occurring during the procedure, and anaesthesia use overall and for selected procedures. The *t*-test was used to test differences in mean surgical times by facility type. It is unclear how much of the difference was the result of efficiency versus patient selection.	Time in surgery, time in operating room, time in postoperative care, total perioperative time	Age, gender, number of diagnoses, symptoms related to surgery (hypertension, nausea, ..), use of anaesthetics	L
IMPACT				
Al-Amin & Housman (2010)	Longitudinal study on 1997–2006 on level of healthcare markets. Data sets collected and developed by Florida's Agency for Health Care Administration: outpatient facility licensure data and inpatient and outpatient surgical procedure data. A total of 244 different procedure types were included.	Organizational mortality	Market demand size, physician referral, type of facility	M
Al-Amin, Zin, Rosko & Aaronson (2010)	Longitudinal study 1990–2005 on the state level. Single specialty hospitals founding rate is estimated from the AHA Annual Survey Database. Only cardiac, surgical, orthopaedic, and oncology hospitals were included. The number of specialist physicians per 100,000, unemployment rate, and state per capita income are derived from the area resource file. Physician expenditures in each state per year are obtained from the center for Medicare and Medicaid services. CON program data are derived from the American Health Planning Association.	General hospital closure rate	Environmental variables (population size, number of specialist physicians, expenditure per physician, state, unemployment rate), Institutional variables (certificate of need program) and ecological variables (general hospital closure rate, state level general hospital size)	M

Bian & Morrisey (2007)	ASC competition, hospital concentration, and managed care penetration hypotheses were studied using four secondary data sources with the use of Medicare Online Survey Certification and Reporting System (OSCAR) and 1993–2001 data from the American Hospital Association. Other data sources included a health maintenance organization enrolment file that reported the number of Health Maintenance Organization enrolees at the county level from 1993 to 2001 and the area resource file from 1993 and the period 1995–2003. Data were analysed on organizational level. No mentioning of patient complexity or morbidity.	Hospital in-patient and out-patient surgical volume	Hospital concentration, HMO penetration, number of specialty surgeons per 10,000 population, non-Federal physicians / 10,000 population, per capita income, unemployment rates, proportion 64+ and total population in hospital area, year	M
Bian & Morrisey (2006)	Longitudinal study 1992–2001 on the statistical-area level. Metropolitan statistical area panel data from the Medicare online survey certification and reporting system. The HMO enrolment file, the American hospital association annual survey of hospitals and the area resource files were used as complementary data sources.	ASCs/10,000 population	Merger and closure information on ASC, HMO penetration, number of HMO enrolees, community hospital concentration, MSA-level covariates (per capita specialty surgeons, per capita non-Federal physicians, proportion 65+, per capita income, unemployment rate)	M
Barro, Huckman & Kessler (2006)	Longitudinal data on cohorts of elderly Medicare recipients who were hospitalized with cardiovascular illness in 1993, 1996, and 1999 Three principal sources: Medicare Provider Analysis and Review (MEDPAR) File, the Agency for Health Care Administration survey and The Dartmouth Atlas of Health Care. Procedures included are cardiac catheterization or angiography, which may be followed by coronary artery bypass graft or percutaneous transluminal coronary angioplasty. Readmissions and mortality rate were used.	Hospital expenditures, use of intensive procedures, health outcomes (mortality and readmission)	Patient characteristics (age, gender, race, diagnosis, 180-day prior expenditure)	H
Carey, Burgess & Young (2008a)	Cross-sectional study with data from 1997–2004 on the hospital level. Revenues, costs and ownership, area wage index and inpatient case-mix index were obtained from data collected by the Centers for Medicare and Medicaid Services. The American Hospital Association annual survey database supplied information on the output variables, hospital bed size, and system membership, and on the number of outpatient surgical procedures. Count-level variables came from the area resource file.	Net patient revenue, total operating expenses (costs) and profit margins	Number of admissions, number of outpatient visits, number of outpatient surgeries, length of stay, payer mix, inpatient case-mix index, input prices, number of staffed beds, general hospitals in the market, number of specialty hospitals entrants, type of SH, average profit margin in region, population growth, per capita physicians in region	H

Carey, Burgess & Young (2009c)	Hospital level data analysis from 1997 through 2004 from the American hospital association Annual survey database from 10 states The effects of SSH competition were examined through the relationship between changes in selected service offerings of general hospitals and the amount of SSH competition in local hospital markets for the most relevant services to competition between general hospitals and SSHs. Covariates included the Herfindahl index, case mix, …	Competition level of single specialty hospitals high technology, safety net	Case mix, per capita physicians, per capita income, hospital size and percentage of hospitals in the market	M
Carey, Burgess & Young (2009b)	The annual survey database for the years 1997 through 2004 supplemented by the Medicare case-mix index, the Medicare cost reports, and the area resource file were studied for 10 key states on the organizational level with longitudinal panel models. The market area was the hospital referral region as defined in the Dartmouth atlas of health care. The dependent variable is the number of full-time equivalent RN and the unit of analysis is the hospital-year.	Nurse staffing level (FTE registered nurses and FTE licensed practical nurses)	Case mix, number of beds, profit status, public status, overall market competition, market share (nonprofit, public, teaching system hospitals)	M
Cram, Bayman, Popescu & Vaughan-Sarrazin (2010)	Cross-sectional study (2000–2005) on the organizational level. Payer administrative data from Arizona, California, Texas, and Wisconsin. Acute myocardial infarction and coronary artery bypass grafting are studied. Data were stratified into patients insured by Medicare and those with other insurance (private insurance, Medicaid, and uninsured/other); secondary diagnoses, identified by ICD-9-CM codes, were considered comorbid conditions.	Differences in patient demographics, comorbidity, risk-standardized mortality	Race, gender	H
Cram, Rosenthal & Vaughan-Sarrazin (2005)	Retrospective cohort study of Medicare beneficiaries who underwent coronary artery bypass graft or percutaneous transluminal coronary angioplasty during 2000 and 2001 in specialty cardiac hospitals and general hospitals. Administrative data were used to compare patient characteristics, hospital procedure volume, and patient outcomes. Multivariate models were made.	Mortality rate	Demographic characteristics (age, gender, race), socioeconomic status, comorbidity, admission source, surgical priority, age, volumes.	H

Chukmaitov, Menachemi, Brown, Saunders & Brooks (2008)	Pooled cross-sectional design (1997–2004) on the organizational level. Ambulatory patient discharge and inpatient discharge data from Florida (AHCA) from 12 most common procedures. 7 and 30-day binary variables for mortality and unexpected hospitalization. Hospital-based outpatient departments served as the reference category. Risk-adjustments for patient demographic characteristics and severity of illness were calculated using the diagnostic cost groups/hierarchical condition categories methodology.	Risk-adjustment 7-day and 30-day mortality and 7-day and 30-day unexpected readmissions	Severity of illness, comorbidity	H
Cimasi, Sharamitaro, Haynes & Seiler (2008)	Longitudinal study (1997–2005) on the hospital level. Identification of specialty hospitals by the centers for Medicare and Medicaid services, the American hospital directory, and the physician hospitals of America. Hospital status was determined from the list of short-term acute care hospitals first by virtue of name, and confirmed via phone calls to facilities and web site research to determine specialized status.	Profitability indicators: operating income to beds, operating income to discharges, net income to beds, net income to discharges	Year	M
Courtemanche & Plotzke (2008)	Empirical longitudinal analysis utilizing data from Medicare and Medicaid Services provider of services files and the AHA annual survey from 1999 to 2004 on hospital, market, and country level. The distance between every pair of healthcare facilities in the same sample was calculated using the "great circle" distance formula.	Hospital outpatient surgical volume	Hospital size, private/public/teaching status, location, number of operating rooms, full time physicians and dentists, overall hospital competition, number of hospitals, number of ASC, population 65+, total population, insurance status, unemployment rate, median income, poverty	H
Hollingsworth, Krein, Birkmeyer, Ye, Kim, Zhang & Hollenbeck (2012b)	Data analysis from the Florida data of the Healthcare Cost and Utilization Project SASD. All discharges for urinary stone disease between 1998 and 2006. Hospital service area level rate of stone surgery, directly standardized to the 2000 United States population by age and gender.	Stone surgery use (relative value unit and annual hospital service area level rate of stone surgery/population in hospital service area)	Age, gender, race, primary payer, socioeconomic status, comorbidity status, and multiple ASCs in hospital service area.	H

Hollingsworth, Ye, Strope, Krein, Hollenbeck & Hollenbeck (2009)	Cross-sectional study on the physician level. Healthcare cost and the utilization project's state ambulatory surgery databases of Florida (1998–2002). Patients undergoing outpatient surgery for urinary stone disease were included. Urologists were considered owners when they performed 30% or more of the ambulatory surgery cases in a year at a given ASC. Patient comorbidity status was determined by a constructed indicator variable identifying those cases for which there were 0–5 comorbid conditions on the discharge record.	Procedural volume of urologist (in ASC and total)	Patient age, gender, race, primary payer, socioeconomic status, level of comorbidity, year	M
Lu, Hagen, Vaughan-Sarrazin & Cram (2009)	Longitudinal analysis of Medicare provider analysis and review files to identify hospitals performing primary or revision total hip arthroplasty or total knee arthroplasty during the years 1991 to 2005. Hospitals were assigned to unique hospital referral regions using hospital zip-code-based algorithms available from the Dartmouth Atlas of health care. Data were analysed on the organizational level Patient case complexity was taken into account by adverse surgical outcomes.	Surgical volume, patient case complexity	Patient demographics, comorbid illnesses, high-risk orthopaedic conditions, and individual hospitals	M
Meyerhoefer, Colby & McFetridge (2012)	Longitudinal data from 4 years (2004–2008) on the hospital level. Medicare data from Florida. Sources are data collected by the Florida agency for health care administration. Procedures included those most common in Florida (knee arthroscopy, hernia surgery, and colonoscopy and cataract surgery).	Patient illness severity, cost risk	Age, gender, ethnicity, payer type, procedure volume (physician and facility), market conditions (ASC market penetration), and patient demographics	H
Mitchell (2005)	Longitudinal data for 6 years (1998–2003) on the physician level. Data from Arizona inpatient discharge data. Sources are the Arizona department of health services and physician directory information from the Arizona medical board. The clinical field is cardiac hospitals. Physician-owners are defined as referring and treating patients at the facility. Sensitivity analyses were performed. Severity-of-illness and multiple comorbid conditions were included in the analyses.	Volumes of cases and severity of illness of case mix	Payer mix (DRG cases treated each year with different types of insurance coverage)	H

Plotzke & Courtemanche (2011)	Longitudinal data analysis utilizing the national survey of ambulatory surgery (outpatient surgeries performed on Medicare patients) with information from the centers for Medicare and Medicaid services from 1994 through 1996 and also 2006. Data were analysed on the physician and procedure level. Data were corrected for gender, age, health status (measured by number of diagnoses), procedure complexity (measured by general anaesthesia (dummy) and multiple procedures), insurance status, and surgery type.	Procedure profitability	Gender, age, health status (measured by number of diagnoses), procedure complexity (measured by general anaesthesia (dummy) and multiple procedures), insurance status, surgery type	H
Schneider, Ohsfeldt, Morrisey, Li, Miller & Zelner (2007)	Longitudinal study from 1997 to 2004 on the hospital level. Hospital financial data from Medicare's healthcare cost reporting system for all US acute-care hospitals. Specialty hospitals were identified using a combination of membership data from the American surgical hospital association and their affiliates, MedCath and a list of hospitals identified by Cram et al (2005). Second, hospitals performing a disproportionate share of services within a particular set of DRGs combined with crosschecking via websites, telephone directories, and telephone calls to differentiate between specialty hospitals and general surgery specialty hospitals in 2004.	Hospital patient care revenue, patient care cost, patient care operating margins	Hospital size, mean length of stay, teaching status, mean cost/case, ownership status, discharges, % Medicare and Medicaid, case mix, staffing level (general, RNs, MDs), occupancy rate, outpatient visits, wage nurses, per capita income, population density, unemployment rate, number of specialty hospitals (new and established), number of physicians	H
Strope, Diagnault, Hollingsworth, Ye, Wei & Hollenbeck (2009)	From 1998 through 2002, ambulatory surgical discharges for procedures within the genitourinary system were abstracted from the Florida State ambulatory surgery data. Statewide utilization rates for ambulatory surgery were calculated by physician-level ownership and financial incentives. 87 procedures of the genitourinary system. The rates were standardized to the US census bureau's population estimates for the state of Florida, and were stratified by setting, ownership status, and incentive status.	Rates of ambulatory surgery	Ownership status, financial incentives, and location of practice	M

4. DISCUSSION

This paper provides an overview of the empirical literature on physician-owned specialized facilities. Our aim was to synthesize the available, though fragmentary, evidence. We structured the results according to seven substantive domains. As is typical of health services research, the reported effects are nuanced. However, the published results show some important findings.

4.1 Performance of specialized facilities

First of all, several studies show improved patient safety in specialized facilities. However, this effect may largely be explained by advantageous patient characteristics (Barro et al., 2006; Chukmaitov et al., 2008; Cram et al., 2005; Cram et al., 2007; Cram et al., 2010; Hollingsworth et al., 2012a, Meyerhoefer et al., 2012, Mitchell, 2005, Winter, 2003) and the larger procedural volume (Barker et al., 2011; Chukmaitov et al; 2011; Lynk and Longley, 2002). In case of the latter, it can be argued that the focused scope of specialized hospitals enables them to increase the volumes cases they treat, thereby improving their safety of care. Furthermore, it is important to note that, when lower severity cases are considered, a small difference in favour of specialized facilities was demonstrated (as in Cram et al., 2010; Hollingsworth et al., 2012a). In contrast, evidence suggests that specialized facilities might not do as well as full service-general hospitals with very sick patients (Greenwald et al., 2006). This could be explained by the availability of the multidisciplinary highly specialized care needed to treat very severe cases, which is only available in full-service general hospitals.

Second, we did not find any empirical evidence for a positive effect on care effectiveness. In contrast, the results of several studies suggest that physician ownership of SHs lowers the threshold for performing procedures and therefore concerns about the possible supplier-induced demand and self-referral have been put forward (Gable et al., 2008; Greenwald et al., 2006; Mitchell, 2008).

Third, evidence exists that specialized facilities have a negative effect on equity of care. Physicians can maximize profits by treating the well-insured population, provide less uncompensated care, and refer financially unattractive patients to full service general hospitals (‘cream skimming’). This finding is not surprising given the financial incentives associated with the ownership status described above.

Fourth, no convincing evidence was found showing that specialized facilities realize economies of scope. Our systematic review could not detect a fundamental cost advantage in favour of ASCs or SHs.

Finally, we did not identify a single study that focused on the criteria of patient-centeredness and accessibility. In case of the former, this is remarkable in view of the increasing role of experiences of patients in research and policy (such as reimbursement) (Manary et al., 2013). In the case of accessibility, it could be argued that specialized hospitals target unmet demand, thereby increasing the accessibility of care (Trybou et al., 2011). This argument is not supported by empirical evidence.

4.2 Impact on full-service general hospitals

Overall, considering the findings of our systematic review, we note that previous research did not detect any fundamental cost or quality advantage in favour of ASCs and SHs. In addition, besides any potential advantage in cost or quality, the impact on full-service general hospitals must also be evaluated. Specialized facilities do not cover the whole scale of services, and the question arises of whether full-service general hospitals can still deliver high quality care in an efficient way when high volumes of certain procedures are shifted to specialized facilities (Hollingsworth et al., 2012a; Lu et al., 2009). One aspect of the issue is that low-volume hospitals (below a certain threshold) could have inadequate experience with the procedures involved, leading to suboptimal clinical outcomes (Elixhauser et al., 2003). Similarly, when the basic, standardized medical workload shrinks or even disappears, general hospitals' ability to treat more complex cases may also decrease. However, it should be noted that the procedural volume of hospitals does not necessarily reflect the number of procedures performed by any one physician. If physicians practicing at specialized facilities also treat the more complex cases at general hospitals, this issue may be tackled. It should be noted that hospital-physician relationships are strained (Trybou et al., 2011), and therefore this approach could be difficult to realize in practice. Furthermore, the rise of specialized facilities could have a significant negative financial impact on full-service general hospitals (Carey et al., 2009a, Carey et al., 2009b; Cimasi et al., 2008). General hospitals also internally cross-subsidize highly necessary but unprofitable services (such as emergency care) with more profitable activities. This also enables them to provide care to the poor and underinsured. When profitable services are no longer performed at full-service general hospitals, they will not be able to cover the cost of these more onerous cases.

5. LIMITATIONS AND CHALLENGES

Our systematic review shows that the results of previous empirical studies are mixed and inconclusive. This finding supports the argument that determining and comparing hospital performance is highly complex, and that adequate measures of costs and quality are frequently not available (Porter and Teisberg, 2006). In addition, when considering quality and the cost of the care provided, it is important to note that specialized facilities focus predominantly on elective procedures and have been found to treat more patients in better health (Hollingsworth et al., 2012a), with fewer comorbid illness (Hollingsworth et al., 2012b), and characterized by a lower severity of illness (Yee, 2011). This makes a valid and reliable comparison of quality of provided care and clinical outcomes difficult. These issues accentuate the need of a randomized study design focusing on homogeneous groups of patients (i.e., by studying a specific subsample of low-acuity cases in general hospitals) while controlling for comorbidity and severity of illness. A case-control study in a randomized sample of hospitals could tackle these issues.

Furthermore, the evidence base suggests that hospital performance depends on factors other than whether or not the hospital is focused or specialized or physician-owned or not (Carey, 2008). Consistent with this view, longitudinal studies of this aspect constitute an important avenue for future research. We further note that a significant number of studies were performed by the same research groups. Connections between these studies may be present and are not accounted for in the systematic review. Finally, research on this topic continues to be concentrated in the US. This is surprising, given the relevance of this trend to current health care delivery in European countries. The results of these systematic review should therefore be interpreted carefully since the regulatory and payment framework between countries differs. The lack of European studies on physician-owned specialized hospitals represents a research priority.

6. IMPLICATIONS FOR RESEARCH AND POLICY

Notwithstanding these limitations, our findings have several implications. First, some studies have demonstrated improved performance of physician-owned specialized facilities as compared with full-service general hospitals. However, on this point the evidence base is too thin and insufficient to recommend a widespread policy of encouragement. Second, it is not clear to what extent these specialized facilities have an impact on the performance of full-service general hospitals, especially since the volume of targeted procedures performed at physician-owned specialized facilities has not led to a significant decline in the patient volume of full-service general hospitals. Therefore, the impact so far on the performance of full-service general hospitals has remained limited. Yet if the volume of certain procedures were to shift significantly towards physician-owned specialized facilities, there could be negative effects on both the quality of the delivered care and the financial health of the full-service general hospitals. Therefore, the development of physician-owned specialized facilities should be monitored carefully. More research is needed to clarify the added value of these facilities and to support evidence-based policymaking on this matter.

In light of these findings, it is also important to consider the different possibilities of policy response to physician-owned specialized hospitals. In addition, it is important to consider the contextual information and potential differences with respect to the payment and regulatory framework between the US and European countries. Notably, the backstory of the rise of physician-owned specialized facilities includes an important financial dimension. More precisely, US physicians have faced significant cuts in their professional fees that were primarily based on a fee-for-service scheme. In response to these cuts physicians felt that by owing specialized hospitals they could compensate this lower income by the revenue originating from the facility fees associated with their professional activity. Subsequently an appropriate compensation level could prevent physicians from migrating to undesired ambulatory entities. Furthermore, rules and regulations for licensure of hospitals could be a powerful policy instrument. More precisely, this could prevent physicians to founding small (i.e. approximately 20 beds) licensed specialty hospitals that focus on certain inpatient procedures and would limit physician-ownership to facilities that focus on the ambulatory setting. In addition the regulatory framework could specify what types of procedures can only be performed in a licensed hospital.

7. CONCLUSION

In this study, we reviewed the available evidence on physician-owned specialized facilities (specialized hospitals and ambulatory surgery centres). We examined the quality and cost of care at these facilities and their impact on the performance of full-service general hospitals. Our results show that little evidence exists in favour of physician-owned specialized facilities and that their impact to date on the performance of full-service general hospitals remains unclear. Therefore, the development of physician-owned specialized facilities should be monitored carefully.

Supplement 1 Evaluative framework with examples of outcomes and measurements

Theme	Definition	Examples of outcomes	Examples of measurements
Safe	Delivering health care which minimizes risks and harm to service users	Mortality rate Postoperative complications Unexpected complications	Likelihood of postoperative complications, likelihood of same day readmission (Hollingsworth et al., 2012). In-hospital mortality for coronary artery bypass grafting (Cram et al., 2009).
Effective	Delivering health care that adheres to an evidence base and results in improved health outcomes for individuals and communities, based on need	Adherence to guidelines Evidence Based Medicine	Administration of ß-blockers on arrival and discharge for acute myocardial infarct (Popescu et al., 2008). Percutaneous coronary intervention indications for treated patients: documented angina, atypical chest pain, or a positive stress test (Cram et al., 2012).
Patient-centred	Delivering health care which takes into account the preferences and aspirations of individual service users and the cultures of their communities	Patient satisfaction Quick return of patients to their homes	Patient satisfaction
Accessible	Delivering health care that is timely, geographically reasonable, and provided in a setting where the skills and resources are appropriate to medical need	Waiting times Expected number of weeks' waiting time	Time from diagnosis to procedure
Equitable	Delivering health care which does not vary in quality because of personal characteristics, such as gender, race, ethnicity, geographical location, or socioeconomic status	Race, gender, uncompensated and charity care	Number of black patients admitted for coronary revascularization (Brahmajee et al., 2008). Uncompensated and charity cardiac care performed (Carey et al., 2009)

Theme	Definition	Examples of outcomes	Examples of measurements
Efficient	Delivering health care in a manner which maximizes resource use and avoids waste	Cost of care delivery	Perioperative times (Hair et al., 2012).
Impact	Effects of SHs on the performance of full-service general hospitals	General hospital financial health	General hospitals’ offerings of services and growth in high-technology diagnostic imaging services in general (Carey, Burgess & Young, 2009c). General hospital profitability (Plotzke & Courtemanche, 2011)

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CHAPTER 3

Aligning Service Processes to the Nature of Care in Hospitals: An Exploratory Study of the Impact of Variation

Aligning Service Processes to the Nature of Care in Hospitals: An Exploratory Study of the Impact of Variation

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ABSTRACT

Operations management (OM) approaches typically aim to reduce the variation in processes by removing clearly identifiable causes of variation -the so-called special causes of variation - leading to improved efficiency and quality. In healthcare, OM must deal not only with special-cause variation, but also with the type of variation that cannot be eliminated: inherent or common-cause variation. Using an exploratory database analysis of four hospitals, this article investigates whether hospital care processes can be assigned to different groups defined by their kind and size of variation, resulting in better alignment of type of care and organization of care. A detailed analysis of the length-of-stay of All Patient Refined Diagnosis Related Groups suggests groups with high and low within-group variation, which might indicate that there are groups of patients with inherently different degrees of variation in length-of-stay due to illness and treatment patterns. As is well-known, hospital care can be divided into sequential and iterative processes. Some patients groups may be classified as high-variation in one hospital but as low-variation in another, which clearly shows that deliberate choices in the design of the operations system of hospitals must be taken into account when analyzing the length-of-stay performance of hospitals. Furthermore, separating common-cause from special-cause variation will increase the likelihood of identifying the right type of process (sequential versus iterative) and business model for the right type of patients.

Key words: All Patient Refined Diagnosis Related Groups (APR-DRG); health care services; common cause variation; length of stay (LOS); operating; special cause variation

1. INTRODUCTION

Healthcare organizations face challenging times. Because of rapidly rising health care expenditure (OECD, 2013) and concerns about the quality of care (WHO, 2006), hospitals find themselves at the locus of the reform debate (Kaplan and Haas, 2014). Against this background, hospital management is charged with designing an organization in which high-quality care and cost-effectiveness are combined while preserving the greatest potential of modern medicine. This challenge has led to a growing number of studies on means to improve care processes by transferring and adopting operations management (OM) theories, concepts, and approaches, such as lean management (Jimmerson et al., 2005; Kim et al. 2006), focused factories (Casalino et al., 2003), and product line-management (Charns and Tewksbury 1991; Fetter and Freeman, 1986). The application and evaluation of manufacturing approaches in health care is of great value. McBride and Mustchin (2013) support this vision with their claim that improvement in the clinical setting is the domain of operational managers and clinical staff. Clinicians are more than willing to search for process improvements that reduce costs while maintaining or improving the overall quality of care, as their main goal is better patient care (Kaplan and Haas, 2014).

There are two important reasons why the anticipated effects of OM in hospitals are seldom fully exploited. The first is related to the reduction of variation. OM approaches try to reduce variation in processes by removing clearly identifiable causes of variation -the so-called special causes of variation. Besides the special causes of variation, OM in healthcare is confronted with a type of variation that cannot be eliminated - inherent or common-cause variation; that must be managed in the best way possible (McLaughlin and Kalunzy, 2000). The level of common-cause variation is determined, for example, by the nature of the illness and may range from low (e.g., urinary tract infection) to high (e.g., complex cancer). Second, care processes are not always designed in line with the nature of the illness, and so the potential for improvement of OM approaches is limited (Bohmer, 2005; Bohmer, 2009; Christensen et al., 2009). This means that health care needs a more radical and fundamental rethinking of the design and management of its processes in line with the nature of the service provided (Bohmer, 2009; Lillrank and Liukko, 2004). In other words, hospitals should look for an appropriate business model (Christensen et al., 2009) with which to improve the value delivered to patients (Kaplan and Porter, 2011).

This study is in line with previous research in the field of OM that explains how, in the manufacturing and service sectors, the design of the process should be in line with the nature of the product or service (Hayes and Wheelwright, 1979; Schmenner, 1986; Schmenner, 2004). Although the importance of achieving a strategic fit is implicit in almost every OM study, the literature has paid limited attention to aligning the nature of care processes and the design of the operating system. Our objective in this study is to fill this gap by investigating the concept of variation in care processes and by examining how this variation determines operating design.

In what follows, we review the relevant literature in order to develop our propositions. We then present our analysis of the data and the study design. This is followed by a description of the findings of our study. We conclude with a discussion of our findings.

2. THEORETICAL FRAMEWORK

2.1 Process choice

The idea that firms should align 'the nature of their product' with 'the nature of the process' was visually introduced by Hayes and Wheelwright in 1979 in the form of the product–process matrix for manufacturing companies. This matrix consists of two dimensions: the product structure and life cycle and the process structure and life cycle. The process structure and life cycle describe four process categories: a jumbled flow (job shop), a disconnected line flow (batch), a connected line flow (assembly line), and a continuous flow. The product structure and life cycle describe the stages of the product life cycle (low to high volume production) and of the product structure (low to high standardization). By taking into account the product–process matrix and aligning these characteristics (the nature of the products, the organizing processes in terms of volume, and the level of customization needed) in their operations, organizations can make their operating units more focused and thus operate them more effectively and efficiently. The core principle of this model posits that manufacturers need to make a choice between, on one hand, low-volume, flexible, high-quality, customized production (job shop, batch) and, on the other hand, high-volume, standardized, low cost production (assembly line, continuous flow). Interestingly, the theoretical principles of the product–process matrix have been supported by empirical findings emphasizing the virtues of aligning manufacturing operations with business strategy (Richardson, 1985; Marucheck et al., 1990). Specifically, Safizadeh and colleagues (1996) who investigated the correlation between process choice, product customization, and competitive priorities in manufacturing plants, found that process choice is highly correlated with the degree of product customization. For example, job shops and batch shops, with their low volume and unique products, tend to have greater customization of their products, higher costs, and higher quality; continuous flow shops (high volume, commodity product), on the other hand, use commonality and flexible automation. What is more, they uncovered evidence that manufacturing performance suffers from mismatches between product plans and process choices. Although the product–process matrix model has been criticized, with opinions being heard that some of the typologies need revision in light of new technologies that increase flexibility, integration, speed, and information (Kim and Lee, 1993), the basic idea that manufacturers can benefit from aligning their products and processes and by considering the amount of customization and the volume to be produced still holds.

The practice of aligning products and processes has also been acknowledged in the service management literature. In contrast to tangible products, a service is not a distinct output of a separate production, distribution, or consumption process. A genuine service is rather a multilateral and open-ended process -unlike production, which is a closed process with unilateral control (Tinnila and Vepsalainen, 1995). For this reason, Schmenner (1986, 2004) developed a service–process matrix adjusted to the service sector, which has a focus on processing customers and grouping services with similar characteristics. The service–process matrix groups services by two major dimensions: First, the degree of interaction with, and customization for, the consumer, here translated into the degree of variation, on the X-axis; this is a continuum with a low degree of variation on one end and a high degree of variation on the other. Second, the throughput time on the Y-axis is a continuum ranging from low to high throughput time. This results in a two-by-two matrix with four quadrants of service processes: the 'service factory' (with low throughput time and little or no variation), the 'service shop' (with low throughput time but high degree of variation), the 'mass service' (with high throughput time but low degree of variation), and the 'professional service' (with high throughput time and high degree of variation). The service–process matrix illustrates, in the first place, the importance of the degree of variation in aligning the nature of the service and the nature of the process. Secondly, it illustrates that the nature of services can vary greatly, depending on their position in the matrix.

These findings indicate the need for different operating designs in both manufacturing and service processes. It is worth noting that this has not yet been incorporated into health care.

2.2 Strategic fit and business models

The concept of strategic fit deals with the alignment of products and processes in firms. The positive impact of strategic fit has been frequently described in the academic and professional literature (Porter, 1996). Hill and Brown (2007) define the internal level of strategic fit as the degree of linkage or consistency between its competitive priorities, operations strategy, and delivery system. Likewise, Peters and Waterman (1982) argue that congruence among strategy, structure, systems, style, staff, shared values, and skills is a prerequisite for organizational success. In addition, Thompson et al. (2010) emphasize the importance of building organizational capabilities and of structuring work efforts so as to perform strategy-critical activities in a coordinated and highly competent manner.

Hill and Brown (2007) accentuate the need for internal strategic fit in service organizations. They observe that the alignment of operational strategy and the service delivery system is positively related to market shares and the return on sales. Gebauer et al. (2010) explored the specific strategy-structure configuration needed to succeed with a chosen strategy service. They concluded that each service strategy is supported by organizational design factors related to the service orientation of the corporate culture, the human resource management, and the organizational structure. To conclude, these studies demonstrate the need for a strategic fit and claim that aligned organizations will be operating at peak performance.

The concepts used to describe strategic fit are quite similar to those that describe business models. Most often, four interlocking concepts are used in creating a business model: the customer value proposition, the profit formula, the key resources, and the key processes (Johnson et al., 2008; Zott et al., 2011). In general, business models describe how the pieces of a business fit together, answering the questions: Who is the customer? What does the customer value? How do you deliver value at an appropriate cost (Johnson et al., 2008)? This is an important tool that can be used to augment product and service innovations, to link strategy, and to coordinate activities within an organization. Different values for the customer require different operating systems, resulting into different business models (Christensen et al. 2009). In terms of the design of the operating system, this means that we should identify the core drivers that translate the values of customers into processes.

We note, theoretically, the importance of differentiating processes when designing operations. The key factors that influence these processes are discussed in the following paragraphs.

2.3 Factors influencing process design

2.3.1 Predictability, uncertainty, homogeneity, variety, complexity and divergence

Safizadeh et al. (1996) illustrated that the following demand characteristics are the main drivers of process choices: level of predictability, level of uncertainty, degree of homogeneity, and level of variety. This is consistent with Schafermeyer et al. (2012), who tested the impact of business process complexity on business process standardization. They defined complexity in terms of low levels of analyzability, high levels of variety (with variety being a quality similar to diversity, referring to differing types of entities) and high levels of non-routine procedures, difficulty, uncertainty, and interdependence in the business complex. They concluded that business process complexity is a major factor that should be considered when deciding on processes to be standardized. The data showed a negative and significant relationship between business process complexity and business process standardization, leading to a recommendation to separate standard processes from complex processes by using process-inherent characteristics. Likewise, Lillrank (2004) decomposed different elements in the process, such as standards, routine procedures, and non-routine procedures. The author differentiates between repetitive processes that can be standardized and non-routine or chaotic processes. Looking at service processes, Shostack (1987) suggested that service production should be considered from the angle of process design, and that two vital attributes of service processes are complexity and divergence. Complexity relates to the number of steps, their sequence, and the interrelationships between them. Divergence is the exceptional latitude or variability of those steps and sequences, with service processes typically being a combination of both.

2.3.2 Process Variation

Two kinds of process variation have been conceptualized: common-cause variation and special-cause variation. Common ‘inherent’ cause variation is a natural pattern in the process, and is created by many factors that are commonly inherent to the process, acting at random and independently of each other (e.g., the severity of an illness), which we must try to manage. Special-cause variation is an unnatural pattern created by a nonrandom event leading to an unexpected change in the process output (such as resource availability), which we must avoid. The effects are intermittent and unpredictable, and mostly require immediate action. These two types of variation are completely different, and need to be dealt with differently. Failure to identify the source of variation as special or common leads to inappropriate actions within the system, which may worsen the situation. Deming (1993) called this 'tampering with the system'—i.e., introducing additional variation through unnecessary adjustments in an attempt to compensate for common-cause variation.

2.4 Health care process design

The values of patients are so different that a 'one size-fits-all' business model is unable to capture this diversity. This needs to be reflected in the operating system by taking into account the same kind of drivers, such as complexity, uncertainty, and variability (Bohmer, 2009, Christensen et al., 2009).

According to Bohmer (2009), the inherent variation in healthcare is linked to the level of uncertainty about the illness, which is itself based on the volume and specificity of knowledge. This leads to a distinction between 'certain care' and 'uncertain care'. In certain care, problems can be diagnosed and treated in a structured, standardized way (precision medicine), supported by the use of medical evidence and clinical practice guidelines. In 'uncertain care', complex unstructured problems demand intense iterative testing before it is possible to make a diagnosis, to propose a treatment (intuitive medicine), or to customize care (Bohmer, 2009; Christensen, et al. 2009). Bohmer (2009) further claims that inherent variation is more limited in certain care than in uncertain care. Patients undergoing certain care can be treated in a process organized as a (production) line, consisting of steps executed in a certain sequence, based on evidence-based protocols. This leads to higher standardization in the process. For uncertain care, less knowledge (evidence) is available, leading to more inherent variation. Patients go through a process involving several feedback loops—that is, an iterative process. This already indicates that the process (sequential versus iterative) differs according to the nature of care (certain versus uncertain care).

Christensen et al. (2009) also take into account the nature of care, separating care into three business models for hospitals with divergent operating systems: 'solution shops', 'value-added process (VAP) business', and 'facilitated networks'. Solution shops are defined as "businesses that are structured to diagnose and solve unstructured problems". In this business model, value is delivered by diagnosing complex problems for which there are no standardized procedures. In some cases, the medical knowledge remains incomplete, and this leads to multiple means of treatment, giving a medical problem that requires a cyclical, rather than linear, process for its solution. The process is thus organized to deal with unique cases. This care process is characterized by iteration, rework, and repeated modification and involves large inherent variation. In contrast, “organizations with VAP process business models take in incomplete or broken things and then transform them into more complete outputs of higher value” (Christensen et al., 2009). In this case, the medical knowledge of the subject is more developed, and many conditions can be treated uniformly in a predictable manner. There is now a low level of inherent variation. Most surgical procedures can be considered as VAPs. In a VAP, a fixed set of activities is performed; through repeatability, uniformity, and standardization of procedures, costs are reduced and the quality of care is improved. The third model, that of the facilitated network business model, is applicable for “enterprises in which people exchange things with one another” (Christensen et al., 2009). For example, chronically ill patients are diagnosed and undergo treatment, but neither a solution shop nor a VAP can completely solve their problem or add value in managing them. In this case, a business model that operates as a network can meet the expectations of chronically ill patients by facilitating the exchange of information for people with different needs. These business models differ, as the nature of care in each model shows different levels of inherent variation, leading to greater or less standardization. Over time, hospitals treat patients from all three models, which results in complex, confusing institutions, where much of the cost is spent on overhead activities rather than on direct patient care (Bohmer 2009; Christensen et al. 2009; Porter and Teisberg 2006). To function properly, these business models must be separated (Christensen et al., 2009). To date, the majority of hospitals still use a one-size-fits-all approach to treat patients with different needs. This approach, referred to by Porter and Teisberg (2006) as the full-service model, cannot meet the variety of needs of patients in a cost-effective way. Figure 12 illustrates the relationship between process characteristics, process design and choice of business model.

Our paper intends to contribute to the existing literature by explicitly focusing on the fundamental differences in the nature of illness and cure and care, which results in a different design for the operating system. Given the exploratory character of this study, we present propositions rather than hypotheses. Thus, according to the previously discussed framework, we formulate our first two propositions.

Proposition 1: Care processes can be divided into processes with low variation and processes with high variation.

Proposition 2: Care processes with lower uncertainty and higher possibility of standardization show lower variation than care processes with high uncertainty and lower possibility of standardization.

Many examples of anecdotal reports on particular aspects of health care process variations can be found in the literature (Appleby et al., 2011; Corallo et al., 2013). These studies have mainly focused on describing small-area (geographic) variation and on reducing such unwarranted variation (such as differences that cannot be explained by illness, medical need, or the dictates of evidence-based medicine between regions) (Ashton, 1999; Berwick, 1991; Corrigan, 2011; Leape, 1990; Weinstein, 2004; Wennberg, 1973; Wennberg, 1999). More precisely, these studies have shown that demographic differences such as age and gender are strong predictors of health care needs, with age being the strongest single predictor (for example, a greater number of women and older people would be expected to have higher rates of hip and knee replacements, having an impact on utilization rates between areas) (Appleby et al., 2011). Apart from the demographic structure, social-economic characteristics can also serve as a major marker of small-area variation (Appleby et al., 2011). A Dartmouth Atlas study that employed several individual-level health indicators concluded that health alone accounted for 18 percent of geographic spending variation (Sutherland et al. 2009). Another recent study found that health status explained 29 percent of geographic variation in Medicare spending (Zuckerman et al., 2010), demonstrating the importance of the severity and comorbidity status. Identifying the causes reveals complexity with many interactions and suggests that a particularly important factor in health care variation arises from variations in the practice of medicine (Appleby et al., 2011). Additionally, Kaplan and Haas (2014) mention that high variation can occur even in the case of outstanding institutions and clinicians. Figure 13 provides an overview of factors influencing variation in the health care process.

The impact of variation in the health care process on internal levels of organizational is less frequently discussed in health care, being mainly focused on operations management issues, especially as a function of lean or six sigma projects (Radnor et al., 2012, Taner et al., 2007). Analogously with the small-area geographic variation studies, we formulate a third proposition.

Proposition 3: There are clear differences in process performance between hospitals.

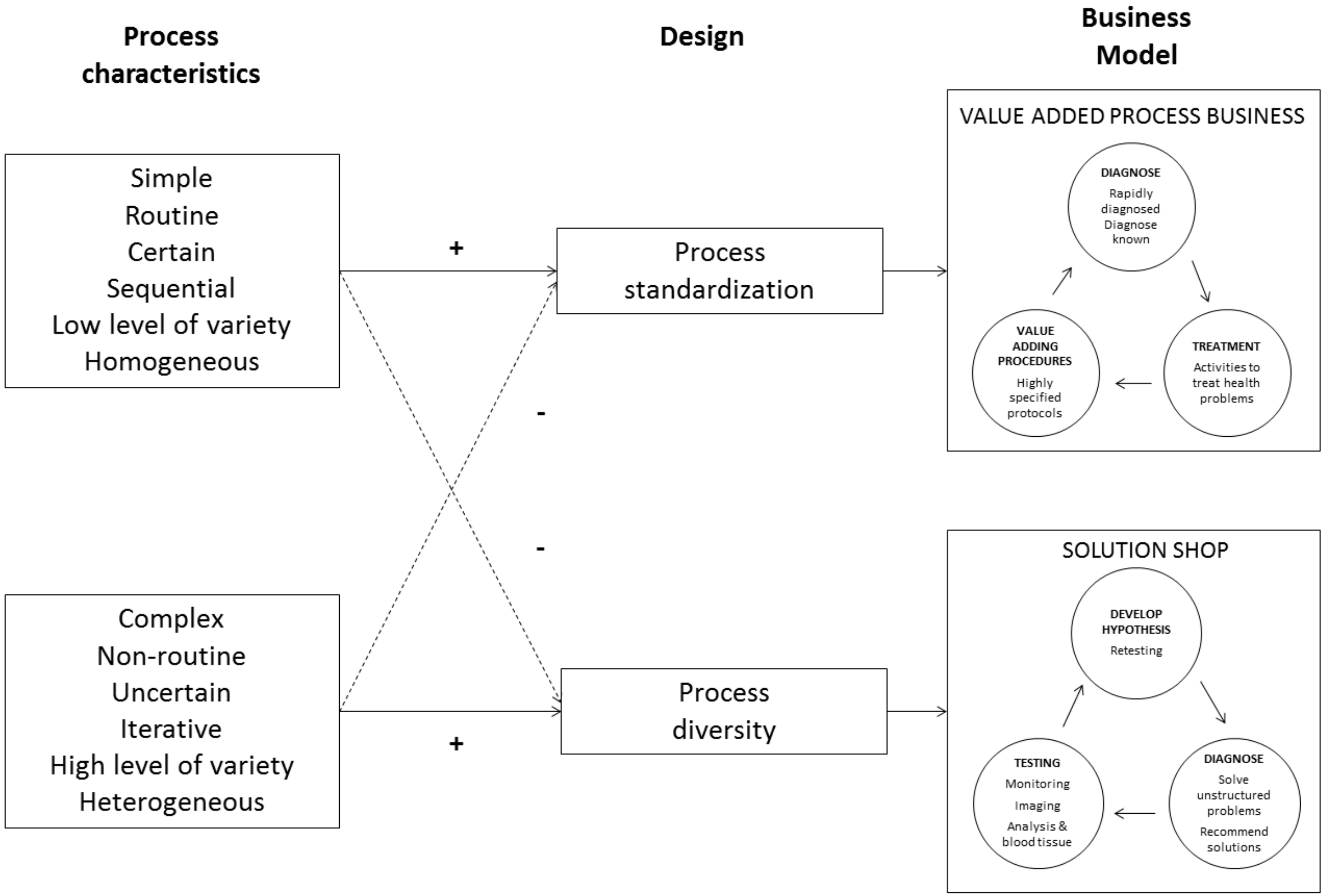

Figure 12 Conceptual framework of the relationship between process characteristics, process design, and choice of business model in health care

3. METHODOLOGY

3.1 Data sources

We conducted a retrospective cross-sectional study with data collected from a convenience sample of four hospitals in Belgium: one university hospital (A), one large private general hospital (B), and two smaller private general hospitals (C and D) (Table 5). The study was approved by the institutional review board (OG 017) of Ghent University Hospital and by the local institutional review boards of all the participating hospitals. The hospitals participated voluntarily. The research was in compliance with the Helsinki Declaration. The APR-DRG databases (all variables as defined by 3M^{TM} All Patient Refined Diagnosis Related Groups (3MHIS, 2003)) of the four hospitals, with all episodes of discharged patients for 2008 and 2009, were included.

3.2 Defining variation

Process variation was quantified using the dispersion of the length of stay (LOS) of patients within groups, considering the differences in the case-mix, as measured by the APR-DRG. LOS is a major indicator of hospital performance and a basic measurement of patients' resource consumption; it is, therefore, much referred to in variation studies (Knaus et al., 1993; Thomas et al., 1997).

The variation of hospitalized patients can be captured through case-mix classification systems such as APR-DRG (Berki et al., 1984; Fetter, 1999). APR-DRG allows the comparison of variation in a standardized way, as patients are classified into clinically homogeneous groups with similar resource intensity (3M HIS, 2003). The international APR-DRG classification , version 15, includes 355 APR-DRG groups and 25 major diagnostic categories. The APR-DRG grouping can be further refined by the severity of illness and risk of mortality. This improves the accuracy by capturing differences in the severity of illnesses among patients. We looked at the within-group variation in inpatient LOS, having grouped them into the APR-DRG case-mix classification system.

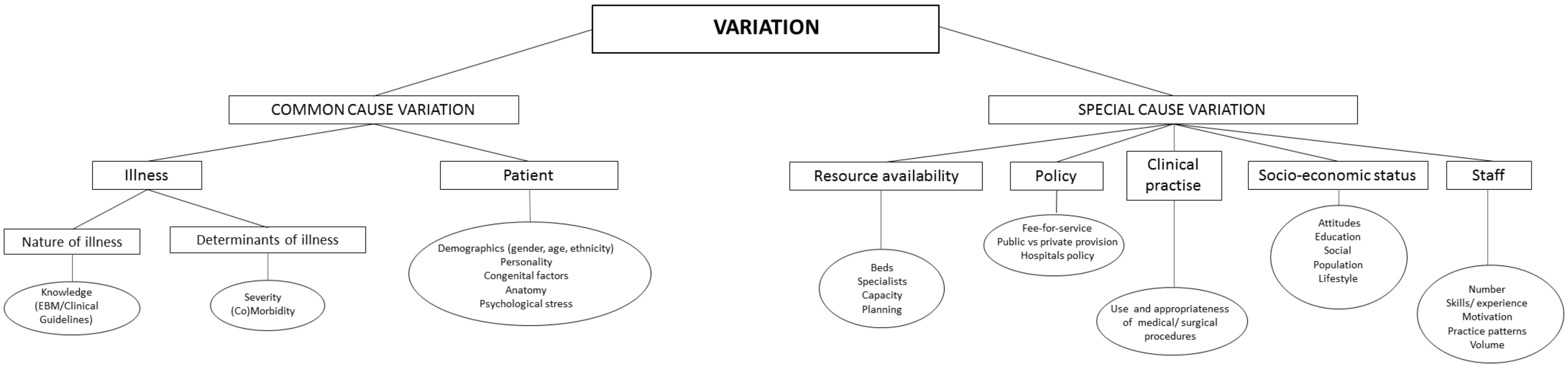

Figure 13 A map of different inducers of variation showing the complexity of possible causes in health care

Table 5 Demographics of hospitals. Values reported as means (SD)

Hospital	Type of hospital*		Size	Hospital beds (N)	Outpatient beds (N)	Employees (physicians) (N)	Mean age patients for data global analysis (years)	Mean LOS for data global analysis (days)	Mean age patients for data severity of illness 1 and mortality risk 1 (years)	Mean LOS for data severity of illness 1 and mortality risk 1 (days)
A	Tertairy, University	Public	Large	1064	156	6000 (380+ 280 in training)	47.0 (24.02)	5.3 (6.47)	42.0 (22.80)	3.3 (3.24)
B	Regional	Private	Large	822	90	2300 (200)	52.5 (24.62)	5.8 (7.21)	44.3 (23.25)	3.5 (3.33)
C	Regional	Private	Small	224	46	660 (60)	53.9 (26.03)	4.0 (5.49)	47.1 (25.30)	2.2 (2.30)
D	Regional	Private	Small	197	22	520 (50)	51.7 (27.60)	6.1 (7.20)	43.1 (24.37)	(3.34)

*All hospitals are non-profit organization but ownership differs
N= number; LOS= length of stay

Only one APR-DRG—the reason for hospitalization—is assigned per stay. Initially, all episodes of discharged patients for 2008 and 2009 were selected for all four hospitals, resulting in a total of 157,108 episodes. The APR-DRG data were linked to demographic data (gender, age), administrative data (dates of admission and discharge), and APR-DRG specific data (procedural or medical, severity of illness, and risk of mortality). The severity of illness (defined as the extent of physiological decomposition or organ-system loss of function) and the risk of mortality (likelihood of dying) are divided into subclasses 1 to 4, indicating respectively minor, moderate, major, and extreme. APR-DRG version 15 was used. Outpatients, episodes with incorrect APR-DRG coding, psychiatric episodes, and burns were excluded (Figure 14). Psychiatric episodes were excluded because of the existence of specialized psychiatric clinics in Belgium, therefore including these APR-DRG groups in general hospitals could bias the results. The APR-DRG groups including burns were excluded because of the presence of one specialized burn center in hospital A. The financing of a burn unit is not based on the APR-DRG resource allocation method in Belgium and therefore comparison between all hospitals was not possible.

3.3 Classifying data

The distribution of LOS is skewed by the unlimited maximum and limited minimum. Standard analyses deal with such problems by first excluding outliers and log-transforming the data (Kulinskaya et al., 2005). After the outliers have been excluded, the natural log of the LOS was used to meet the assumption of normality. Extreme outliers were excluded (these are observations with LOS greater than P75+3*(P75-P25) or, where P75 equals P25, greater than (2*P75) +3*((2*P75)-P25; P: percentile) (Fontaine, 2004).

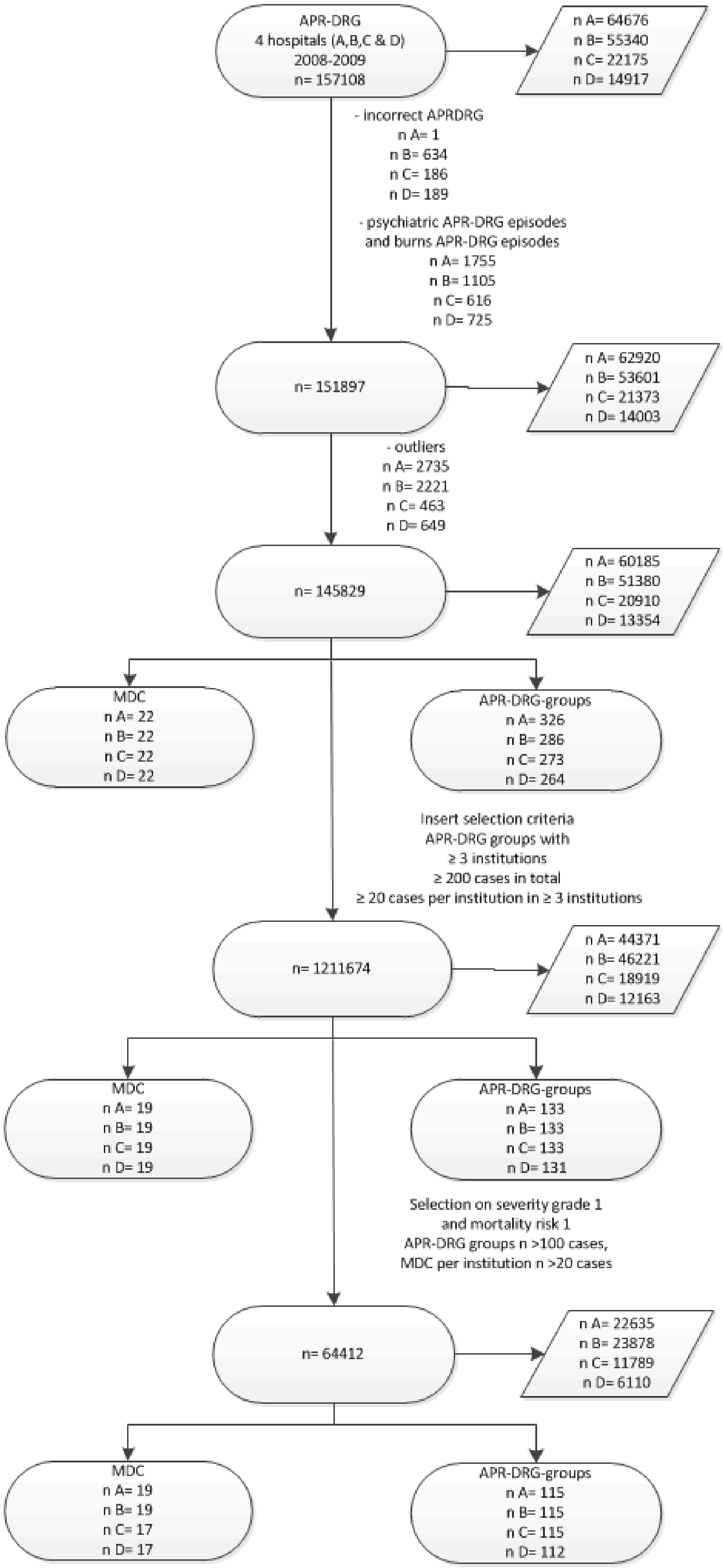

Figure 14: Overall flow chart of included patients

The APR-DRG within-group variation was captured by plotting the LOS into four classification groups: very low variation, low variation, high variation, and very high variation. This method of plotting standardized rates is considered useful for comparing the “variation profiles” of different procedures (Birkmeyer et al., 1998). The classification was accomplished by dispersing the patients’ LOS around the mean within each APR-DRG group: the greater the dispersion, the higher the variation classification (Figure 15). Analogously to the variation studies in the Dartmouth Atlas (http://www.dartmouthatlas.org/), the following method was used:

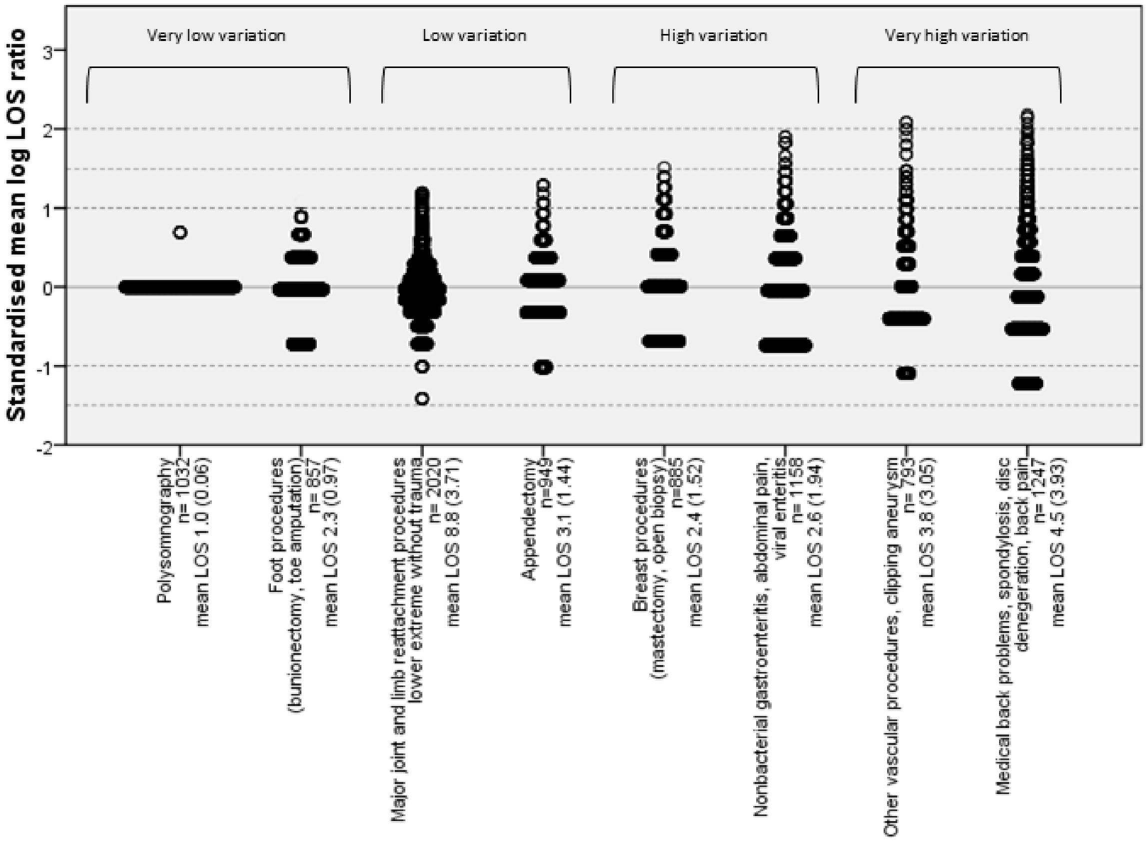

Figure 15 Example of the system classifying APR-DRG groups (severity of illness 1 and mortality risk 1) into very low variation, low variation, high variation, and very high variation

Step 1: The variation of APR-DRG groups was captured using the logLOS expressed as a ratio with the mean of the APR-DRG group (divide the logLOS of each subject by the logLOS mean of the APR-DRG group to which the subject belongs)

Step 2: Mean standardization for logLOS data to zero per APR-DRG group (logLOS of each subject minus the logLOS mean of the APR-DRG group to which the subject belongs)

Step 3: The data were plotted on a logLOS scale; see Figure 15 (APR-DRG groups were classified into very low variation between -1 and 1, low variation between -1.5 and 1.5, high variation between -2 and 2, and very high variation larger than -2 or 2 on the log scale). This choice follows the methodology used in the studies from the Dartmouth Atlas group that documented small area variations in health care delivery in the United States.

3.4 Statistical analysis

Multivariate analysis (MANOVA) was applied to analyze the quantitative variables. The chi-square (χ^2) test was used to compare categorical variables between groups. Cramér's V was used as a measurement of association, with 1 indicating full, 0.75 strong, 0.5 moderate, 0.25 minor, and 0.0 no cohesion (Field, 2009). Hierarchical linear regression analysis resulted in predictors for variance in the logLOS.

The overall flowchart is depicted in Figure 14. The data analysis consisted of three phases: first, we conducted a general analysis, not considering the severity of illness, the mortality risk, or the hospital. A second analysis was performed for cases with severity of illness 1 and mortality risk 1; finally, a comparative analysis was performed between the hospitals. As the within-group mean logLOS differed for each phase, we made no comparisons between the general analysis and the others. Independent variables were selected on the basis of previous studies' findings (Figure 13).

For comparison of patient volume on the general level of APR-DRG groups, the number of patients was set at 500 patients/APR-DRG group (i.e., minimum volume of 500 patients per group over all hospitals); for comparison at the hospital level, the volume was set at 300 patients/APR-DRG group (i.e., minimum volume of 300 patients per group per hospital);. P-values are reported as two-tailed with a significance level (α) of 0.05. SPSS 19.0 (IBM, Chicago, IL) was used.

4. RESULTS

4.1 General Analysis

The general analysis showed that 24% (32/133) of the APR-DRG groups had very low (2/133) or low variation (30/133), while 76% (101/133) had high (84/133) or very high variation (17/133). To explain the variance in logLOS, hierarchical regression was applied (Table 6). The APR-DRG variable was entered in model 1; in model 2, structural variables (age, gender, hospital, and procedure or medical APR-DRG) were added; in model 3, the severity of illness and the mortality risk were added. Given that all correlations were below 0.60 and the variance inflation factors were below 3.00 (with a maximum value of 1.795) for all variables, we assume that multicollinearity was not an issue (Hair et al., 2009).

Model 1 showed an R^2 of 0.017, $p \leq 0.001$; for model 2, $R^2 = 0.123$, $p \leq 0.001$; and for model 3, $R^2 = 0.267$, $p \leq 0.001$. This explains 2% of the logLOS variance for model 1 and 27% for model 3.

As we did not encounter multicollinearity, and since the adjusted R^2 for each model was greater than that obtained in the former model, the extra information brought by the new variables was greater than the penalty of adding variables.

4.2 Analyses of APR-DRG groups with severity of illness 1 and mortality risk 1

We analyzed the logLOS for patients with severity of illness 1 and mortality risk 1 in different APR-DRG groups, thus excluding the variance effect of these two dominant variables. This revealed that 37% (43/115) of APR-DRG groups had low or very low variation, while 63% (72/115) had high or very high variation (Table 7).

Hierarchical regression with logLOS as an independent variable and the APR-DRG group as the predictor variable (model 1) showed $R^2 = 0.017$, $P \leq 0.001$. Model 2 (APR-DRG groups with age, gender, hospital and procedural or medical APR-DRG) showed $R^2 = 0.084$, $P \leq 0.001$, thus explaining up to 8% of the logLOS variation (Table 8). Given that all correlations are below 0.60 and that the variance inflation factors are less than 3.00 (having a maximum value of 1.971) for all variables, we can assume that multicollinearity was not an issue here (Hair et al., 2009). The adjusted R^2 for each model was greater than that obtained in the former model, and so the extra information brought in by the new variables was greater than the penalty of adding variables.

Comparing the number of patients (above or below 500 patients/APR-DRG group) in the four classifications (very low variation, low variation, high variation and very high variation) showed a significant difference ($\chi^2 = 3952$, $P \leq 0.001$, $V = 0.330$), with a larger number of patients in the very low and low groups. However, when performed within the hospitals, this comparison (above or below 300 patients/APR-DRG group) showed no significant difference ($\chi^2 = 0.264$, $P = 0.607$, $V = 0.024$).

In the groups of very low and low variation, significantly more procedural than medical APR-DRGs were found than in the high and very high groups (χ^2 = 6.038, P = 0.014, V = 0.234). This result was also found within the hospitals (χ^2 = 15.965, P ≤ 0.001, V = 0.234).

Table 6 Hierarchical regression analysis of LogLOS with all APR-DRG groups (general analysis)

	LogLOS					
	Variable	b	SE(b)	t	p	R^2
Model 1					≤0.001	0.017
	APR-DRG	-8.730	0.000	-0.129	≤0.001	
Model 2					≤0.001	0.123
	APR-DRG	-6.840	0.000	-35.470	≤0.001	
	Age	0.010	0.000	102.470	≤0.001	
	Gender	0.180	0.005	36.472	≤0.001	
	Institute	0.253	0.006	44.781	≤0.001	
	Procedure or medical APR-DRG	-0.114	0.005	-22.592	≤0.001	
Model 3					≤0.001	0.267
	APR-DRG	-5.341	0.000	-30.251	≤0.001	
	Age	0.006	0.000	60.081	≤0.001	
	Gender	0.190	0.005	42.156	≤0.001	
	Institute	0.193	0.005	37.270	≤0.001	
	Procedure or medical APR-DRG	-0.095	0.005	19.705	≤0.001	
	Severity of illness	0.402	0.009	101.443	≤0.001	
	Mortality risk	0.146	0.011	30.824	≤0.001	

APR-DRG= All Patient Refined Diagnosis Related Groups

As shown by Table 7, about 60% of the APR-DRG groups in each hospital could be allocated to care with very low and low variation. The hospitals differed in the number of APR-DRG groups showing very low, low, high, and very high variation (χ^2 = 32.675, P ≤ 0.001, V = 0.155), with significant differences between the hospitals in the very low group. There were also differences in the type of the APR-DRG groups between the hospitals. Only 16 out of 115 (14%) groups are situated in similar variation groups in all hospitals (very low variation n = 1, low variation n = 12, and high variation n = 3); 25 out of 115 (22%) are divided between very low and low variation; and 13 out of 115 (11%) are in the high and very high-variation groups; the other 61 (53%) APR-DRG groups are mixed between multiple variation groups, demonstrating that the same APR-DRG group can have different levels of variation in different hospitals. For example, caesarean sections were classified as high variation in three hospitals, but very low variation in the university hospital. Other examples include sinus and mastoid procedures, where the variation was high for one hospital and very low for the three other (Table 8), after controlling for the case mix (severity of illness and mortality risk).

Table 7 shows that, for all hospitals, the mean age of patients in the very low variation group was 25 years younger than that of patients in the very high variation group. Additionally, compared to the other classifications within these hospitals, an older population was seen in the very low variation group in hospitals C and D (respectively 62.5 and 54.5), and a younger population in hospital A and B (34.5 and 20.6). Other variables (number of patients, number of APR-DRG groups, LOS, logLOS) are summarized in Table 7.

Table 7 Data for APR-DRG groups with severity of illness 1 and mortality risk 1 divided into four groups: APR-DRG groups with very low within-group variation, low within-group variation, high within-group variation, and very high within-group variation. Values are reported as mean or count (percentage)

	Very low	**low**	**high**	**Very high**	**p-values within hospitals**
All hospitals					
N patients	1880	29639	23610	9283	
N APR-DRG groups	2 (2%)	41 (35%)	48 (42%)	24 (21%)	
LOS	1.6	3.3	3.0	3.4	≤0.001
logLOS	0.3	0.9	0.8	0.9	≤0.001
Age	22.9	41.8	46.5	47.5	≤0.001
Hospital A					
N patients	3165	11828	5598	2044	
N APR-DRG groups	15 (13%)	52 (45%)	31 (27%)	17 (15%)	
LOS	3.8	3.2	3.2	3.2	≤0.001
logLOS	1.0	0.9	0.8	0.8	≤0.001
Age	34.5	43.0	44.0	43.0	≤0.001
Hospital B					
N patients	529	11736	9727	1886	
N APR-DRG groups	4 (3%)	64 (56%)	37 (32%)	10 (9%)	
LOS	1.7	3.55	3.1	3.9	≤0.001
logLOS	0.3	1.0	0.9	0.9	≤0.001
Age	20.6	44.4	45.0	43.9	≤0.001
Hospital C					
N patients	2320	4581	3686	1202	
N APR-DRG groups	28 (25%)	42 (37%)	32 (28%)	11 (10%)	
LOS	1.9	2.5	1.9	2.2	≤0.001
logLOS	0.3	0.7	0.4	0.5	≤0.001
Age	62.5	43.5	38.9	53.5	≤0.001
Hospital D					
N patients	1046	2470	2071	533	
N APR-DRG groups	27 (24%)	49 (44%)	30 (27%)	5 (5%)	
LOS	3.8	3.2	4.2	2.6	≤0.001
logLOS	0.9	0.9	1.16	0.6	≤0.001
Age	54.5	42.7	36.7	44.7	≤0.001
P-values between hospitals					
LOS	≤0.001	≤0.001	≤0.001	≤0.001	
logLOS	≤0.001	≤0.001	≤0.001	≤0.001	
Age	≤0.001	≤0.001	≤0.001	≤0.001	

N= number; APR-DRG= All Patient Refined Diagnosis Related Groups; LOS= length of stay; logLOS= logarithm transformation of length of hospital stay

Table 8 Hierarchical regression analysis of LogLOS with APR-DRG groups with severity of illness 1 and mortality risk 1

		LogLOS				
	Variable	**b**	**SE(b)**	**t**	**p**	**R^2**
Model 1					≤0.001	0.017
	APR-DRG	-6.710	0.000	-33.582	≤0.001	
Model 2					≤0.001	0.084
	APR-DRG	-5.658	0.000	-28.292	≤0.001	
	Age	0.005	0.000	37.933	≤0.001	
	Gender	0.181	0.006	32.097	≤0.001	
	Institute	0.295	0.006	46.681	≤0.001	
	Procedure or medical APR-DRG	0.102	0.006	3,.368	0.001	

LogLOS= logarithm transformation of length of hospital stay; APR-DRG= All Patient Refined Diagnosis Related Groups

Table 9 Random examples of APR-DRG groups, severity level 1 and mortality risk 1, assigned to very low (vl), low (l), high (h) and very high (vh) variation classification in each hospital

APR-DRG group	Hospital A	Hospital B	Hospital C	Hospital D
47 Transient ischemia	l	l	h	h
53 Seizure	h	l	l	h
54 Migraine & other headaches	l	l	h	h
58 Other disorders of nervous system	l	l	l	vl
73 Eye procedures except orbital	l	l	vl	vl
93 Sinus & mastoid procedures	l	h	vl	vl
94 Mouth procedures	vl	l	l	vl
97 Tonsil & adenoid procedures	l	l	h	l
141 Asthma & bronchiolitis	l	l	l	l
179 Vein ligation & stripping	vl	l	vl	l
190 Acute myocardial infarction	vl	l	l	l
192 Cardiac catheterisation for ischemic heart disease	h	l	h	vl
197 Peripheral & other vascular disorders	vh	h	l	vl
203 Chest pain	l	l	vl	l
204 Syncope & collapse	vh	h	vh	l
225 Appendectomy: appendix removal	l	l	l	l
241 Peptic ulcer & gastritis	vh	h	l	l
244 Diverticulitis & diverticulosis	l	l	l	l
249 Nonbacterial gastroenteritis, nausea & vomiting	h	h	h	h
263 Laparoscopic cholecystectomy	l	l	l	vl
302 Knee joint replacement	l	l	vl	vl
308 Hip & femur procedures for trauma, except joint replacement	h	vh	h	h
350 Musculoskeletal signs, symptoms, sprains & minor inflammatory dis, joint pain	vh	l	h	h
361 Skin graft for skin & subcutaneous tissue diagnoses	h	vh	vh	vh
362 Mastectomy procedures	vl	l	vl	vl
383 Cellulitis & other bacterial skin infections	l	h	h	h
403 Procedures for obesity	l	l	vl	l
420 Diabetes	l	l	l	l
446 Urethral & transurethral procedures	l	l	l	l
463 Kidney & urinary tract infections	l	l	l	l
482 Transurethral prostatectomy	vl	l	l	l
540 Caesarean delivery	vl	h	h	h
560 Vaginal delivery	l	l	l	h
723 Viral illness	l	l	l	h
862.2 Polysomnography	vl	vl	vl	

APR-DRG= All Patient Refined Diagnosis Related Groups

5. DISCUSSION

Our discussion of the results is based on the three propositions formulated in this study. First, with respect to proposition 1 ("Care processes can be divided into processes with low variation and high variation"), our results confirmed that patient groups can indeed be split into 'low-variation groups' and 'high-variation groups'. Without considering the severity of illness, mortality risk, or hospital (the general analysis), 24% of APR-DRG groups had low to very low variation. Although the cut-offs for the distribution of the variation groups were chosen on arbitrary grounds, these results indicate a difference in the degree of dispersion, as the groups with small LOS variation (low dispersion in throughput time; for examples, see disorders of the nervous system, asthma and bronchiolitis, or laparoscopic cholecystectomy in Table 9) might benefit from, or are consequences of, standard sequential care. On the other hand, APR-DRG groups with high and very high variation in LOS (high dispersion in throughput time; for examples, see hip and femur procedures for trauma or skin graft for skin and subcutaneous tissue diagnoses in Table 9) might benefit from more customized care (Bohmer, 2005; Bohmer, 2009; Christensen et al., 2009), although the reasons for this high variation need to be clarified through further research. As is well known, hospital care processes can be classified as sequential or iterative (Bohmer, 2009). However, it is not yet known how many hospital patients belong to each of these two types of processes.

It would be interesting to further investigate how care in the low-variation groups is organized and what type of business model is used, with the aim of looking for opportunities to further improve the processes, with attention on reducing variation where possible. Various process tools, such as lean and six sigma, are available to pursue such improvements, but as has been said, improvements of this kind will only be sustainable when the right business model is selected.

The high and very high-variation groups also require further attention. A first action might be to look at the causes of the variation. Healthcare workers often see high variation as inherent to certain pathologies, but this must not be taken for granted. Carefully analyzing the causes of variation—revealing and reducing special-cause variation and managing common-cause variation—and choosing the right business model is also of great importance.

Proposition 2 ("Care processes with lower uncertainty and higher possibility of standardization show lower variation than care processes with high uncertainty and lower possibility of standardization") might explain why some categories have much higher within-group dispersion than others. The fact that procedural APR-DRGs are more abundant in the lower variation groups than in the high-variation groups may indicate that there are important differences between procedural and nonprocedural APR-DRGs. This might be explained by the possibility of more standardized, sequential approaches for procedure-based care, which is not the case for care not based on procedures, which is more iterative, and which relates to professional service in the service–process matrix (Bohmer, 2009). A possible explanation for the higher variation in the nonprocedural APR-DRGs might be that this type of care is typically seen as unpredictable by health care workers and that less attention may be given to standardization and protocols.

Another possible factor is that, in the group of care processes with lower uncertainty, a larger number of illnesses or procedures are evidence-based, leading to less variation. Research has shown that, where there is strong evidence and professional consensus that an intervention is effective, there tends to be little or no variation in clinical practice; this is the case, for example, with surgery following a hip fracture (Wennberg and Gittelson, 1982; Corallo et al., 2014). However, clinical practice variations manifest for admissions, such as tonsillectomies, where there is weak evidence and professional uncertainty of which treatment is effective (Corrigan and Mitchell, 2011). Where evidence for a choice of treatment is highly available (as is the case with appendectomy, acute myocardial infarction, laparoscopic cholecystectomy, knee joint replacement, and eye procedures), admissions show very low or low variation, thus supporting this argument (Table 9).

A notable and important finding is that the differences in the distribution of variation groups between the four hospitals are significant; additionally, they cannot be explained exclusively by the severity of illness or by the risk of mortality, as we compared patients within the lowest level of severity and mortality group (Table 9). This finding supports proposition 3 ("There are clear differences in process performance between hospitals). The reasons behind such differences may vary, but they remain complex (Figure 13). For example, the differences between hospitals may be caused by under registration of the severity of illness or mortality risk. However, this seems unlikely, as the hospitals are all equipped with electronic patient records from which data are extracted, thus reducing such errors. Some differences could be justified by hospital policy and management differences. The example of the caesarean section showing very low variation in the university hospital is an example of a standardized approach where the LOS is strictly managed. In contrast, smaller hospitals may take patients' preferences more into account, resulting in larger dispersions of LOS (Table 9). It may also be that physicians adapt to the colleagues they work with, leading to differences between hospitals (De Jong et al., 2006). The example of the caesarean section demonstrates how a standardized process (with relative high volume and very low variation), preferably organized as a service factory in a VAP business model, can show a high degree of special-cause variation across three hospitals. This demonstrates the importance of distinguishing common cause from special-cause variation. As the nature of our data doesn't allow deeper insights on the causes of the special-cause variation, future research in this area is needed.

Differences in variation between hospitals may be a signal of underperformers, but even then there is a need for careful analysis and the stepwise application of improvements in order to reduce special-cause variation. Further research could identify the reasons for the noted differences between the hospitals, and might reveal differences in the design of their operating systems. As differences in variation between the hospitals do exist, it is not our intention to indicate which hospital gives 'better' care, as this study did not take into account the quality and outcome of care. It is nonetheless important to know what determines the variation by recognizing the special-cause and common-cause variation, in order to obtain equivalent groups. Classifying pathologies or procedures into the wrong business model could impair the quality of care (Figure 12). Therefore, the causes of differences in the classifications between hospitals need further investigation.

Variation as described is a mix of 'common-cause' or 'inherent' variation and 'special-cause variation'. For example, the 'severity of illness' and the 'mortality risk of the patient' are important variables in explaining the degree of inherent variation. Thus, when correcting for the severity of illness and the mortality risk, 37% of the APR-DRGs showed low to very low within-group variation, and in each hospital up to 60% of the APR-DRGs demonstrated low variation and very low variation. The importance of using severity-adjusted outcomes and adequate case mix adjustments (such as for disease severity) is well-established in the literature, and is essential in uncovering the reasons for health care variation (Mercuri and Gafni, 2011; Rosen et al., 1995). Data from the literature suggest that from 10% to as much as 61% of variation (for example, in resource use) is explained by the severity of illness (Horn et al., 1986; Lezzoni et al., 1990; Shwartz et al., 1996). Regression analysis shows similar results: as much as 9% of the variation was caused by the severity of illness and the mortality risk. Other well-known reasons for variation (such as the availability of physicians, the number of hospital beds, differences in patient socio-demographics, differences in the use and appropriateness of medical and surgical procedures) have been considered in previous variation studies over the last few decades (Corrigan and Mitchell, 2011; Fisher et al., 1994; Fisher et al., 2003; Knaus et al., 1993; Stukel et al., 2005; Wennberg and Gittelson, 1982; Wenneberg, 1999), but Mercuri and Gafni (2011) found that such lists were likely to be incomplete, as significant unexplained variation remained in each study. Moreover, Corallo et al. (2014) concluded in their literature review that further studies of the causes and consequences of variation are important in illustrating the difficulty of identifying the common-cause variation. Although these case-mix systems explain part of the dispersion of inpatient LOS, a significant degree of variation remains unexplained. The crucial question is whether this is common-cause variation or special-cause variation as these require different management approaches.

Our study also shows that volume plays an important role. APR-DRG groups allocated to the very low and low-variation groups are high-volume, unlike the high and very high-variation groups. However, these volume-related findings were not confirmed in the data from the individual hospitals.

Finally, the data show great differences between the large and small hospitals in the ages of patients in the very low variation group. One possible explanation for this could be that older patients typically choose rural hospitals. Tai et al. (2004) showed that aged patients strongly prefer hospitals in their neighborhood. Adams et al. (1991) suggested that the provision of specialized services in large urban centers did not attract the oldest population; those over 85 years exhibited preferences for a greater scope of service, though in smaller, more rural facilities. Buczko (2008) examined hospital use and suggested that nonelderly rural residents have increasingly bypassed local rural hospitals. If elderly patients do bypass rural hospitals this appears to be primarily due to the regional specialization of care (Buczko, 2008).

The following limitations of our study need to be considered: first, because of the retrospective nature of the study, detailed analyses were not available; this limits the possibilities of exploring the various causes of variation. Secondly, the data set is very large, so statistical tests are significant even for very small effects. Third, the fact that the data concern only the Flemish region and describe only four hospitals cautions against generalization. Nevertheless, medical conditions can be assumed to be universal, so these results may have broader implications for practice. Moreover, such limitations do not, in our view, substantially detract from the significance of the finding that different types of services (care) can be distinguished in hospitals, which leads to the hypothesis that different processes and business models are required to manage these types of services. Our findings do, however, require extensive further research into the care processes of hospitals, not only to explain the differences between hospitals and the causes of variation (common cause versus special cause), but also to establish whether the processes in the low-variation groups and the high-variation groups are fundamentally different, thus requiring different business models, replacing hospitals' current one-size-fits-all approach. Furthermore, the findings might just not be the case for hospitals, as the applicability of the conceptual framework (Figure 12) is broader than hospitals alone, and could therefore be transferred to other health care settings. Testing the proposition in other settings with a mixed-method design could yield more in-depth results.

Our database research deliberately focused on the recognition of processes in health care that need different operating designs. It would be interesting to uncover the underlying mechanisms behind the reasons for variation. Such future research could purposefully use qualitative or observational design of the operating system. Additionally, we recommend further research to examine whether the right choice of operating system enhances quality and reduces costs in health care settings, for both complex and standard care processes.

6. CONCLUSIONS

By using the dispersion in LOS and considering the differences in case-mix, as measured by the APR-DRG, APR-DRG groups with high and low within-group variation were found—with less variation for procedural APR-DRGs than for medical APR-DRGs. This means that there are groups of patients with inherently greater or less variation in illness and treatment patterns, supporting the conceptual framework. Different business models in hospitals should therefore be considered for these groups, instead of the one-size-fits-all 'full-service' model. There was, however, a significant difference in the distribution of APR-DRG groups across variation groups in the different hospitals. Further research should investigate whether this variation is due to common causes or special causes. Separating common-cause variation from special-cause variation will increase the likelihood of applying the right business model for the right type of patients in terms of care processes.

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CHAPTER 4

A multilevel analysis of factors influencing the flow efficiency of the cataract surgery process in hospitals

Under review

ABSTRACT

Purpose: To detect factors contributing to variation in cataract surgery processes.

Methods: A multilevel study was conducted to compare the process of cataract surgery between hospitals in Belgium. The main data were collected through nonparticipative observations and time measurements in four hospitals. Physicians (n=16) performing cataract surgery in the selected region and their patients (n=274) undergoing cataract surgery were observed. Flow efficiency is measured in the operating room (OR) as time for preparation, surgery, exit and turnover.

Results: Flow efficiency in the OR can be negatively influenced by the severity of the cataract ($p \leq 0.001$) and the presence of special-cause variation ($p \leq 0.001$). Administering topical analgesia instead of peribulbar ($p \leq 0.001$), retrobulbar ($p \leq 0.05$) or general analgesia ($p \leq 0.001$) enhances flow efficiency. The experience of physicians (>15 years) impacts flow efficiency. The volume of cataracts performed annually per surgeon did not have a significant impact on flow efficiency. The use of specialized scrub nurses ($p \leq 0.05$) and the eye clinic design ($p \leq 0.05$) benefit flow efficiency.

Conclusion: Controllable and uncontrollable factors with clinical and organizational causes influencing flow efficiency in the cataract process were found. These factors can be taken into account in the management of the health care process.

1. INTRODUCTION

The number of cataract operations performed has increased considerably in recent decades (WHO, 2000). In many countries, cataract surgery now accounts for over half of all ophthalmic surgery, and has become one of the most common elective surgical procedures (Stenevi et al., 1995). Due to its large volume, cataract surgery receives a considerable part of health care budgets. What is more, the number of cataract surgeries is expected to increase dramatically (Taylor, 2000), challenging health care providers to improve efficiency in terms of lead times, hospital visits, and costs. It has been described how costs (Ellwein et al., 1998; Lundstrom et al., 2000) and cataract pathways (Van Vliet, 2011) can vary considerably between different providers of cataract surgery, and even between different surgeons in the same surgery unit (Filer et al., 1991). However, variations in patient outcomes for cataract surgery are small (Desai et al., 1999; Powe et al., 1994). As a result, the variations in cataract surgery can mainly be differentiated in terms of how the care process is organized (Van Vliet et al., 2011).

There are two kinds of variation in a process: common-cause variation and special-cause variation (McLaughlin and Kaluzny, 2000). Common or 'inherent' cause variation is a natural pattern in the process, created by many factors that are commonly inherent to the process, acting at random and independently of each other (e.g., the severity of an illness). Special-cause variation is an unnatural pattern created by a nonrandom event leading to an unexpected change in the process output (such as resource availability). The effects are intermittent and unpredictable, and mostly require immediate action. These two types of variation are completely different, and must be dealt with differently. Failure to identify the source of variation (as special or common) leads to inappropriate actions within the system. The factors of variation have been widely discussed in the literature. Previous variation studies have focused mainly on describing small-area (geographic) special-cause variation and on reducing such unwarranted variation (e.g., differences between regions that cannot be explained by illness or medical need) (Ashton et al., 1999; Berwick, 1991; Corrigan and Mitchell, 2011; Leape et al., 1990; Weinstein et al., 2004; Wennberg, 1999; Wennberg and Gittelsohn, 1973) (Figure 16). Despite the large number of cataract extractions that are performed, little is known about the variation in the cataract surgery process itself. Performance in surgery programs is influenced by specific structural and operational elements. As the operational focus is on reducing time spent by removing the non-value-adding waste (Ohno, 1998), it may be of interest to compare facilities structurally and operationally (Ellwein et al., 1998) in order to explore the reasons for variation and to enhance flow efficiency.

Flow efficiency focusses on the unit that is processed in the organization, while resource efficiency concerns the efficiency of the resources that add value within the organization. Flow efficiency does not deal with increasing the speed of value-adding activities, but rather focuses on maximizing the density of the value transfer and eliminating non-value-adding activities (Modig and Ahlström, 2012). Optimally, the goal is to achieve the shortest lead time, with the lowest costs, and without reducing quality. This study discusses the role of the organization, the surgeon, and the case-mix variables of patients in the variation of cataract surgery processes by means of multilevel analysis.

This paper aims to provide an answer to the following research question: What are the factors influencing the flow efficiency of cataract surgery in different hospitals?

2. METHODS AND SUBJECTS

2.1 Study design

A comparative benchmark multilevel study was conducted to compare the process of cataract surgery across hospitals. A comparative benchmark study focusses upon how similar activities are organized by different organizations (Ellis, 2006), and entails a comparison of the performance and underlying processes (Watson, 1993).

2.2 Subjects

This study uses data from four hospitals (at five sites) in one region in Belgium. The composition of the population, the size, and the availability of a sufficient volume of cataract surgery, and the different status of the hospitals (university versus general, small versus large), were the reasons for the selection of the sites. All ophthalmologists performing cataract surgery (n = 18) in these hospitals were invited to participate. Data was gathered from October 2013 until June 2014. The study protocol was approved by the institutional review boards (OG 017), and all participants took part voluntarily.

2.3 Data collection

The main data were collected using nonparticipating observation and time measurement. A survey was conducted to gain additional information on certain characteristics of the surgeons, such as their experience and position in the operating room (OR). Unclear events and information gaps were clarified in interviews with the staff.

2.4 Variables

The focus of this study is on flow efficiency. Flow efficiency is measured by the amount of time needed for cataract surgery at the OR. The total throughput time is divided into four time variables, used here as the **dependent variables**: the *preparation time* for the patient at the OR (entry patient to incision), *surgery time* (start of incision to end of incision), *exit time* (end of incision to exit patient), and *turnover time* between operations (exit patient to entry of next patient).

As most patients experience a significant improvement in vision (the main clinical outcome) after surgery (Powe et al., 1994; Schein et al, 1994), and since the incidence of complications is relatively low (The Royal College of Ophthalmologists, 2010), the outcome parameters were not taken into account in this study. In other words, we assume that the outcomes of the different surgeries are comparable. The **independent variables** were mainly selected based on the findings of previous studies (Figure 16). The dataset contains patient-level variables (level 1) that are potential predictors of variation in the care process, such as demographics (age, gender) severity (normal versus severe), analgesia (topical, topical plus intracameral, retrobulbar, peribulbar, or general), and the presence of special-cause variation (such a missing lens, waiting for sterilized material, technical problems with devices, telephone calls for the surgeon, …). The severity of the cataract is determined by the conditions that make surgery more difficult, including preoperative aggravating conditions, small pupil with need for mechanical stretching, dense cataract, corneal opacities with reduced visibility of the surgical field and so on.

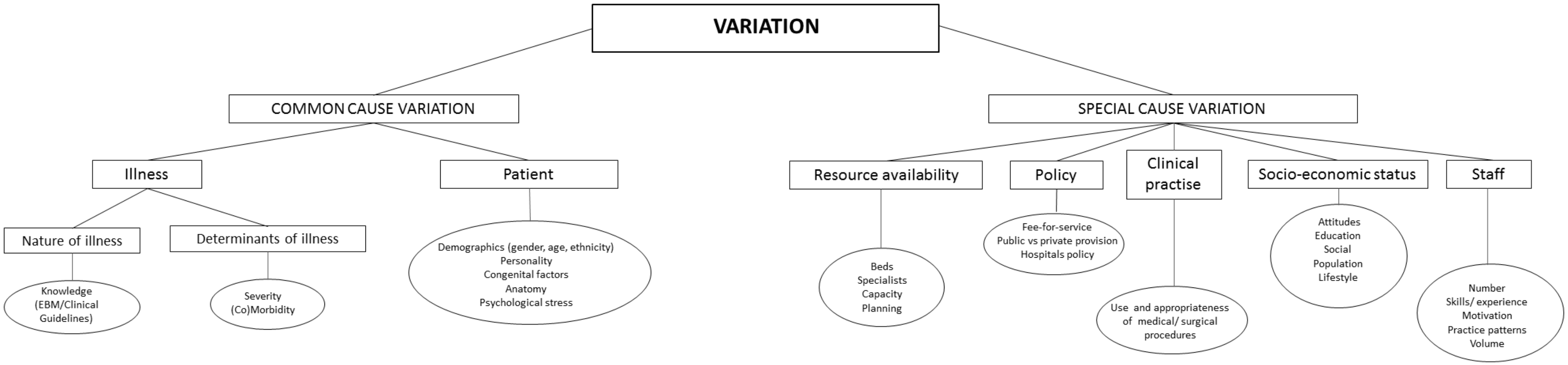

Figure 16 Possible inducers for variation in the health care process from De Regge et al, (2015)

To assess possible explanatory variables at surgeon level (level 2), the following variables were selected: job experience (low: < 5 years; medium: 5–15 years; high: > 15 years), volume (number of cataracts per year per surgeon: high: > 300; medium: 100–300; low: < 100), positioning of surgeon during surgery (behind the patient or next to the patient), organizational design of the hospital (eye clinic design versus non-eye clinic (e.g. day surgery unit)), and the assistance of a specialized ophthalmologic nurse (scrub person).

2.5 Data analysis

Qualitative data on the process were collected in a structured way, allowing for quantitative interpretations. The quantitative data (such as the surgery time measurements) were measured in minutes at specified points in the process. These fixed points were similar in all cataract cases.

The main statistical tool for this study was a two level hierarchical linear multilevel model. The multilevel model analyzed the effects on flow efficiency on the cataract surgery. Multilevel modelling is a statistical methodology for examining hierarchical or nested data, and is well-rationalized for health care, as studies of individuals may need to take into account differences in the properties of the groups to which the individuals belong (Diez-Roux, 2000). This gives the opportunity to explain variation in the dependent variable at one level as a function of variables defined at various levels, plus interactions within and between levels. All multilevel models were performed with MLwiN 2.28. The models were estimated using iterative generalized least squares (IGLS) estimations. The intraclass correlation (ICC) was computed on the basis of two variance components. The ICC refers to correlation among lower level units (patients) within higher level units (surgeons). At first, we drew up a base model depicting a null random intercept situation with the dependent variable as the response and only a constant term in the model. This model estimates the overall average time across all surgeons and all patients. We later added additional predictor variables at both levels (patient and surgeon). The variable assumed to generate the largest time gain was used as a reference, where necessary.

The chi-square ($\chi2$) test was used to compare categorical variables.

3. RESULTS

Sixteen of the 18 ophthalmologists agreed to participate in the study and were included. Thirteen of the 16 surgeons responded to request for additional demographic and professional information. In total, 274 cataract operations were observed, with multiple observations per surgeon (min 15; max 19). Power calculations, using SPSS SamplePower3 (IBM), showed that the power ($\alpha = 0.05$) was 85% for the variable total time in the OR, assuming a 25% time difference, thus requiring a sample size of 13 patients. The mean age of the surgeons was 47 years (30–69) (n = 13), with seven female and nine male surgeons. The mean age of the patients was 74 years (45–98), with 145 female and 129 male patients. The demographics and organizational design characteristics of the hospitals can be found in Table 10. All but one of the cataract surgeries were performed using the phacoemulsification technique. Special-cause variation was observed in 19% of cases (51 of the 274) as the location of the ophthalmologist (switched during surgery) (n = 15), technical problems with devices (n = 6), sterile instruments not ready (n = 4), problems with materials (n = 4), surgeon disturbed during OR (n = 4), sterility of operating field disrupted by patient (n = 3), missing lens (n = 2), getting acquainted with new material (n = 2), surgeon late to OR (n = 2), delay in administering eye mydriatic (n = 1), high work pressure on ward (n = 1), forgetting to prime device (n = 1).

3.1 Preparation time (Table 11)

The first model (M1) is an intercept-only model whose results are reported in Table 11. The intercept in this model is 21.992 minutes, which is the average preparation time in the OR across all surgeons and all patients. M1 estimates the surgeon level variance as 46.484 and the patient level variance as 47.715. The total amount of variation in preparation time at the OR is then 94.199. If we calculate the intraclass correlation (ICC) on the surgeon level, we find that the ICC is 46.484/94.199 = 0.493, meaning that 49.3% of the variance in preparation time at the OR is variance between surgeons, while approximately 50% of the total variance is variance within surgeons between patients. We can thus conclude that it is worth analyzing these data using multilevel analysis.

Table 10 Demographics and organizational design of the hospitals

	Hospital A	Hospital B		Hospital C	Hospital D
Total Size	Large (> 1000 beds)	Large (> 1000 beds)		Intermediate (526 beds)	Large (> 800 beds)
		Site 1	**Site 2**		
Size		Intermediate (± 400 beds)	Small (± 150 beds)	Small (mainly polyclinic)	Small (mainly polyclinic)
Number of ophthalmologists performing cataract surgery /Number of ophthalmologists	3/12	3/4	4/6	1/3	7/9
Organizational design clinic	**Centralized one-day clinic** (for multiple disciplines) in hospital	**Decentralized eye clinic*** in hospital	**Decentralized eye clinic** in hospital	One-day admission at **hospital ward**	**Decentralized eye clinic** in day clinic

*Eye clinics are hospital-associated locations in which outpatients are given eye treatment; the bulk of the procedures are organizationally separated from those of the hospital.

A second model (M2) was estimated and included fixed predictors on level 1 (Table 11). This model predicts a mean preparation time of 20.597 minutes. As the decrease in deviance (from 1882.568 to 1835.376; $\Delta = 47.192$, $p \leq 0001$) was statistically significant, this implies that the quality of the model did in fact improve when the level 1 predictors were added. Looking at the results in Table 11 and comparing then with those from M1, we can see that the addition of the fixed explanatory variables on level 1 (patient demographics, cataract severity, analgesia, and the presence of special-cause variation) reduced the amount of variance at both the surgeon and patient level. The between-surgeon variance is reduced from 46.484 to 29.598, while the within-surgeon variance is reduced from 47.715 to 40.818. Having accounting for the explanatory effects on level 1, the proportion of unexplained variance that is due to differences between surgeons slightly decreased from 49.3% to 42% (29.598/(29.598+40.818)). In the fixed part of the model, the severity of the cataract, the presence of special-cause variation, and the use peribulbar analgesia compared to topical analgesia increases preparation time at the OR.

In a third model (M3,) level 2 fixed predictors were added (Table 11). M3 predicts an average preparation time of 26.302 minutes. As the decrease in the variance (from 1835.376 to 1493.365; $\Delta = 342.011$, $p \leq 0.001$) was significant, this shows that the quality of the model was improved by adding the level 2 predictors. The between-surgeon variance has reduced from 29.598 to 10.920. This illustrates that, having accounted for the explanatory levels on level 2, the proportion of unexplained variance that is due to differences between surgeons dropped from 42% to 21.3% (10.920/(10.920+40.411)). In the fixed part of M3, the presence of a specialized nurse enhances time efficiency to 7.146 minutes below average, but the presence of special-cause variation decreases efficiency to 2.831 minutes above average. Likewise, the use of general analgesia affects preparation time in the OR.

3.2 Surgery time (Table 12)

The intercept in model 1 (M1) is 18.355 minutes, which is the average surgery time across all surgeons and all patients. M1 estimates the surgeon level variance as 25.424 and the patient level variance as 47.908. The total amount of variation in surgery time is 73.332. The ICC on the surgeon level is 24.424/73.332 = 0.333, meaning that 33.3% of the variance in surgery time is variance between surgeons.

A second model (M2) was estimated and included fixed predictors on level 1 (Table 12). This model predicts a mean surgery time of 14.546 minutes. As the decrease in deviance (from 1874.698 to 1816.772; $\Delta = 57.926$, $p \leq 0.001$) was statistically significant, this implies that the quality of the model did in fact improve when the level 1 predictors were added. Looking at the results in Table 12, and comparing them with those from M1, we can see that the addition of the fixed explanatory variables on level 1 reduced the amount of variance at both the surgeon and patient level. The between-surgeon variance is reduced from 25.424 to 14.177 and the within-surgeon variance is reduced from 47.908 to 38.473. Having accounted for the explanatory effects on level 1, the proportion of unexplained variance that is due to differences between surgeons decreased slightly from 33.3% to 26.9% (14.177/(14.177+38.473)). Again, in the fixed part of the model, the severity of the cataract and the presence of special-cause variation lead to increased surgery times. As the form of analgesia influences the surgery time (for example, retrobulbar by +3.856 minutes and general by +5.617 minutes, compared to topical analgesia) it was interesting to look into the relationship between the severity of the cataract and the form of analgesia. Table 13 demonstrates that analgesia is not chosen as a function of severity, as there are significantly fewer surgeries of severe cataracts than of normal cataracts under retrobulbar or peribulbar analgesia.

Additionally, we allowed the slope of the severity to differ across surgeons, as there might be differences between surgeons in terms of surgery time for dealing with severe cataracts. Some ophthalmologists might operate faster, and others a slower pace. Random coefficients for severity on the surgeon level did not explain any more variance (Su12 19.068 (12.685)).

In the third model (M3), the level 2 fixed predictors were added (Table 12). M3 predicts an average surgery time of 10.750 minutes. As the decrease in the variance (from 1827.634 to 1513.257; $\Delta = 314.377$, $p \leq 0.001$) was significant, this indicates that the quality of the model was improved by adding the level 2 predictors. The between-surgeon variance has reduced from 14.177 to 6.383. The proportion of unexplained variance due to differences between surgeons dropped from 26.9% to 12.3% (6.383/(6.383+45.449)), illustrating that a large share of variation on the surgeon level is explained by the variables in M3. Table 12 indicates that shorter job experience increases surgery, with 12.838 minutes, compared to the highly experienced surgeon.

Figure 17 demonstrates the mean surgery time in minutes (minimum, maximum) of each surgeon.

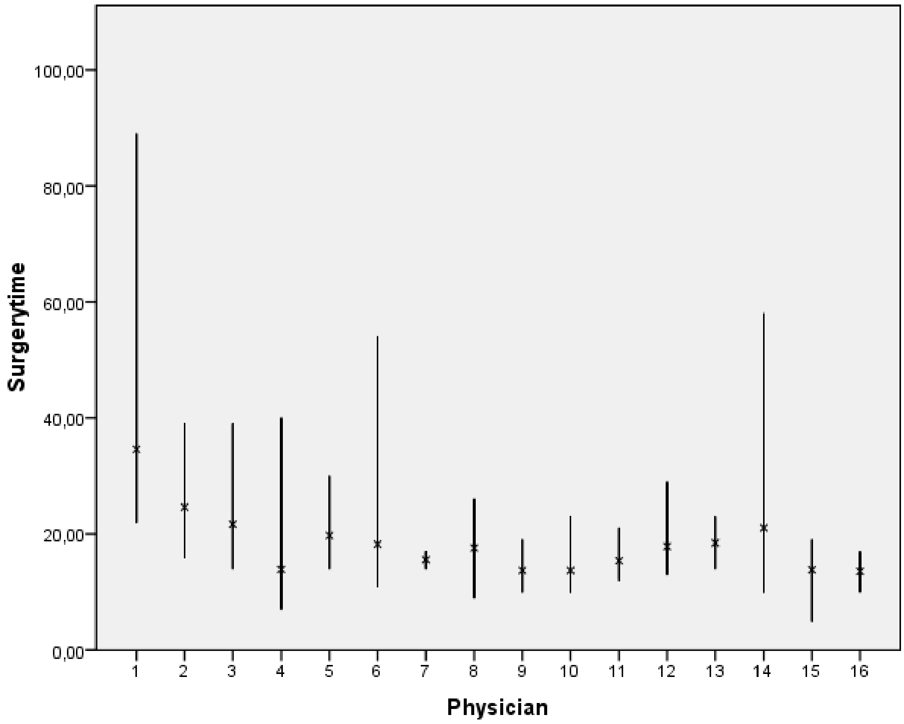

Figure 17 Plot of mean values (minimum, maximum) for surgery time (minutes) per surgeon

Finally, the crosslevel interaction effect of severity of cataract*job experience of the surgeon and of severity of cataract*volume were analyzed to investigate whether more experienced surgeons (in terms of years and volume) took less time to perform surgery on severe cataracts (M3). The interaction effect severity of cataract*job experience of surgeon showed a significant effect (7.368 (3.780), P = 0.05) for surgeons with medium experience, compared to surgeons with high experience.

3.3 Exit time (Table 14)

The intercept in model 1 (M1) is at 4.015 minutes, which is the average exit time across all surgeons and all patients. M1 estimates the surgeon level variance as 2.449 and the patient level variance as 4.365, with the total amount of variation in preparation time being 6.814. The ICC on the surgeon level is 4.015/6.814 = 0.589, meaning that 58.9% of the variance in preparation time is variance between surgeons.

The second model (M2) included the fixed predictors on level 1 (Table 14). This model predicts a mean exit time of 3.411 minutes. As the decrease in deviance (from 1219.071 to

1128.224; $\Delta = 90.847$, $p \leq 0.001$) was statistically significant, this indicates that the quality of the model did in fact improve when the level 1 predictors were added. Looking at the results in Table 14 and comparing with those from M1, we can see that the addition of the fixed explanatory variables on level 1 reduced the amount of variance at both the surgeon and patient level. Having accounting for the explanatory effects on level 1, the proportion of unexplained variance due to differences between surgeons decreased from 58.9% to 23.9% (1.015/(1.015+3.227)).

In the fixed part of the model, general analgesia compared to topical analgesia and the presence of special-cause variation increase exit time at the OR.

In the third model (M3), the level 2 fixed predictors were added (Table 14). M3 predicts an average turnover time of 2.911 minutes. The decrease in the variance (from 1128.224 to 922.857; $\Delta = 205.349$, $p \leq 0.001$) was significant, which suggests that the quality of the model was improved by adding the level 2 predictors. Performing the cataract surgery in an eye clinic and higher surgeon job experience increases the flow efficiency in exit time at the OR. The volume of cataract surgery/surgeon/year had the opposite effect.

Table 11 Results of multilevel analysis of preparation time with explanatory variables at level 1 and level 2.

	M1: Null model			**M2: + level 1 variables**			**M3: + level 2 variables**		
Fixed part	**Coefficient**	**s.e.**	**sig**	**Coefficient**	**s.e.**	**sig**	**Coefficient**	**s.e.**	**sig**
Intercept (minutes)	21.992	1.755	**	20.597	1.664	**	26.302	4.949	**
Level 1									
Demographics									
Gender (men vs. women)				-0.427	0.829	n.s.	-0.734	0.911	n.s.
Age (age-gm)				-0.091	0.046	n.s.	-0.086	0.051	n.s.
Severity									
Normal vs. severe				3.473	1.061	**	2.778	1.139	*
Analgesia									
Topical				Ref			Ref		
Topical + intracameral				-8.114	4.313	n.s.	-7.396	4.373	n.s.
Retrobulbar				0.568	1.758	n.s.	1.881	1.897	n.s.
Peribulbar				13.548	4.436	**	0.000	0.000	n.s.
General				2.800	2.752	n.s.	2.831	1.193	**
Special cause variation									
absent vs. present				4.093	1.056	**	2.831	1.193	*
Level 2									
Job experience									
Low							-7.399	7.042	n.s.
Medium							-5.543	3.576	n.s.
High							Ref		
Volume									
Low							-0.469	3.575	n.s.
Medium							-1.682	6.258	n.s.
High							Ref		
Habits									
Staying							Ref		
Moving							-0.469	3.575	n.s.
Organizational design									
Eye clinic							Ref		
No eye clinic							2.133	4.864	n.s.

Specialized ophthalmologic scrub nurse									
Yes							Ref		
No							-7.146	3.099	*
Random part									
S_e^2	46.484	17.425	**	29.598	11.320	*	10.920	5.214	*
S_{u0}^2	47.715	4.201	**	40.818	3.594	**	40.411	3.925	**
Deviance	1882.568			1835.376			1493.365		

** p ≤ 0.001, *p ≤ 0.05, n.s. not significant

Table 12 Results of multilevel analysis of surgery time with explanatory variables at level 1 and level 2

	M1: Null model			**M2: + level 1 variables**			**M3: + level 2 variables**		
Fixed part	**Coefficient**	**s.e.**	**sig**	**Coefficient**	**s.e.**	**sig**	**Coefficient**	**s.e.**	**sig**
Intercept (minutes)	18.355	1.328	**	14.546	1.236	**	10.750	4.279	**
Level 1									
Demographics									
Gender (men vs. women)				1.014	0.802	n.s.	1.056	0.978	n.s.
Age (age-gm)				0.008	0.045	n.s.	-0.002	0.054	n.s.
Severity									
Normal vs. severe				5.746	1.533	**	4.616	1.786	*
Analgesia									
Topical				Ref			Ref		
Topical + intracameral				2.949	2.607	n.s.	0.772	3.634	n.s.
Retrobulbar				3.856	1.548	*	2.774	2.108	n.s.
Peribulbar				5.568	3.319	n.s.	0.000	0.000	n.s.
General				5.617	2.536	*	3.477	3.091	n.s
Special cause variation									
absent vs. present				3.109	1.302	*	2.503	1.277	*
Level 2									
Job experience									
Low							12.838	5.922	*
Medium							-0.918	2.994	n.s.
High							Ref		
Volume									
Low							-1.207	5.303	n.s.
Medium							-2.400	3.679	n.s.
High							Ref		
Habits									
Staying							Ref		
Moving							0.992	2.962	n.s.
Organizational design									
Eye clinic							Ref		
No eye clinic							5.040	4.170	n.s.

Specialized ophthalmologic scrub nurse									
Yes							Ref		
No							-1.823	2.565	n.s.
Interaction									
Severity*job experience									
Severe*low experience							4.464	6.940	n.s.
Severe*medium experience							7.368	3.780	*
Severe*high experience							Ref		
Severity*volume									
Severe*low volume							-0.074	7.309	n.s.
Severe*medium volume							-7.920	4.416	n.s.
Severe*high volume							Ref		
Random part									
S_e^2				14.177	6.009	*			
S_{u01}	25.424	9.961	**	16.431	7.084	*	6.383	3.547	n.s.
S^2_{u1}				19.068	12.685	n.s.			
S_{u0}^2	47.908	4.219	**	38.473	3.488	**	45.449	4.414	**
Deviance	1874.698			1861.772			1513.257		

** $p \leq 0.001$, *$p \leq 0.05$, n.s. not significant

Table 13 Comparison between categorical variables: severity of the cataract and form of analgesia.

	Form of analgesia														
	Topical			**Topical + intracameral**			**Retrobulbar**			**Peribulbar**			**General anesthesia**		
Severity of the cataract	Number of total (%)	Chi^2(df)	sig	Number of total (%)	Chi^2(df)	sig	Number of total (%)	Chi^2(df)	sig	Number of total (%)	Chi2(df)	sig	Number of total (%)	Chi2(df)	sig
Normal	132 (48%)	67.60 (1)	**	30 (11%)	17.86 (1)	**	37 (14%)	10.38 (1)	**	16 (6%)	10.90(1)	**	8 (3%)	3.60 (1)	n.s.
Severe	28 (10%)			5 (2%)			14 (5%)			2 (1%)			2 (1%)		
Percentage normal/severe per analgesia	83/17			86/14			73/27			80/20			89/11		

** $p \leq 0.001$, *$p \leq 0.05$, n.s. not significant

3.4 Turnover time (Table 15)

The intercept in model 1 (M1) is at 3.424 minutes, which is the average turnover time across all surgeons and all patients. M1 estimates the surgeon level variance as 1.915 and the patient level variance as 6.009, with the total amount of variation in preparation time being 7.924. The ICC on the surgeon level is 1.915/7.924 = 0.242, meaning that 24.2% of the variance in preparation time is variance between surgeons.

The second model (M2) was estimated and included fixed predictors on level 1 (Table 15). This model predicts a mean turnover time of 2.911 minutes. The decrease in deviance (from 1012.823 to 992.184; $\Delta = 20.639$, $p \leq 0.001$) was statistically significant, suggesting that the quality of the model did in fact improve by adding level 1 predictors. Looking at the results in Table 15 and comparing with those from M1, we can see that the addition of the fixed explanatory variables on level 1 reduced the amount of variance at both the surgeon and patient levels. Having accounting for the explanatory effects on level 1, the proportion of unexplained variance due to differences between surgeons barely decreased, from 24.2% to 16% (1.075/(1.075+5.616)). Similar to the previous analysis, in the fixed part of the model, the severity of the cataract and general analgesia, rather than topical analgesia, increases turnover time at the OR.

In the third model (M3), the level 2 fixed predictors were added (Table 15). M3 predicts an average turnover time of -0.298 minutes. As the decrease in the variance (from 992.184 to 1828.022; $\Delta = 164.162$, $p \leq 0.001$) was significant, this suggests that the quality of the model was improved by adding the level 2 predictors. Performing the cataract surgery in an eye clinic and using a specialized scrub nurse increases flow efficiency in turnover time at the OR.

Table 14 Results of multilevel analysis of exit time at OR with explanatory variables at level 1 and level 2

	M1: Null model			M2: + level 1 variables			M3: + level 2 variables		
Fixed part	**Coefficient**	**s.e.**	**sig**	**Coefficient**	**s.e.**	**sig**	**Coefficient**	**s.e.**	**sig**
Intercept (minutes)	4.015	0.411	**	3.411	0.346	**	2.911	0.289	**
Level 1									
Demographics									
Gender (men vs. women)				0.072	0.232	n.s.	0.190	0.267	n.s.
Age (age-gm)				-0.007	0.013	n.s.	-0.005	0.015	n.s.
Severity									
Normal vs. severe				0.176	0.296	n.s.	0.335	0.330	n.s.
Analgesia									
Topical				Ref			Ref		
Topical + intracameral				-0.020	0.841	n.s.	1.286	0.567	*
Retrobulbar				0.602	0.454	n.s.	-0.584	0.522	n.s.
Peribulbar				0.110	0.983	n.s.	0.000	0.000	n.s.
General				6.626	0.738	**	5.175	0.817	**
Special cause variation									
absent vs. present				0.895	0.295	*	1.181	0.350	**
Level 2									
Job experience									
Low							3.136	0.921	**
Medium							1.076	0.453	*
High							Ref		
Volume									
Low							-1.697	0.801	*
Medium							-1.943	0.555	**
High							Ref		
Habits									
Staying							Ref		
Moving							-0.357	0.451	n.s.
Organizational design									

Eye clinic							Ref		
No eye clinic							1.742	0.686	*
Specialized ophthalmologic scrub nurse									
Yes							Ref		
No							-0.291	0.393	n.s.
Random part									
S_e^2	2.449	0.957	**	1.015	0.426	*	0.000	0.000	n.s.
S_{u0}^2	4.365	0.384	**	3.227	0.284	**	3.539	0.334	**
Deviance	1219.071			992.184			922.857		

** $p \leq 0.001$, *$p \leq 0.05$, n.s. not significant

Table 15 Results of multilevel analysis of turnover time at OR with explanatory variables at level 1 and level 2

	M1: Null model			M2: + level 1 variables			M3: + level 2 variables		
Fixed part	**Coefficient**	**s.e.**	**sig**	**Coefficient**	**s.e.**	**sig**	**Coefficient**	**s.e.**	**sig**
Intercept (minutes)	3.424	0.385	**	2.911	0.420	**	-0.298	1.041	**
Level 1									
Demographics									
Gender (men vs. women)				-0.046	0.351	n.s.	-0.018	0.413	n.s.
Age (age-gm)				0.014	0.019	n.s.	0.020	0.022	n.s.
Severity									
Normal vs. severe				1.040	0.460	*	1.330	0.523	*
Analgesia									
Topical				Ref			Ref		
Topical + intracameral				0.046	0.937	n.s.	-0.553	0.854	n.s.
Retrobulbar				1.054	0.619	n.s.	0.227	0.868	n.s.
Peribulbar				-1.154	1.303	n.s.	0.000	0.000	n.s.
General				3.915	1.261	*	2.564	1.511	n.s.
Special cause variation									
absent vs. present				0.699	0.472	n.s.	1.042	0.586	n.s.
Level 2									
Job experience									
Low							3.982	1.391	*
Medium							-0.968	0.678	n.s.
High							Ref		
Volume									
Low							-0.043	1.251	n.s.
Medium							2.284	0.830	n.s.
High							Ref		
Habits									
Staying							Ref		
Moving							-0.363	0.683	n.s.
Organizational design									

Eye clinic							Ref		
No eye clinic							2.296	1.034	*
Specialized ophthalmologic scrub nurse									
Yes							Ref		
No							2.116	0.586	*
Random part									
S_e^2	1.915	0.841	*	1.075	0.534	*	0.000	0.000	n.s.
S_{u0}^2	6.009	0.605	**	5.616	0.566	**	6.468	0.689	**
Deviance	1012.823			992.184			828.022		

** $p \leq 0.001$, *$p \leq 0.05$, n.s. not significant

4. DISCUSSION

Hospital processes are currently designed as a function of short turnover times and smooth transitions (as in the case of an eye clinic with low transfer distance between operating room and entry/recovery room and decentralized check in), enhancing flow efficiency for illnesses that can be treated in a structured way, such as cataracts. Our study investigated factors that influence flow efficiency in the cataract surgery process on the surgeon and patient levels, and revealed some controllable and uncontrollable factors with clinical and organizational causes (see Figure 18 for summary).

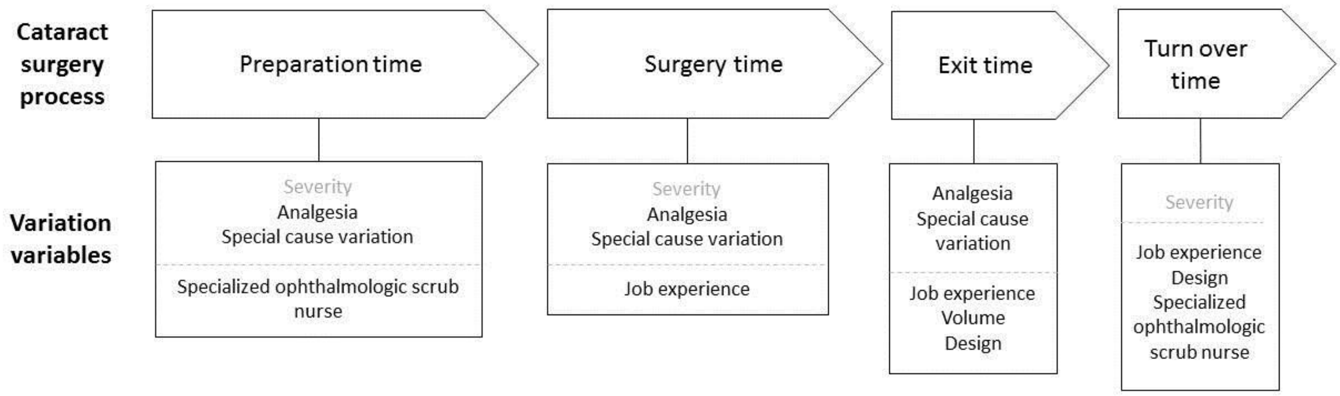

Figure 18 Factors influencing flow efficiency in the cataract surgery process

First, we found that, for the independent variables of preparation time, surgery time, and exit time, the flow efficiency was negatively influenced by the level 1 variable severity of the cataract. It is important to take this into account when planning OR schedules, as we cannot influence severity of illness. So far, two major patient classes are considered in the literature on operating room planning and scheduling, namely elective and non-elective patients. The former class represents patients for whom the surgery can be well planned in advance, whereas the latter class groups patients for whom a surgery is unexpected and hence needs to be performed urgently (Cardoen et al., 2010). Our results show that it is important to pay attention to the severity of the cataract at surgery time, even though cataract surgery is classified as elective (predictable). With respect to planning the operating room this (surgery) duration uncertainty must be taken into account (i.e., severe cataract versus normal cataract). What is more, the first point of contact with the surgeon determines the progression of the cataract, and thus the severity of the cataract. The surgeon cannot influence this first point of contact and therefore cannot control this severity.

Secondly, our analysis illustrates that, on the surgeon level, the time for surgery is influenced by the surgeon's experience. We found a significant difference in surgery time between surgeons with high job experience (> 15 years) and surgeons with low experience (< 5 years). There was, however, no effect found for the volume (the number of cataract surgeries performed per year per surgeon).

Additionally, there was an interaction effect demonstrating that surgeons with medium experience took more time to operate on severe cataracts than did surgeons with high experience. This effect was not found for surgeons with low job experience relative to surgeons with high job experience. This could be explained by the fact that surgeons with low experience avoid operating on patients with severe cataracts at the beginning of their career. Again, we did not find any interaction effect between the severity of the cataract and the volume in our study. This demonstrates that all surgeons (with low, medium, and high volumes of cataract surgeries/year) need longer surgery times for severe cataracts.

Job designs that increase functional specialization are expected to increase quality and efficiency outcomes because of repetition, focus, and the resulting ability to gain higher levels of expertise and skill (e.g., Smith, 1991; Taylor, 1911). Our results indicate (1) that preparation and turnover time can be enhanced by the use of a specialized ophthalmologic scrub nurse, and (2) that exit time and turnover time may be ameliorated by the design of an organization supporting the functional specialization. Scrub nurses are specialized in instrumenting ophthalmologic surgeries, and it seems logical that their expertise, routine, and knowledge can reduce total surgery time. Setting up an eye clinic that brings together all the specialized competences needed to treat cataract patients has a positive effect on flow efficiency (Modig and Ahlström, 2012; Van Vliet et al., 2011).

Our results illustrate that the difference in administering analgesia was a significant variable influencing flow efficiency. More specifically, general analgesia extends exit and turnover time, compared to the use of topical analgesia. Retrobulbar and general analgesia prolonged preparation time at the OR. Although guidelines suggest local analgesia for cataract surgery, one institution mainly used retrobulbar and general analgesia, which was described as a patient preference due to anxiety, and one surgeon used peribulbar analgesia solely. Properly managed local analgesia is easier and safer than general analgesia, especially in patients with significant cardiac or pulmonary problems (Lundstrom et al., 2012). General analgesia should be used only in specific cases (including confused patients and certain medical conditions), and tends to induced extended stays for patients and lower output at the hospital level (Lundstrom et al., 2012). This is in contrast with our findings, in which no relationship can be found between the severity of the cataract and the form of analgesia. Ophthalmologists should be aware of this finding and consciously choose the most appropriate form of analgesia as a function of the patient. However, we must take into account that data regarding the general medical condition of the patient was not considered here.

During the observations, some special-cause variation was detected, leading to a difference in flow efficiency. This variable was a significant disturber of the flow efficiency in preparation—confirming the adage that “a good beginning is half the work”—as well as during the surgery preparation, which was prolonged, and in the exit of the patient. We must emphasize the importance of differentiating between the kinds of variation. As special-cause variation arises because of unusual circumstances and is not an inherent part of a process managing this kind of variation involves locating and removing the unusual or special cause. It must be kept in mind that common-cause variation (such as the severity of the illness) will always be significant. As common-cause variation is inherent in a process managing common-cause variation thus requires improvements to the process.

In health care operations management, more efforts need to be made to understand how medical conditions, in combination with structural and operational elements, affect daily processes and hence flow efficiency.

5. CONCLUSION

Different factors influencing the flow efficiency in the cataract surgery process were detected. Taking into account these factors will increase throughput time at the operating room and enhance quality. However, we note that not all hospitals fully exploit the most efficient design to operate the care process. Consequently, the cataract surgery process does not function at the maximum flow efficiency in these hospitals.

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CHAPTER 5

Do we (have to) walk the line?

Improving care processes through optimized design of the operating system

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ABSTRACT

The impact of the design of the operating system on operational performance is seldom discussed in health care. We conducted a comparative mixed-method case study analysis of sequential care processes in hospitals. We examined differences in the organization of sequential care processes, whether sequential care processes with fully compatible operating systems perform better than those not fully compatible with the operating system, and the causes of variation in sequential care processes. Our findings suggest that, overall, hospitals design their operating system for low turnover times and smooth transitions. They show that aligning structure and processes components with the operating system positively influences operational performance. However, we note that not all cases make optimal use of this concept. Besides special-cause variation disrupting flow efficiency, the results demonstrate that other variables that can be taken into account in planning care processes influence the process. Above that, this paper provides practitioners and academics with a fresh perspective on standardized practices and the factors limiting standardized processes. It also serves as a foundation for future initiatives for improving operational performance in hospitals.

Key words: health care, standardization, operational performance, operations management, cataract

1. INTRODUCTION

Worldwide, hospital care plays a central role in health care delivery and is the largest category of health care spending (American Health Association, 2011), accounting for about one third of all health care expenditure. From an organisation perspective, hospitals dominate the rest of the health care system (McKee and Healy, 2000). Yet, in spite of their importance, hospitals show high degrees of variability and a lack of standardization, resulting in unsatisfactorily low efficiency (McGlynn et al., 2003). In addition, costs vary widely across geographic areas and these geographic differences are not associated with more reliable delivery of evidence-based care or better health outcomes (Fisher et al., 2003). In sum, hospitals are critical but costly resources in health care, so the challenge is to design processes that are flexible while also working to standards that create consistency (Walley, 2007).

In order to improve, our view of health care delivery needs to change (Porter and Teisberg, 2007, Porter and Teisberg, 2006). More precisely, the main purpose of health care systems is not to minimize costs but to maximize value for patients, which in the long run results in better health per dollar spent (Kaplan and Haas, 2014). Value for patients encompasses many of the other goals, such as quality, safety, patient centeredness, and cost containment, and integrates them (Porter and Teisberg, 2006). One key principle guiding the change in health care delivery is that medical practice should be organized around medical conditions and care cycles, instead of around providers. Similarly, the Institute of Medicine (1999, 2001) promotes transparent care processes organized around patients' needs (Kohn et al., 1999, IOM, 2001). Research into improving health care should deal with finding new ways of organizing care and identifying the best methods of organizing and delivering services. Accordingly, the following research question emerges: How should the delivery of care be organized in order to achieve value?

To answer this question, multiple authors (Bohmer, 2005, Bohmer, 2009, Lillrank and Liukko, 2004, Christensen et al., 2009) have claimed that health care professionals are charged with providing two very different types of care: sequential care and iterative care. Sequential care refers to care provided to patients that can be quickly diagnosed (e.g., urinary tract infections and cataracts). These patients have well-known, structured problems; they can be treated by predictable, reliable, low-cost care. In contrast, iterative care refers to patients with unknown conditions (e.g., endocarditis or complex cancer). Such care may require many resources to diagnose and treat, and the outcomes are often uncertain (Bohmer, 2009). From an operational point of view, these unstructured problems make work highly variable. In reality, health care entails a mix of standard and nonstandard processes, certain and uncertain circumstances, and different approaches to disease and illness. The reason we differentiate structured and unstructured problems is that they require different 'operating systems'. An operating system describes the configuration of all the resources and activities that come together to create a service or product (Bohmer, 2009). The operating system for patient problems that are addressed by sequential processes differs from that required when care is provided through an iterative process (Bohmer, 2009). Sequential care requires the (re)organization of care by standardizing the care process, leading to less variation and greater transparency in the performance of care. In contrast, iterative care needs a customized approach.

The impact of the design of the operating system on the organizational level is seldom discussed in health care. A few studies have focused on the effects of lean or six sigma projects (Mazzocato et al., 2010, Radnor et al., 2012), frequently on a single unit level (Andersen et al., 2014), and thereby neglect the degree of fit between process and the underlying system. Because a good fit will facilitate the creation of value in health care, we believe that the design of the operating system should be studied in more depth. We do this in the context of sequential care, because the operating system of such processes is much better described than in the context of iterative care.

This study aims to assess (1) differences in the enrolment of sequential care processes; (2) whether sequential care processes with fully compatible operating systems perform better than sequential care processes not fully compatible with their operating system; and (3) the causes of variation in sequential care processes.

This study builds further on the insights developed in previous research in the field of Operations Management (OM) that explores how, in the manufacturing and service sectors, the design of the operating system should be aligned with the nature of the product or service (Hayes and Wheelwright, 1979, Schmenner, 1986, Schmenner, 2004). Although the importance of achieving a fit is implicit in almost every OM study, the literature has paid limited attention to actually aligning the care processes and the underlying design of the operating system to the nature of care.

This paper is structured as follows: first, an overview of the literature is given and the evaluative framework is described. Second, the research methodology is outlined. Third, the findings are presented and interpreted. Finally, conclusions are drawn, followed by practical implications, research limitations, and avenues for further research.

2. FRAMEWORK

2.1 Theoretical framework

Health care is a complex, multiproduct environment where services are often highly variable and care is customized to individual patient needs (Bohmer, 2009, Christensen et al., 2009). In addition, the level of uncertainty in health care indicates that the care processes differ according to the nature of both illness and care (Christensen et al., 2009, Bohmer, 2009). We can distinguish two ways of problem solving: (1) by applying preformed, pretested solution to a well-understood problem, and (2) by constructing a unique solution to a less well-characterized problem. Both ways are very different: the former is a sequence of well specified steps and the latter is an iterative process of trial and error with multiple feedback loops. Health care professionals are tasked with providing these two very different types of care (Bohmer, 2009). From an operations point of view, such processes require different operating systems and should be organized in separate ways (Bohmer, 2009, Bohmer, 2005, Christensen et al., 2009, Lillrank and Liukko, 2004, van Merode et al., 2004). Yet the way today's hospitals organize their care processes is not always in line with the nature of illness and care; nowadays the majority still use a one-size-fits-all approach to treat patients with different needs. It is clear that this approach, referred to as 'the full-service model' (Porter and Teisberg, 2006) cannot meet the variety of needs of patients in a qualitative, cost-effective way. In this study, we build further on the insight that the design of the care process and the underlying operating system should be in line with the nature of illness and care—a view that is supported throughout the OM literature (Bohmer, 2005, Bohmer, 2009, Christensen et al., 2009, Lillrank and Liukko, 2004).

2.1.1 The design of the care process

Processes are the way an organization gets things done, how it implements its business strategy, how it makes and delivers its products, and how it meets its objectives. Processes should be planned, and require resources, skills, and management (Slack et al., 2009).

For optimal care delivery, the organizational structure and care process should be designed to promote quality and efficiency. The design must take the characteristics of the care process into account. It is also essential to understand the nature of what is being managed (Bohmer, 2009). Knowledge of how to design and run organizations that create high-quality products cost-effectively has been gathered by OM over the last century, especially in the manufacturing industry. OM techniques have been applied widely to optimize flow (Meredith et al., 2011). This results in more standardized production processes and work practices and in better operational performance (Slack et al., 2009). However, the anticipated effects of OM in hospitals are seldom fully exploited. OM approaches try to reduce variation in processes by removing clearly identifiable causes of variation—the special causes of variation. Besides such special causes, there is a type of variation that cannot be eliminated—inherent or common-cause variation. Special-cause variation can be eliminated, but common-cause variation can only managed in the best way possible (McLaughlin and Kaluzny, 2000). In health care, the level of common-cause variation is among others determined by the nature of the illness and may be high or low. Care processes are not always designed in line with the nature of the illness, and so the potential for improving OM approaches is limited (Bohmer, 2009, Bohmer, 2005, Christensen et al., 2009). Health care thus needs a more radical and fundamental rethinking of the design of the process in line with the nature of the care provided (Bohmer, 2009, Lillrank and Liukko, 2004).

In our research, we focus on the design of the operating system of sequential processes. We investigate whether the delivery of sequential care matches a standard process by examining the design of the operating system and its fit.

2.1.2 Design of operating systems in health care

In production terms, the care process can be defined as the set of independent tasks and decision that takes the input of a sick patient and produces a value-added output (Bohmer, 2009). The transformation that makes this happen depends on the input itself—on whether the problem presented is structured or unstructured. The care processes, sequential or iterative, are embedded within a system made up of many structures and processes that allow them to function (Bohmer, 2009). Such processes include the delivery of supplies and resources, the transfer of information, etc. The structures involve the physical environment in which care is delivered, the workforce that organizes and performs activities, the departmental structure, etc. The operating system expresses the configuration of all the resources and activities that together create the service or product (Bohmer, 2009). The structure and process components of the health care operating system act to facilitate and constrain the process by which the problem is solved.

Processes differ in a terms of type, characteristics, and layout; this has a direct impact on the design of the operating system.

2.1.3 Process type

Operating processes can be categorized into different types for manufacturing and for services. The choice of process can be based on the volume and variety of the product or service that an organization offers. The idea that firms should align ‘the nature of their product’ with ‘the nature of the process’ was first introduced by Hayes and Wheelwright in 1979 through their product–process matrix for manufacturing companies (Hayes and Wheelwright, 1979). This matrix consists of two dimensions: the product structure and life cycle and the process structure and life cycle. The process structure and life cycle describe four process categories: a jumbled flow (job shop), a disconnected line flow (batch), a connected line flow (assembly line), and a continuous flow. The product structure and life cycle describe the stage of the product life cycle (low to high volume production) and product structure (low to high standardization). By considering the product–process matrix and aligning these characteristics (the nature of the products, organizing processes based on the volume and level of customization needed), organizations can make their operating units more focused and operate them more effectively and efficiently. The core principle of this model is that manufacturers must make a choice between the low-volume, flexible, high-quality, customized production (job shop, batch) and the high-volume, standardized, low-cost production (assembly line, continuous flow). Reflecting the characteristics of sequential care in this matrix, we can conclude that sequential care features a high-volume, standardized process that can operate as an assembly line or even as a continuous flow.

2.1.4 Process characteristics

According to Slack, Chambers, and Johnston (2009), the goal of any organization is to make most effective use of its operations. Operational improvement can be influenced by the *variety* of output, the degree of operational *visibility* to the customer, the *volume* of the output, and *variation* in the demand of the product and services—the 4V model (Slack et al., 2009). As depicted in Figure 19, in this model of OM, sequential care processes are typically characterized by high volume, low variety, low variation in demand, and medium visibility. Even in sequential care processes, there is a certain level of contact and interaction between the patient and the physician or other staff. We therefore select the option of medium visibility.

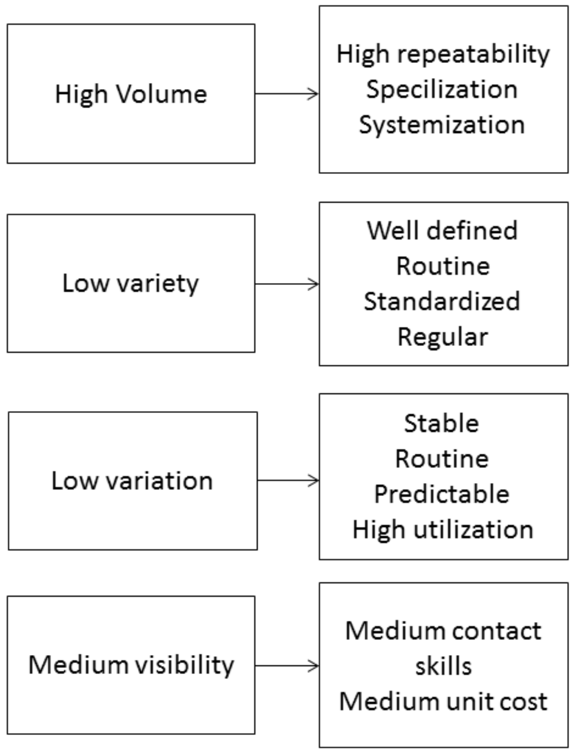

Figure 19 The 4V Process Model for sequential care, adapted from Slack et al., (2009)

2.1.5 Layout

In manufacturing, facility layout consists of configuring the site in terms of lines, buildings, major facilities, work areas, and other pertinent features. An efficient layout can reduce unnecessary material handling, help keep costs low, and maintain product flow through the facility (Slack et al., 2009). We distinguish two main layouts: (1) Process layout are found in firms that produce customized, low-volume products that may require different processing requirements and sequences of operations; their purpose is to process goods or provide services that involve a variety of processing requirements; (2) Product layouts are found in flow shops (repetitive assembly or continuous flow industries), producing high-volume, highly standardized products that require highly standardized, repetitive processes. In theory, sequential layout allows the entire process to be laid out in a straight line, which at times may be totally dedicated to the production of only one product or product version. Subsequently, there are other layouts, such as fixed-position layout (appropriate for a product that cannot be moved) and combination layouts (for situations that call for a mixture of the main layouts). For sequential care processes, the product layout is most appropriate.

In evaluating the design of health care processes, we can consider the process type, volume–variety requirements, and process layout (Figure 20). Optimizing the design of the operating system in terms of process type, characteristic, and layout can results in improved outcomes.

2.1.6 Standardization as a strategy for sequential care

In this context, it is important to distinguish between standard processes and standardized processes. A standard process exhibits predetermined input, procedures, and specified output and is repeated identically (Schafermeyer et al., 2012). Standard processes have the potential to be exactly defined and standardized (Lillrank, 2003). As the events in the process and the outcomes become better understood, the standard process can be designed to accept a specified type of input (Lillrank, 2003). The process is predictable, and can therefore be completed in a consistent manner with a constant cycle time. This makes it possible for the required resources—manpower, equipment, and materials—to be known and available (Schafermeyer et al., 2012). Given a predictable process, it can be determined whether customers' needs can be met and changes can be made to the planning of manpower and resources. It must be kept in mind that standard processes are not permanent and should be updated to reflect changes in cycle times, manpower, and resource availability. Standardization is then defined as the creation of standard, uniform processes. Standardization requires solid recruiting and training (so that operations are performed consistently and reliably), facility design and process engineering which allow one clear goal and one procedure to be focused on, and the consistent use of protocols (Ross et al., 2006). Identifying the best way of executing and of turning standard processes into standardized processes is a very important task of the operations management (Lillrank and Liukko, 2004). Schafermeyer et al. (2010) and Rosenkranz et al. (2010) found that organizations differed in the way they managed their standardization initiatives (Schafermeyer et al., 2012, Rosenkranz et al., 2010).

One well known example of standardization and its benefits in health care is the use of evidence-based medicine (EBM). EBM is the conscientious, explicit, and judicious use of current best evidence, primarily from clinical trials, in making decisions about the care of individual patients (Sackett et al., 1996). EBM generally denotes the use of standardized clinical practice guidelines using the best available scientific evidence to inform medical decision-making and to encourage more effective care. In general, the goal of EBM is to improve quality through the standardization of medical care. EBM is typically implemented through clinical guidelines, protocols, or best practices, all of which are used to standardize patient care (Romana, 2006). The empirical study of Bozic et al. (2010) revealed that process standardization with maximal adherence to evidence-based processes results in substantially improved clinical outcomes and shorter hospital stays. Rozich et al. (2004) found similar results in their study on the standardization of an insulin protocol in hospitals that contributed to reduced variance and enhanced safety. We note that the studies of Bozic et al. (2010) and Rozich et al. (2004) were conducted on processes that resemble sequential care (total joint replacement surgery and an insulin protocol for regular insulin use, respectively).

The sequential care process can be categorized as a standard process; it would therefore benefit from standardization. Again, optimizing the design of the operating system in terms of this standard process will result in improved outcomes. However, an important challenge is to balance the needs of the process—type, characteristics, and layout—with clinical requirements.

2.2 Conceptual framework

To better understand how the design of the operating system (the fit of structure and process elements) impacts the quality of the care process, a conceptual framework has been developed. In this context, a variety of models in health care have been presented in the literature. One of the best known is Donabedian's conceptual framework which distinguishes between three dimensions: *structure*, *process*, and *outcome* (Figure 20), on which a facility's quality of care is said to be based. Consequently, to optimize the quality of the delivery of care, structure, process and outcome should all be considered. 'Structure' refers to the setting in which providers deliver care and the characteristics of the care system, such as organizational structure and the characteristics of the staff and targeted population. 'Processes' concern the activities that take place between practitioners and patients. 'Outcomes' are the result of care and can reflect all aspects of the care-delivery process (Donabedian and Arbor, 1980). Donabedian's model has been extensively used by health service researchers to examine outcomes related to differences in structure and process of care (Baars et al., 2010). In our research, components of each dimension will be identified, measured and compared across hospitals and their operating in the context of sequential care. Our conceptual model (Figure 20) illustrates how process choice, design of the operating system, and outcomes are linked.

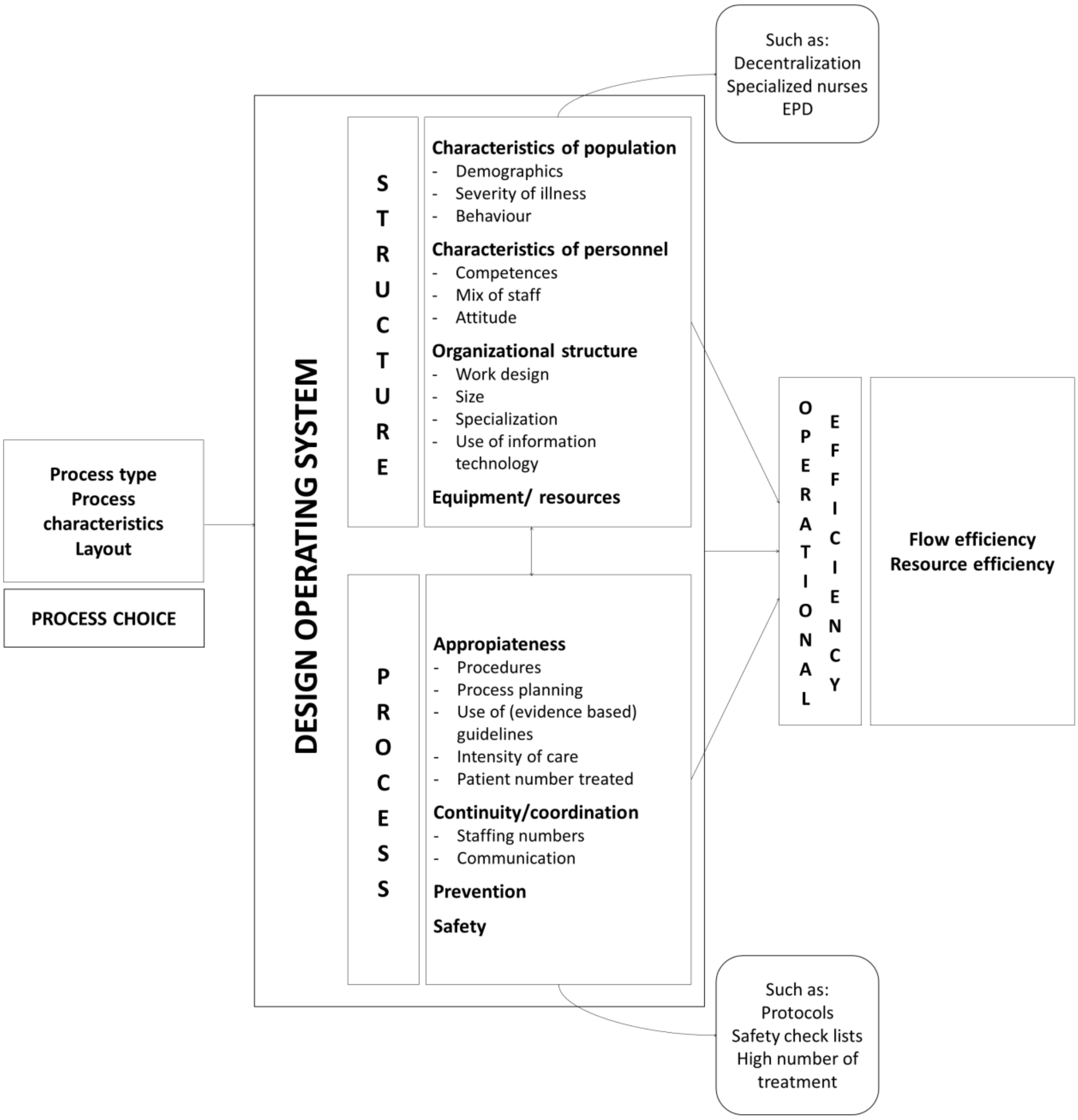

Figure 20 Conceptual framework showing links between process choice, operating system design, and outcome.

In order to develop specific quality measures for the selected care process, we have adopted the classification of Baars et al. (2010). With a literature review, they developed a conceptual framework for the classification of structure and process quality indicators (Baars et al., 2010). This classification enabled us to endorse indicators corresponding to the structure and process measures of Donabedian's model. According to Baars et al. (2010), the characteristics of the population, the staff, and of the organization should be included in defining structure. Process consists of the indicators of appropriateness, continuity and coordination, prevention and safety (Baars et al., 2010).

In Donabedian's model, 'outcome' refers to the result of care (Donabedian and Arbor, 1980). As most patients experience a significant improvement in vision (the main clinical outcome) after surgery (Powe et al., 1994; Schein et al., 1994) and since the incidence of complications is relatively low (The Royal College of Ophthalmologists, 2010), the outcome parameters were not taken into account. In other words, we assume that the outcomes of the different surgeries are comparable. Above that, in this study, no direct postoperative complications occurred. Our focus is on operational efficiency, and more precisely on efficiency of flow, and of resources. As the operational focus is on reducing time spent in removing non-value-adding waste (Ohno, 1998), it is of interest to compare facilities structurally and operationally (Ellwein et al., 1998) to explore the reasons for variation and enhance efficiency. Resource efficiency is the most traditional view in efficiency literature, and focuses on the optimal use of value-adding resources within an organization (Modig and Ahlström, 2012). Efficiency means producing the maximum amount of output for a given amount of input or, alternatively, producing a given output with minimum input quantities (Farell, 1957; Lovell, 1993). This way of looking at efficiency dominates how organizations are organized, controlled, and managed. Flow efficiency, however, focuses on the unit processed in an organization. Flow efficiency is not about increasing the speed of value-adding activities, but about maximizing density of the value transfer and eliminating non-value-adding activities (Modig and Ahlström, 2012). Finally, reducing health care costs is a priority and can be achieved by a good balance between flow efficiency and resource efficiency, without reducing value for the patient.

The concepts described above bring us to the main research questions: First, "Is there a good fit between the process choice and the design of the operating system in sequential care?" Second, "What is the impact of design of operating system—the configuration of structure and process elements—on operational performance (in terms of efficiency of flow and resources) of the sequential care process?"

3. RESEARCH METHOD

3.1 Research design

A comparative benchmark study with a mixed-method design was conducted to compare a sequential process between hospitals. A comparative benchmark study focuses on how similar activities are organized by different organizations (Ellis, 2006) and compares the performance and underlying processes (Watson, 1993). The mixed-method design was deemed appropriate because of the nature of the research question. The qualitative data were used to gain an understanding of underlying reasons and to provide insights into relationships and problems. Quantitative data were used to establish differences between the organizations, uncover patterns, and formulate facts about the relationships between the design of the operating system and the operational performance variables.

3.2 Setting and sample

We selected the cataract surgery process to examine the design of the operating system of sequential processes. Cataract—a clouding of the lens—is the leading cause of curable blindness in the world (WHO, 2000). Surgical removal of cataracts remains the only effective treatment available to restore or maintain vision, with phacoemulsification (an ultrasonic device that breaks up and removes the cloudy lens) being the preferred surgical technique (Lundstrom et al., 2012). These factors limit treatment variation (Van Vliet et al., 2011). Cataract is a high-volume, relatively low-risk procedure. EBM, protocols, and preferred practice patterns for cataract surgery are well established (Lundstrom et al., 2012, Royal College of Ophthalmologists, 2010). The cataract surgery process shows all the characteristics of a sequential process with a high potential fit for standardization.

We mainly focused on the surgical procedure of cataract treatment performed in the Operating Room (OR). In this setting, the inputs of medical personnel, OR technology, and surgical supplies combine for the purpose of producing successful patient outcomes. The aim is to study the impact of the design of the operating system of the surgery on the operational performance related to this treatment; consequently, OR-related flows, resources, and costs were considered.

In Belgium, different organizational designs providing cataract surgery exist. In hospitals, the surgery can be provided at a decentralized eye clinic (a small eye center within the hospital), at a centralized one-day clinic (OR center combined with other minor surgery), or through day-admission to a hospital ward. Private (physician-owned) specialized eye clinics were not included in this study, as we focus on the design of the operating system in hospitals. This study uses data from four hospitals at five sites in one region in Belgium. The composition of the population, the size and availability of a sufficient volume of cataract treatments, the different statuses of the hospitals (university versus general, small versus large), and the different organizational designs were reasons for region. All ophthalmologists performing cataract surgery (n = 18) in these hospitals were invited to participate.

The variation in patient outcomes is very limited in cataract surgery (Van Vliet et al., 2011). Based on this finding, we assume that the observed differences in the process choice and operating system of cataract care in the different hospitals have no impact on the outcome of cataract care. This further means that the observed differences in efficiency of resources, flows, and costs are not at the expense of the quality of the outcome.

3.3 Data collection

Data was gathered in the period from October 2013 to June 2014. The study protocol was approved by institutional review boards (OG 017) and all participation was voluntary.

To evaluate the cataract treatment, core data from the care processes were needed. Our multisource data concern the patient (age, gender, and medical condition), the physician (experience and preferences), and the organization and its operations (resources, capacity, throughput, turnover).

Most data was collected through observations and time measurements in the OR, resulting in qualitative and quantitative data. To reduce the risk of events proceeding differently because of observation, only one researcher was involved in the observations. Limiting the observations to one observer allowed the participants to get used to the researcher's presence. The researcher observed every interaction in the cataract treatment. This research method was deemed best to fully understand and measure the complexity and integrity of the investigated process. Additional information was gathered by walkthroughs of the process and visual material (pictures). Finally, a survey was conducted to gain information about the physician. Financial data were requested from the participating organizations. Unclear events and gaps in information were clarified using informal interviews with staff.

3.4 Data analysis

The first step in data analysis was to map the process to define the cataract procedure using patient chart reviews. This allowed identification of the different steps of the process. Next, qualitative process data were collected in a structured way, allowing matrix analysis, quantitative interpretations, and event analysis.

The outcome measurement is operational performance, i.e., the dependent variables in this study are resource efficiency and flow efficiency. We looked inter alia at flow efficiency in terms of total time at the OR. These time measurements were analyzed using multilevel analysis, MLwiN 2.28. Multilevel analysis is a suitable approach for modeling data with complex hierarchical structures, considering both the context and the individual subjects. The dependent variable is on the lowest level, and explanatory variables may be defined at any level (including aggregates of level-one variables) (Snijders and Bosker, 2012). The models are estimated using iterative generalized least-squares estimations. At first, we used a base null random intercept model with the dependent variable as the response and only one constant term. This model estimates the grand average time across all physicians and all patients. We then added additional predictor variables at both levels. The dataset contains patient variables that are potential predictors of the time efficiency: demographics (age and gender of the patient) and severity of the cataract. The severity of the cataract refers to conditions making surgery more difficult, including preoperative aggravating conditions, small pupil with need of mechanical stretching, dense cataract, and corneal opacities with reduced visibility of the surgical field. We also included the form of analgesia at this level. However, the form of analgesia is also a way to check whether physicians follow the EBM regarding analgesia use during cataract surgery. To assess possible explanatory variables at the physician level (level 2), the following variables were selected: job experience (low: < 5 years; medium: 5–15 years; high: > 15 years), volume (number of cataracts per year: high: > 300; medium: 100–300; low: < 100), positioning of surgeon during surgery (behind or next to the patient). Additionally, we expanded the model with organizational structure (eye clinic setting versus non-eye-clinic setting) and the assistance of specialized ophthalmologic nurse. Finally, the observed special-cause variation (e.g., technical problems) was added at all levels (patient, physician, organization). The variable assumed to generate the largest time gain was used as reference, where necessary.

Relating to the resource efficiency, a systematic comparison of resources and costs between the hospitals was conducted, and an estimation of the direct cost per cataract surgery was made. To systematically compare direct costs of the different designs of the operating system, we took into account the personnel costs that were made in direct patient contact and devised a standard cost per team member, based upon the average Belgian hourly nurse wages in euros. Also the costs for disposable and nondisposable materials (with 10 years depreciation for nondisposables) were included. We applied the *ceteris paribus* assumption for overhead costs, such as electricity, heating, maintenance material, infrastructure, etc.; as the costs do differ between hospitals but are not related to the design of the operating system of the cataract surgery, these costs were not included. We allocated costs per cataract considering the mean daily number of cataracts operated on in the facility.

4. FINDINGS

This section outlines the findings of this empirical study. We present qualitative findings and then the quantitative data.

Sixteen of the 18 ophthalmologists agreed to participate in the study and were included. Thirteen of the 16 physicians responded to the request for additional demographic and professional information. In total, 274 cataract operations were observed (a total of 218 hours of observation), with multiple observations per physician (min 15; max 19). Power calculations, using SPSS SamplePower3 (IBM), showed that the power ($\alpha = 0.05$) was 85% for the variable total time in the OR, assuming a 25% time difference, thus requiring a sample size of 13 patients. The mean age of the physicians was 47 years (30–69) (n = 13), with seven female and nine male physicians. The mean age of the patients was 74 years (45–98), with 145 female and 129 male patients. The demographics and organizational design characteristics of the hospitals can be found in Table 16.

4.1 Process choice: defining the cataract surgery process

The process was mapped using patient chart reviews and supplemented with observations defining the cataract procedure. In cataract treatment, we find a highly standardized approach to the process (Figure 21).

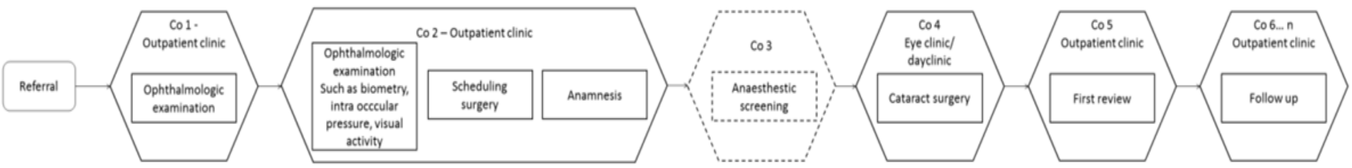

Figure 21 Patient flow map of the cataract treatment process; Co = consultation

Switching our focus to the cataract surgery process in the OR, we can see a standardized approach (Figure 22) with little deviation between the different settings. It is clear that, on average, the vast majority of the patients undergo the same number and same kind of medical interactions. The existence of Cataract Surgery Guidelines (Royal College of Ophthalmologists, 2010), EBM guidelines for cataract surgery (Lundstrom et al., 2012), and clinical pathways in the hospitals limit the variation, provide certainty, and enhance predictability of the care process. The organizational choice of the design of operating system in the hospitals (decentralized eye clinic versus centralized one-day clinic versus day admission to hospital ward) is demonstrated in Table 17. These results illustrate the operational focus of some hospitals on improving care processes by minimizing throughput time, organizing resources in autonomous work cells, and avoid high interference with other processes.

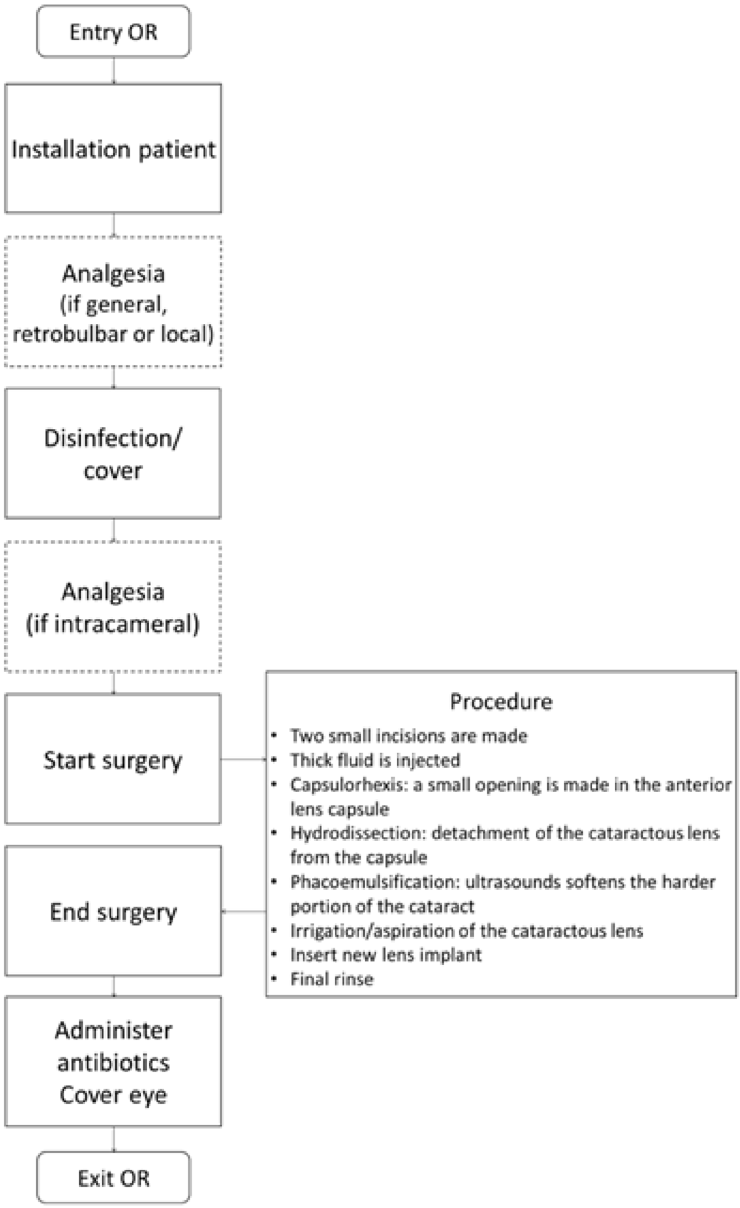

Figure 22 Flow chart of cataract surgery in the Operating Room (OR), based on observations during the study

Table 16 Demographics and organizational design of the hospitals

	Hospital A	Hospital B		Hospital C	Hospital D
Total Size	Large (> 1000 beds)	Intermediate (554 beds)		Intermediate (526 beds)	Large (> 800 beds)
		Site 1	**Site 2**		
Size		Intermediate (± 400 beds)	Small (± 150 beds)	Small (mainly polyclinic)	Small (mainly polyclinic)
Number of ophthalmologists performing cataract surgery /Number of ophthalmologists	3/12	3/4	4/6	1/3	7/9
Organizational design (eye) clinic	**Centralized one-day clinic** (for multiple disciplines) in hospital	**Decentralized eye clinic*** in hospital	**Decentralized eye clinic** in hospital	One-day admission at **hospital ward**	**Decentralized eye clinic** in day clinic
Organizational design Operating Room (OR)	OR room specific for eye surgery	OR room specific for eye surgery	OR room specific for eye surgery	OR room specific for eye surgery	OR room specific for eye surgery

*Eye clinics are hospital-associated locations at which outpatients are given eye treatment; the bulk of the procedures are organizationally separated from those of the hospital.

4.2 The qualitative findings providing insights

In the conceptual framework (Figure 20), we can distinguish the process and structural elements observed in the cataract surgery processes.

4.2.1 Structure elements

We can divide structure into patient and personnel characteristics, organizational structure, and equipment/resources (Figure 20)

To interpret these data, we refer to Table 17. For organizational structure, we notice that organizational differences between hospitals can be found in terms of work design, size, and specialization. Patients were received at an eye clinic (2/5 sites), at a one-day clinic (1/5), or in the ward (1/5). The choice of the eye clinic (including decentralized OR, but mainly centralized reception at the entrance of the hospital (2/3)) revealed minimal transfer distance for the patient.

Most of the physicians work with a specialized scrub nurse (10/16). Materials were similar in all settings (see Figure 23 for an example). In the eye clinics, a short turnover is expected, so a minimum of four available chairs for the preoperative and postoperative admission of patients is provided in the entry and recovery area. Figures 23 and 24 show that the physical layout of resources aligns all activity in the process sequence of the cataract surgery, preventing delays.

Figure 23 Samples of materials on operating tables in different hospitals

Figure 24 Example of entry/recovery area in the cataract surgery process

4.2.2 Process elements

The process elements included appropriateness (procedure, process planning, EBM, intensity of care, and number of patients treated), continuity/coordination (staffing numbers and communication), prevention, and safety (Fig 20). Table 18 and 19 list the results of the process elements.

Planning of the operations and the preoperative and postoperative procedures took place in similar ways, with some small differences, in all hospitals. Practical processes (such as transfer) were better organized in the eye clinic, mainly because of the setting. Regarding the use of EBM guidelines and preferred practices, some physicians were more oriented towards the use of a safety net—e.g., always providing the patient with an intravenous line. Additionally, hospital A has the policy of requiring all cataract patients to be sober before surgery, although there is no necessity for sobriety when using topical or retrobulbar analgesia (which is the case for 80% of their cataract patients). Hospital A also shows a high use of general anesthesia (20%) compared to other hospitals (where we note no use of general analgesia for the cataract surgery); topical analgesia is recommended and most commonly used for cataract surgery.

Prevention—e.g., administering antibiotics—seems to be standard at all hospitals. This is in line with EBM, where results showed that antibiotics injected into the eye reduced the risk of endophthalmitis by 80%– 90% (Gower et al., 2013). In all hospitals, a standard safety checklist was present, although this was most clear in hospital D, where not only the safety checklist was checked and signed off by the OR nurses and the physician, but this list was also visible (mounted on the wall) in XL format with a proactive policy to follow safety guidelines.

Looking at the intensity of care, we can see that hospitals with an eye clinic have a higher average daily number of patients and a shorter average total OR time (Table 18). As shown in Table 19, the hospitals with an eye clinic for cataract surgery used notably lower staffing levels than the other hospitals, both in the entry–recovery area and in the OR. Back-office staff (including logistics, sterilization, and cleaning departments) were not taken into account.

Table 17 Structure elements (work design, size, specialization, use of information technology) in the different hospitals

	Hospital A	Hospital B Site 1	 Site 2	Hospital C	Hospital D
Work design					
OR[4] setting	Specific for eye surgery, shared with other disciplines (on different days)	**Only for eye surgery**	**Only for eye surgery**	Specific for eye surgery, shared with other disciplines (on different days)	Specific for eye surgery, shared with other discipline one day a week
OR allocation	OR reserved for eye surgery on specific days a week	OR **only for eye surgery**	OR **only for eye surgery**	OR mainly for eye surgery	OR mainly for eye surgery (one day a week, minor surgery)
Preoperative administration	At the entrance of the one-day clinic (by administration and nurse) **Decentralized**	At the entrance of the eye clinic **Decentralized**	At the entrance of the hospital **Centralized**	At the entrance of the hospital **Centralized**	At the entrance of the hospital and of the eye clinic **Centralized**
Transfer to OR	Long transfer distance (>150 m)	**Very short transfer distance (<5m)**	**Very short transfer distance (<5m)**	Short transfer distance (<50 m)	Short transfer distance (<10 m)
Size					
Global setting of OR for eye surgery	Nine **centralized** ORs for different minor surgical disciplines (e.g., stomatology, ORL)	Two **decentralized** ORs for minor surgical disciplines (e.g., urology) Separated room for admission of the eye surgery patients	**Decentralized** OR only for eye surgery	Four **centralized** ORs for different minor surgical disciplines (e.g., stomatology, ORL)	Two **decentralized** ORs for eye surgery
Preoperative admission area/room	8 positions (chairs or beds) individual rooms available	4 positions (chairs)	5 positions (chairs)	Beds in hospital ward	4 positions (chairs)

[4] Operating Room

Use of information technology					
Administration	Mainly electronic	Mainly on paper, electronic surgical report	Mainly on paper, electronic surgical report	Mainly on paper, electronic surgical report	Mainly on paper, electronic surgical report
Equipment/ resources					
Material in OR	**Prepared standardized packages**	**Prepared standardized packages**	**Prepared standardized packages**	**Prepared standardized packages**	**Prepared customized standardized packages**
	Fixed operation table	Fixed operation chair	Fixed operation chair	Fixed operation chair	Rotatable OR chair/table (patient is brought in on operating table)
General equipment	Full installation	Basic installation	Basic installation	Semibasic installation	Semibasic installation
Material admission room	Chairs (inc. transport to OR)	Chairs	Chairs	Chairs	Beds
Specialization					
Design clinic for cataract surgery	One-day clinic	Eye clinic	Eye clinic	Eye clinic	Integration in general ward
Specialized scrub nurse	No	Yes	Yes	Yes	Yes

Table 18 Process elements (procedures, process planning, EBM, safety, patient number treated, intensity of care) in the different hospitals

	Hospital A	Hospital B Site 1	 Site 2	Hospital C	Hospital D
Procedures					
Procedures	Sterile field is made up immediately prior to patient's arrival	Sterile field is made up in advance (while previous patient is in OR)	Sterile field is made up immediately prior to patient's arrival	Sterile field is made up in advance (between patients in OR, always one patient ahead)	Sterile field is made up immediately prior to patient's arrival
Preoperative check-in	Parameters: - anamnesis - blood pressure, pulse - Clothes : - operation gown (remove all clothes except underwear), bathrobe, cap, disposable slippers Administration of medication (e.g., eye drops)	Parameters: - blood pressure, pulse Clothes: - gown above clothes, cap Administration of medication (e.g., eye drops)	Parameters: - blood pressure, pulse Clothes: - gown above clothes, cap Administration of medication (e.g., eye drops)	Parameters: - blood pressure, pulse Clothes: - cap, removal shoes Administration of medication (e.g., eye drops)	Parameters - blood pressure, pulse - anamnesis by anesthetist Clothes: - gown above clothes, cap Administration of medication (e.g., eye drops) Oxygen (nose) tube, electrodes Check up by anesthetist (anamnesis)
Postoperative policy	Parameters - Control blood pressure, pulse Provide something to eat/drink Help patient get dressed Explain follow-up care Post up consultation day 1, appointment scheduled in advance	Parameters - Control blood pressure, pulse Provide something to eat/drink Explain follow-up care Post up consultation day 1, appointment scheduled in advance	Parameters - Control blood pressure, pulse Provide something to eat/drink Explain follow-up care Post up consultation day 1, appointment scheduled in advance	Parameters - Control blood pressure, pulse Provide something to eat/drink Explain follow-up care Post up consultation day 2, appointment scheduled in advance	Parameters - Control blood pressure, pulse Patient can get something to eat or drink at the hospital restaurant Explain follow-up care Post up consultation (day depend on physician preferences), appointment scheduled in advance

In between operations	Clean up used materials Clean up by **cleaning staff**	Clean up used materials Clean up by nurse if necessary	Clean up used materials Clean up by nurse if necessary	Clean up used materials Clean up by nurse if necessary	Clean up used materials Clean up by nurse if necessary
Process planning					
Planning OR	Block scheduling, bundled by surgery OR scheduled for eye surgery (per ophthalmologist)	Block scheduling, bundled by surgery OR scheduled per ophthalmologist	Block scheduling, bundled by surgery OR scheduled per ophthalmologist	Block scheduling, bundled by surgery OR scheduled for eye surgery	Block scheduling, bundled by surgery OR scheduled for eye surgery per ophthalmologist
Transfer to OR	OR nurse picks up the patient (with bed or in chair)	Patient is brought in (on foot) by nurse at eye clinic	Patient is brought in (on foot) by OR nurse or by nurse at eye clinic	Patient is brought in (by wheelchair) by ward nurse	OR nurse picks up the patient (with bed or in chair)
EBM					
IV	**Always**	Only when required by physician	When performing retrobulbar analgesia	Only when required by physician	**Always**
Sobriety	**Always sober**	Not sober	Not sober	Not sober	Not sober
Form of analgesia % of total in hospital	Topical: 17% Topical + intracameral: 0% Retrobulbar: 63% Peribulbar: 0% General: 20%	Topical: 36% Topical + intracameral: 64% Retrobulbar: 0% Peribulbar: 0% General: 0%	Topical: 85% Topical + intracameral: 0% Retrobulbar: 15% Peribulbar: 0% General: 0%	Topical: 24% Topical + intracameral: 0% Retrobulbar: 76% Peribulbar: 0% General: 0%	Topical: 85% Topical + intracameral: 0% Retrobulbar: 15% Peribulbar: 0% General: 0%
Prevention					
Antibiotic policy	Always administer antibiotics	Always administer antibiotics	Always administer antibiotics	Administer antibiotics when indicated	Always administer antibiotics
Safety					
Safety checklist	Present, signed by physician	Present	Present	Present	Explicitly present check by nurse and physician

Intensity of care					
Monitoring OR	Heart rhythm, saturation, blood pressure	Saturation , pulse	Saturation, pulse	Saturation, pulse	Heart rhythm, saturation, blood pressure
Average number of patients/day	8	13.6	13.6	11.2	13.6
Average time (minutes)/cataract surgery treatment	61	35	35	43	36
Communication					
Information brochure patients	Available	Available	Available	Available	Available
Communication between personnel OR-entry/recovery area	Difficult and indirect	Optimal and direct	Optimal and direct	Difficult and indirect	Optimal and direct
Flexibility					
Transfer	Patients is brought back (in bed or chair) to one-day clinic or recovery (after general anesthesia) by OR nurse Nurse fetches next patient for OR in combination	Patient is picked up (on foot) by nurse of eye clinic	Patient is brought back (on foot) by OR nurse	Patient is picked up (with wheelchair) by ward nurse Nurse brings next patient along	Patients is brought back (with operating table/chair) to eye clinic by OR nurse Nurse fetches next patient for OR in combination

4.3 The quantitative findings looking at operational performance

4.3.1 Flow efficiency

Flow efficiency showed special-cause variation (i.e., not process related variation) in 19% of cases (51 out of 274). This was mainly on the organizational level, such as technical problems with devices (n = 6), sterile instruments not ready (n = 4), problems with materials (n = 4), missing lenses (n = 2), delay in administering eye mydriatics (n = 1), high work pressure on the ward (n = 1), or forgetting to prime devices (n = 1). On the physician level, there was the location of the ophthalmologist (switched during surgery) (n = 15), getting acquainted with new material (n = 2), physician late to OR (n = 2), and physician disturbed during OR (n = 4). And on the patient level, we saw the sterility of the operating field being disrupted by the patient (n = 3).

Table 20 provides the data analysis of the time measurements at the OR, considering the characteristics of the patients and personnel, work design, and specialization of personnel. Factors influencing the total OR time are revealed. The first model (M1) is an intercept-only model, with intercept at 37.291 minutes, which is the average total time in the OR for all physicians and all patients. If we calculate the intraclass correlation (ICC) on the physician level, we find an ICC of 0.506, meaning that 50.6% of the variance in time in the OR is variance between physicians, while approximately 50% of the total variance is variance of the physician between patients. We can conclude that it is worth analyzing these data using multilevel analysis. A second model (M2) was drawn up and included patient fixed predictors (level 1). This model predicts a mean total OR time of 35.006 minutes. As the decrease in deviance (from 2016.699 to 1968.054; $\Delta = 48.645$, $p \leq 0.001$) was significant, this suggests that the quality of the model did improve by adding the level-1 predictors. Considering the results and comparing these with the results from M1, we can see that the addition of the fixed explanatory variables at level 1 reduced the variance on both the physician and patient level. In the fixed part of the model, the severity of the cataract and the use of general analgesia compared to topical anesthesia (analgesia with eye drops) increase total OR time. Additionally, we allowed the slope of severity to differ across physicians, as there might be differences between physicians on total OR time when confronted with severe cataracts. Some might operate faster, while others might work at a slower pace. Using a model with random coefficients for severity at the physician level did not, however, explain more variance when comparing the results to M2 (Su12 10.178(6.795)). It therefore added no value to the model and was not included. In a third model (M3), physician fixed predictors (level 2) were added. M3 predicts an average total OR time of 32.683 minutes. The between-physician variance is reduced to 9.134. This illustrates that, after accounting for explanatory levels at level 2, the proportion of unexplained variance due to differences between physicians dropped to 11%, illustrating that almost all variation at physician level is explained by the variables in M3. In the fixed part of M3, the presence of a specialized nurse enhances time efficiency to 4.976 minutes below average. The presence of special-cause variation decreases efficiency to 5.913 minutes above average. Finally, the crosslevel interactions effect of severity cataract*job experience of physician and severity cataract*volume were analyzed to determine if surgeons more experienced (in years and volume) took less time to perform surgery on severe cataracts. However, the interaction effects were not significant and thus not included in the final model.

4.3.2 Resource efficiency

Cataract treatment was more resource efficient in hospitals with an eye clinic design than in hospitals without (Tables 19, 20, and 21). The costs associated with staffing levels varied; e.g., staffing costs were 3.5 times higher at hospital A than at hospitals B and D with the eye clinic design. The number of cataract operations was 1.5 times higher in hospitals B and D than in hospital A where, on average, surgery took 1.5 times as long.

Table 19 Number of staff for cataract surgery

	Hospital A	Hospital B		Hospital C	Hospital D
		Site 1	Site 2		
Centralized admission					
Administrative staff	N/A	N/A	1	1	1
Entry/recovery area					
Administrative staff	1	1	N/A	N/A	N/A
Nurses	3	1	1	2	1
Operating Room					
Nurses	2/3	1	1	1	1/2
Scrub nurse or assistant ophthalmologist	1	1	1	1	1/0
Ophthalmologist	1	1	1	1	1
Total	8/9	5	5	6	5

Table 20 Multilevel analysis of total OR time

	M1 Random intercept model			M2 + patient variables			M3 + physician variables			M4 + organizational variables and overall variables		
Fixed part	**Coefficient**	**s.e.**	**sig**	**Coefficient**	**s.e.**	**sig**	**Coefficient**	**s.e.**	**sig**	**Coefficient**	**s.e.**	**sig**
Intercept (minutes)	37.291	2.293	**	35.006	2.217	**	32.683	1.912	**	37.667	4.292	**
Patient variables Level 1												
Demographics												
Gender (men vs. women)				0.472	1.040	n.s.	0.521	1.228	n.s.	1.300	1.211	n.s.
Age (age-gm)				-0.052	0.059	n.s.	-0.044	0.069	n.s.	-0.022	0.067	n.s.
Severity												
Normal vs. severe				6.746	1.340	**	6.843	1.548	**	6.131	1.506	**
Analgesia												
Topical				Ref			Ref			Ref		
Topical + intracameral				-2.107	5.674	n.s.	3.864	4.318	n.s.	1.552	3.515	n.s.
Retrobulbar				3.761	2.247	n.s.	2.145	2.333	n.s.	2.292	2.452	n.s.
Peribulbar				4.733	5.736	n.s.	-	-		-	-	
General				15.217	3.502	**	13.176	3.785	**	12.641	3.768	**
Physician variables Level 2												
Job experience												
Low							14.717	6.120	*	11.387	5.678	*
Medium							-0.721	3.248	n.s.	1.369	2.844	n.s.
High							Ref			Ref		
Volume												
(Number cataracts/year)												
Low							4.401	6.253	n.s.	0.716	5.002	n.s.
Medium							-2.093	4.292	n.s.	-3.351	3.475	n.s.
High							Ref			Ref		
Habits												
Staying							Ref			Ref		
Moving							-2.163	3.257	n.s.	0.372	2.841	n.s.

Organizational variables												
Organizational design												
Eye clinic										Ref		
No eye clinic										-3.920	4.072	n.s.
Specialized ophthalmologic scrub nurse												
Yes										Ref		
No										4.976	2.467	*
Overall Variables												
Special-cause variation												
Not present vs. present										5.913	1.586	**
Random part												
S_e^2	79.556	29.736	**	51.538	19.736	*	9.134	5.348	n.s.	4.102	3.271	n.s.
S_{u0}^2	77.632	6.835	**	65.978	5.806	**	75.835	7.364	**	71.935	6.986	**
Deviance	2016.699			1968.054			1627.071			1609.484		

Table 21 Cost per cataract surgery in euros

	Hospital A	Hospital B		Hospital C	Hospital D
		Site 1	Site 2		
Material/surgery					
Nondisposable	12.68	9.55	9.55	9.55	10.51
Disposable	855.04	855.04	855.04	855.04	855.04
Medication/disinfection/fluids	93.64	93.64	93.64	93.64	93.64
Staff/surgery					
Mean cost	132.53	37.71	37.71	43.99	61.05
TOTAL	**1093.89**	**995.93**	**995.93**	**1002.22**	**1020.23**

5. DISCUSSION

The findings based on qualitative and quantitative analysis suggest that, overall, hospitals design their operating system in terms of low turnover times and smooth transitions. The main research question looked at the fit between the process choice and the design of the operating system in sequential care. Cataract surgery is a standard process that can be standardized. Standardized material and protocols that follow best practice and aim to maximize the service level for patients are being used, indicating the possibilities and advantages of standardization for sequential care. However, we note that not all cases make optimal use of this concept. We looked the impact of the design of operating systems on the operational performance of the sequential care process (in terms of flow and resource efficiency); the results above thus indicate that hospitals treating cataract patients in the setting of an eye clinic—taking into account the structure and process elements—enhance flow and resource efficiency. As the structure and processes were optimized in the eye clinic, we found not only that more patients were treated, but also shorter turnover times (shorter total OR times). We also noticed a significantly lower level of staffing that did not affect the efficiency at the eye clinics, and even resulted in lower costs. As hospital A had remarkably fewer surgeries per day than the other organizations, it could be stated that capacity use (e.g., non-disposable material) and human resources (e.g., staffing level) are far from optimal, resulting in both higher costs and lower revenues. These elements emphasize the importance of the fit between the design of the operating system and the sequential care process. This also confirms the importance of walking the line, as deviating from the optimal design causes lower efficiency in sequential care processes. To abide by the standards and walk the straight path brings benefits within the sequential care process.

Besides the presence of special-cause variation that prolong OR time, the analysis demonstrated some other variables that influence the cataract process. First, on the patient level, our results show that it is important to pay attention to the severity of the cataract: even though cataract surgery is classified as elective (predictable), flow efficiency was negatively affected by the severity of the condition. The prolonged surgery time for the severe cataracts should be taken into account when planning OR schedules. Second, our analysis illustrates that, on the physician level, the time for surgery is influenced by the surgeon's experience. We found a significant difference in surgery time between physicians with length job experience (> 15 years) and physicians with short experience (< 5 years). There was, however, no effect found for the volume (the number of cataract surgeries performed per year per physician). We must emphasize that our results looked at the surgery time, and not at the clinical outcomes, as this was not our main focus. So it remains possible that high surgeon volume is associated with improved patient outcome, as shown in previous research (Chowdhury et al., 2007). Third, our results illustrate that the difference in administering analgesia was a significant variable influencing flow efficiency. More specifically, general analgesia extends the total OR time, as compared to the use of topical analgesia. Although guidelines suggest that local analgesia be used for cataract surgery, one institution used mainly retrobulbar (injection with analgesia in the orbit within the muscle cone behind the globe of the eye) and general analgesia—described as a patient preference due to anxiety; one physician solely employed peribulbar analgesia (injection with analgesia in the orbit outside the muscle cone). Properly managed local analgesia is simpler and safer than general analgesia, especially in patients with significant cardiac or pulmonary problems (Lundstrom et al., 2012). General analgesia should be used only in specific cases (including confused patients and certain medical conditions). Ophthalmologists should be aware of this finding and consciously choose the most appropriate form of analgesia for the patient. Fourth, total OR time can be reduced by the use of a specialized ophthalmic scrub nurse. Scrub nurses are specialized in instrumenting ophthalmologic operations, and it seems logical that their expertise, routine, and knowledge can reduce operating time. Setting up an eye clinic that brings together all the specialized competencies needed to treat cataract patients has a positive effect on flow efficiency (Van Vliet et al., 2011, Modig and Ahlström, 2012). Fifth, the presence of special-cause variation significantly disturbed the flow efficiency. We must emphasize the importance of differentiating between the kinds of variation and the presence of 'artificial' special-cause variation (Appleby et al., 2011). As to whether these factors are controllable or not, it must be borne in mind that, for example, common-cause variation—such as the severity of the illness—will always be significant.

We can recommend the use of highly specialized personnel (Chowdhury et al., 2007). For example, hospital managers may consider the level of experience of the ophthalmologist when planning OR allocation.

6. MANAGERIAL IMPLICATIONS

Hospital managers seeking to improve operational performance will benefit from this research, which shows that optimizing the process through the design of the operating system enhances operational performance in case of sequential care processes. This finding assists hospital managers and physicians in being cognizant of the process choices they make. The managers are advised to first understand the process choices of each care process. For instance, sequential care processes can be considered as standard processes and may benefit from standardization. The research also indicates variables that can cause hitches in the flow of the process; acting with awareness of this is essential. On the other hand, not all care processes show the characteristics of sequential care processes, and it is thus equally important to fully understand the contribution of the classification scheme developed in this paper.

We highlight the importance of the fact that operating systems and processes must be deliberately designed if they are to produce enhanced medical outcomes.

7. LIMITATIONS AND FURTHER RESEARCH

Although this research provides a deeper understanding of the effects of optimal design of the operating system on sequential care processes in hospitals, in the context of today's variety of care processes, several limitations need to be addressed. First, the use of a specific type of care process—cataract surgery—implies that additional caution is needed in generalizing our findings. The research is also limited to hospitals in Belgium. To increase understanding of the relationship between the design of the operating system and operational efficiency in different contexts, it would be insightful to replicate this study using a larger representative sample of hospitals. It would also be valuable to perform an international study that considers the differences between different types of health care systems. The methodology described in this study could be extrapolated for this use. As with all observational studies, there is an element of subjectivity to the observations that are made. We also accentuated the possibility of learning from each other when comparing care processes between different organizations. One should not be resistant to replicating best practice on the organizational level.

A second and obvious research limitation is the limited number of centers. Our findings would have benefited by the inclusion of more centers.

Another limitation is the contextual environment of our research design; we focused on the internal environment and setting. Although measurements in our study were conducted on the level of the organization, the physician, and the patient, consideration of the contextual environments would make the investigation more comprehensive. Future research should investigate the internal and external factors that might influence the design of the operating system of hospitals. Future researchers may also extend the current analysis by investigating the willingness of medical personnel to standardize processes and whether there is an association between the use of incentives and the level of standardization.

In our view, these limitations do not, however, substantially detract from the significance of our finding that the design of the operating system of sequential processes can be optimized and that the higher the level of standardization (in terms of optimal design) of the operating system, the better the efficiency of these processes.

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CHAPTER 6

GENERAL CONCLUSION AND DISCUSSION

1. MAIN FINDINGS

The main objective of this dissertation is to provide guidance in the organization of care delivery, in order to achieve higher quality and more efficient outcomes within hospital settings. In four studies (one systematic literature review, one exploratory, and two empirical studies), we have addressed the central research question of this dissertation: How should the delivery of care be organized in order to achieve higher quality and greater efficiency? Each of the studies focuses on a different aspect of the design of the operating system we desire to investigate (Figure 25). This chapter offers an overarching reflection on all the studies. As a starting point, we revisit the framework developed in Chapter 1.

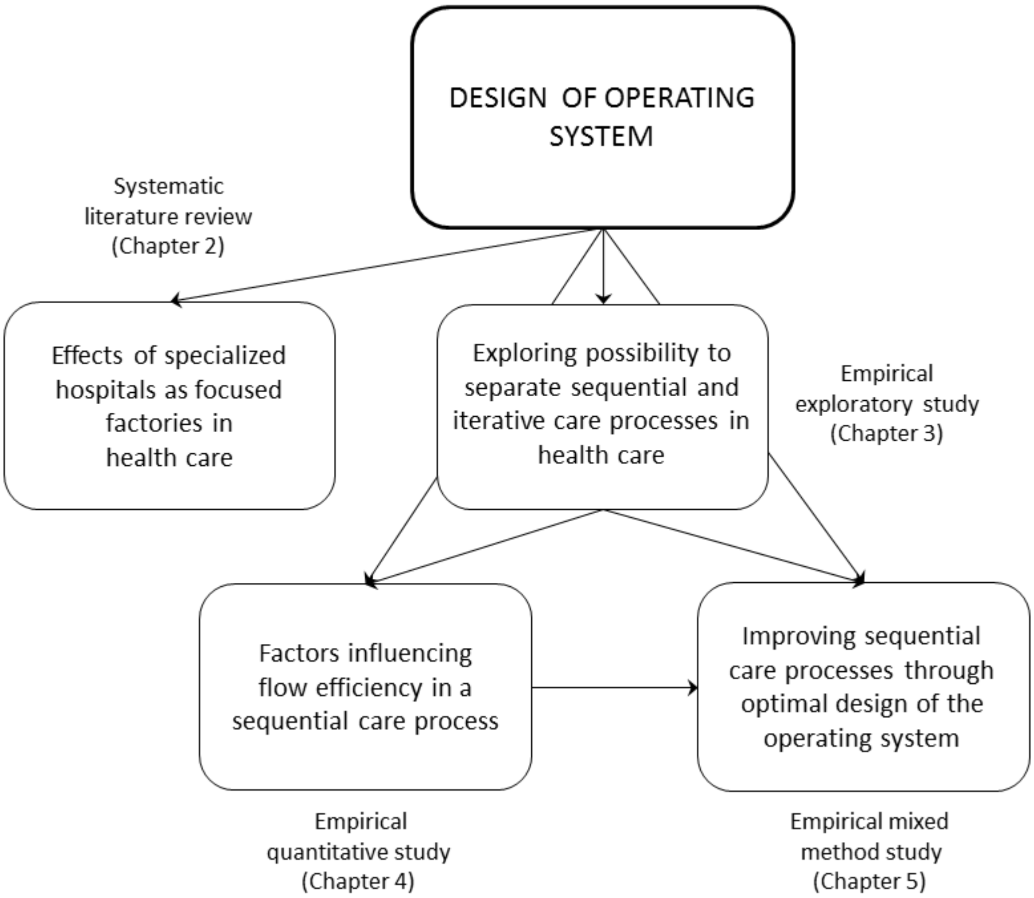

Figure 25 Overview of the described studies

The first study looks at the concept of focused factories as implemented in standalone specialty hospitals in health care. We believe that sequential and iterative care requires different operating systems if it is to improve patient and hospital outcomes. This makes it plausible that hospitals focusing on the sequential care process should perform better, since concentrating on one specific treatment or disease is said to increase hospital care efficiency. In manufacturing contexts, the focused factory is described as '*a plant established to focus the entire manufacturing system on a limited, concise, manageable set of products, technologies, volumes, and markets precisely defined by the company's strategy, its technology, and its economics*' (Skinner, 1974; Skinner, 1985) When distinct products are produced in the same manufacturing system, it is likely that trade-offs will need to be made. Focusing means avoiding such trade-offs, which can reduce the company's or organization's level of competitiveness (Hayes et al., 2005; Mukherjee et al., 2000; Ruwe and Skinner, 1987; Skinner 1974, Skinner 1985). In the case of services, focusing means segmenting markets and providing distinct delivery systems for each (Davidow and Uttal, 1989; Schmenner, 1986). Relatively homogeneous customer groups can be targeted through this approach, which gives organizations access to smaller and more predictable patterns. These can then be managed more easily (Davidow and Uttal, 1989).

Recently, specialized facilities have emerged in the US alongside the traditional full-service general hospital as alternative settings of care delivery. These facilities are typically hospitals that treat patients with specific medical conditions and those in need of specific medical or surgical procedures. The design of their operating system has been adjusted to the needs of their particular target groups, which is supposed to lead to improved efficiency and quality of care. However, our study reveals that there is no convincing evidence for this statement. Furthermore, our results show that the rise of specialized facilities could have a significant negative financial impact on full-service general hospitals, which suggests the need for caution in dealing with this approach. However, our findings on standalone specialized facilities cannot be generalized to the operating system of focused factory settings within general hospitals. This is supported by the recent empirical study of Cook et al. (2014), who state that creating a 'focused factories' within the known solution shop model of the traditional full-service general hospital (most general hospitals today) can be effective in both improving quality and reducing costs in some cases. Their findings encourage the design of different operating systems for different care processes within one institution (i.e., hospitals).

To better understand the European hospital context and to explore if there are different care processes we conducted a second study that uses database analysis to explore whether it is possible to classify health care process into different groups. As argued in Chapter 1, there are two types of processes in health care: sequential and iterative care processes. These are very different, but both types could benefit from the alignment of the configuration of the operating system to the specific characteristics of each type of process, i.e. the characteristics of either a sequential or an iterative process. Our results indeed supports this idea, as we identify processes with inherently very low to low dispersion in LOS, as well as those that show high to very high dispersion in LOS within APR-DRG groups. Consequently, these findings indicate that a difference in the degree of dispersion actually exists and is detectable. The group with small LOS dispersion might benefit from standard sequential care[5]. Groups with high and very high dispersion in LOS, on the other hand, might benefit more from customized care. Furthermore, we find differences in the distribution of the classification groups between the different hospitals. As mentioned in Chapter 1, these findings were the main trigger to further investigate what the causes of variation are, especially in a sequential care process—as we hypothesized that there should be little difference between hospitals in this process. Further research is therefore necessary to identify the reasons for inter-hospital differences, with a specific emphasis on the role of operating system dissimilarities. As the inter-hospital differences could not be explained exclusively by the severity of illness or by the risk of mortality of the patients, this implies that there could be differences in the process and the underlying operating system in the hospitals. The reasons behind such differences may vary, but remain complex. Therefore, in the final two studies, we looked into a sequential process—namely, the cataract surgery process. We use two new empirical studies to investigate the sequential care process in more detail. Specially, these studies focus on cataract surgery, as this process shows all the characteristics of a sequential process with a high potential fit for standardization. The first of these studies (Chapter 4) focuses on the surgery process in the OR. This study identifies controllable and uncontrollable factors with clinical and organizational causes influencing flow efficiency in the cataract process. These factors can be taken into account in the management of health care process. In the second study (Chapter 5), we examine differences in the organization of this sequential care process and see whether sequential care processes with a fully compatible operating system perform better than sequential care processes in a not entirely compatible operating system. Likewise, we investigate whether this process would be suited by a high level of standardization. Our findings demonstrate that, overall, in the case of cataract surgery, hospitals design their operating system as a function of low turnover times and smooth transitions. Aligning structure and process components with the operating system positively influences operational performance. Yet our results show that not all cases in our study align their operating systems

[5] The group with small LOS variation might also be a direct consequence of a standard approach in the care process, as variation is reduced when standardizing processes.

with the process. Consequently, performance in these cases might be improved by optimizing the design of the operating system to the characteristics of the care process. Another important finding involves the fact that sequential care processes can be considered standard processes, and might therefore benefit from standardization. Our research also provides variables that can cause hitches in the flow of the process; acting in line with this knowledge is essential.

2. ACADEMIC CONTRIBUTIONS

In this research, we have synthesized and built on literature originating from the fields of operations management, service management, and health care management, with a focus on hospital care. The contributions to each of these research fields will be now discussed individually. Since some contributions apply to multiple scientific fields, there is some overlap between the subsections.

2.1 Operations management

This project has made important contributions to the operations management literature. First, the research has addressed process choice (i.e., process type, process characteristics, and process layout) in a service industry. Although the importance of achieving a fit between the nature of the process and the nature of the product is implicit in OM (Hayes and Wheelwright, 1979), there has been little attention paid in the literature to the examination of the alignment of care processes and the design of their operating systems in health care. Previous research has focused mainly on optimal process development in manufacturing (Marucheck et al., 1990; Richardson, 1985; Safizadeh et al., 1996). However, Bohmer (2009) and Christensen et al. (2009) identified the importance of hospitals reconstructing their operational activities as a function of the process type they possess. As already indicated, the nature of the service in health care is generally determined by the extent to which the underlying health care problem is structured. The nature of the service (structured versus unstructured health problems) determines the nature of the care process—that is, sequential versus iterative processes. By exploring the concept of process choice in the field of hospital care on an operational level—suggesting different modes of operation—we have contributed to operations management. For example, in considering the product–process matrix in the context of health care (Figure 26), we can clearly situate the sequential care process (e.g., cataract surgery process) in the quadrant on the lower right. Placing the sequential care process in the left box would lead to a mismatch in the alignment of the design of the operating system and the process, and hence negatively impact efficiency.

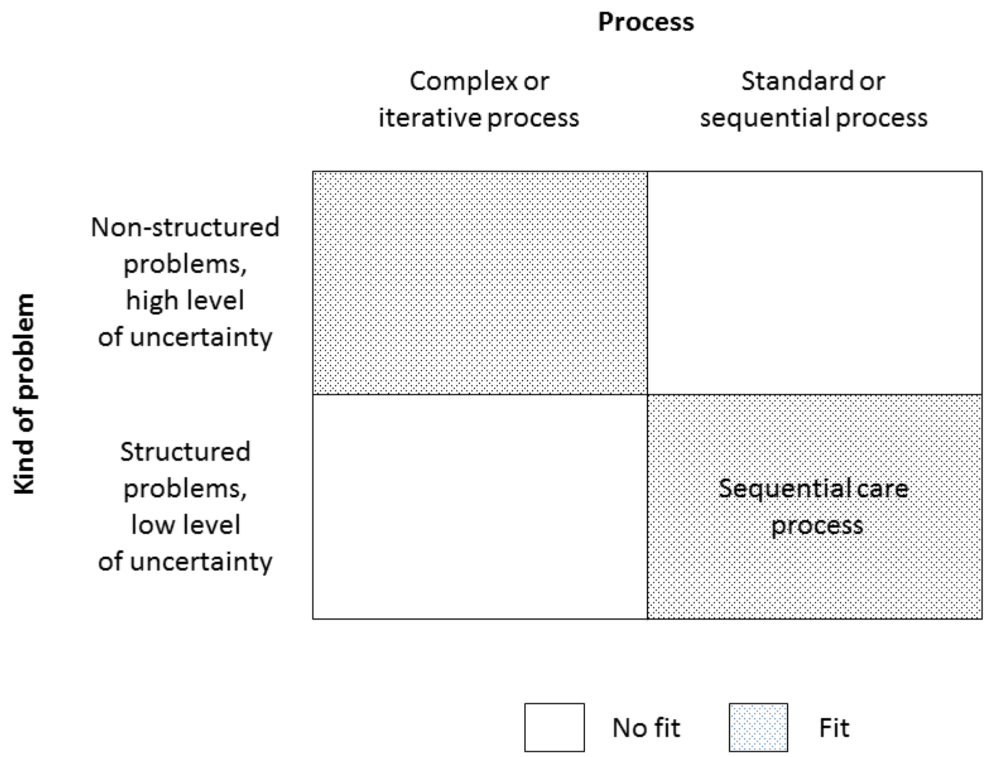

Figure 26 The sequential care process in the Product–Process Matrix for health care. Adapted from Gemmel et al., (2013)

Second, in our study the case of cataract surgery was used to represent the sequential care process. In this process we were able to distinguish different steps in the process (Figure 27) and identified in each step controllable and uncontrollable factors influencing the flow. These steps can easily be translated to other sequential care surgery processes (like hip- and knee surgery). This implies that efforts should be focused on maximizing the flow efficiency by minimizing the negative controllable factors and manage the uncontrollable factors in the best possible way for each different step in the process.

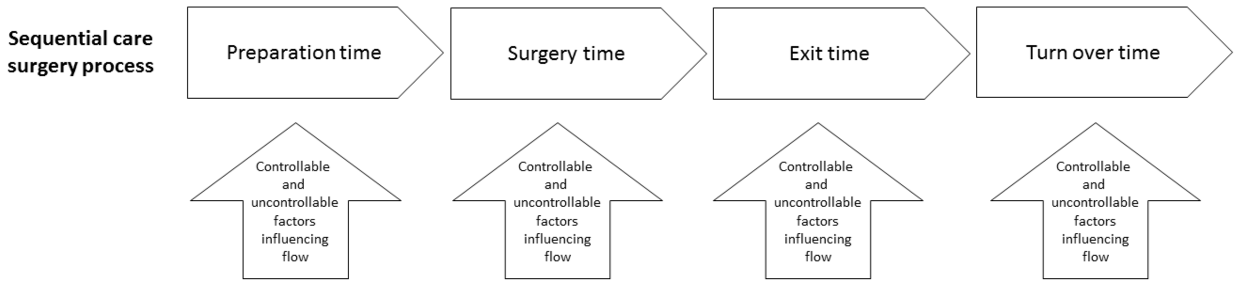

Figure 27 Different steps in the sequential care surgery process

Third, the observation that process standardization has a positive effect is inherited from the field of OM (Boyer and Pronovost, 2010). In our study, we were able to apply this concept to a health care process (i.e., to structured problems) and to link this concept to increased operational performance in this sector. Although standardization in health care can be expected to raise lots of resistance, this research shows that standardization can reduce inappropriate variation when used correctly (i.e., for the right kind of care process).

Fourth, OM techniques have been widely applied to optimize flow (Meredith et al., 2011); they show a unique set of skills that can contribute to substantial improvements in a wide area of medical situations and organizations (Boyer and Pronovost, 2010). We have thoroughly addressed the various aspects of how to optimize a sequential care process—a topic that forms part of the process improvement literature. We have thereby addressed the various calls that have been made to enhance operational performance in health care, striving for continuous improvement (Berwick et al., 2002). This study has brought some insights into the design of an optimized operating system. In addition, we have shed light on the process and on the structural factors that lead to variation in a standardized process on the patient, physician, and organization level (Figure 28). Again, these factors must be considered when looking at improving processes in health care as well in the sequential care process as in iterative care processes.

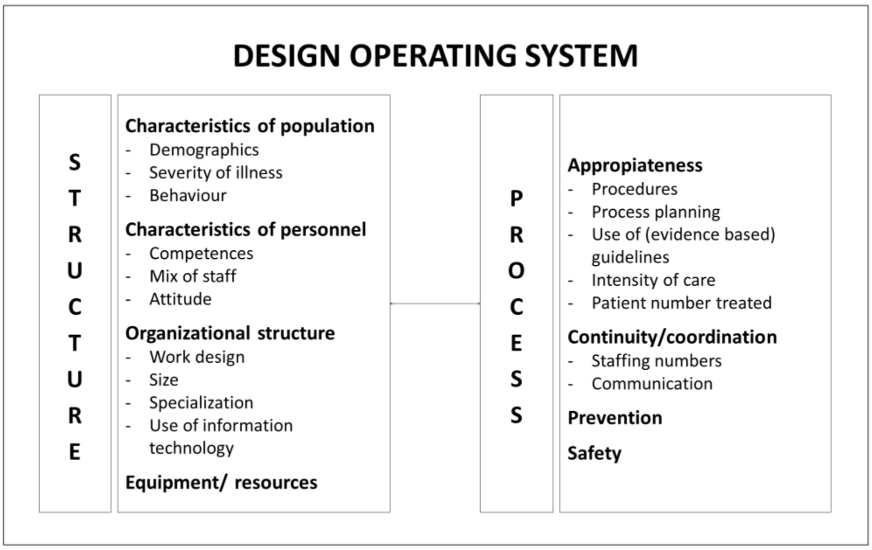

Figure 28 Structure and process elements in the care process

Overall, OM seeks the most efficient design to operate the care process as a function of the organization's objectives and the characteristics of the process. Applying this mind-set to health care management can improve operational performance.

2.2 Service management

Within the service sector, we focused on public services. Such services play an important and significant role in societies around the world. Major economies worldwide are dominated by services, with many countries having more than 70% of their gross domestic product (GDP) generated by services. The share of GDP attributed to health care services in particular is continuously increasing in developed countries (OECD Health Data, 2013). Beyond this, health care is arguably the most important and personal service people can have. At the same time, health care faces a financial challenge and high resource use (Berry and Bendapudi, 2007). There is a growing awareness that service research might be relevant to the challenges faced by the public sector, and more specifically, by health care. Ostrom et al. (2010), for instance, in identifying research priorities for service research, call for health care-related research into topics such as how to enhance access, quality, and productivity in health care, how to deliver services in a sustainable manner, and how to integrate 'design thinking' into service practices, processes, and systems. Our research has contributed to an increased understanding of this field, by means of our carefully prepared and conducted research, and fills the need for health care-related research in this service area.

While Roth and Menor (2003) stress the importance of the design of the service process (i.e., how) to effectively and efficiently deliver a specific service outcome, the dominant models in service design literature still focus on the service product (i.e., outcome) only. As such, the service process and people involved in the delivery of the service product are largely ignored (Bessant and Davies, 2007; Voss and Hsuan, 2009). In contrast, this research adopts a broader service lens by empirically focusing on the service process (i.e., the totality of the sequential care process in cataract surgery) and its outcome (i.e., the service delivery product). Specifically, this study offers a comprehensive view on service provision taking into account the organization, the physician and the patient.

2.3 Health care management

Within the health care management field, the majority of the research to date has focused on 'techniques' or 'projects' for improving performance (e.g., lean, six sigma, and clinical pathways). However, these techniques or projects do not consider the differences in the 'nature of care' (i.e., the sequential versus the iterative care process). OM approaches try to reduce variation in processes by removing clearly identifiable causes of variation—the so-called special causes of variation. Besides the special causes of variation, OM in healthcare is confronted with a type of variation that cannot be eliminated—inherent or common-cause variation; this can only be managed in the best way possible (McLaughlin and Kalunzy 2000). The level of common-cause variation is among others determined by the nature of the illness, and may range from low to high. Care processes are not always designed in line with the nature of the illness, which limits OM processes' potential for improvement. (Bohmer 2005; Bohmer 2009; Christensen et al. 2009). Our research embosses the OM approaches and links them to the health care sector by taking the nature of the care processes into account and illustrating (1) how to detect reasons of variation and (2) the possibilities on how to manage common cause variation. This can result in a continuous enhancement of care provision.

Overall our research revealed some unexpected results. We could not confirm that the approach of sequential care is uniform over all hospitals. This result is surprising as this sequential care process characterizes a well-defined evidence based practice. Not only are these results interesting, but also important as health care is a domain of significance (in terms of utility for society). What is more, our findings are useful and likely to change behaviour of managers and practitioners (Cachon, 2012).

3. IMPLICATIONS AND RECOMMENDATIONS FOR PRACTICE

In this section, we discuss the implications of this dissertation. Our research is relevant on macro-level (i.e., region, state, (inter)national to policy makers); meso-level (i.e., hospitals); and the micro-level (i.e., physician, personnel, the processes itself).

First, this dissertation calls for increased attention to be paid to the operating design approaches for the different care processes in hospitals. The starting point of this research is the 'one-size-fits-all' concept currently employed by hospitals, but which does not correspond with the current composition of care needs. The full-service hospital has been described organizationally as a 'solution shop', in which medical problems are assumed to be unstructured and to require expert physicians to determine each course of care (Bohmer, 2009). If universally applied, this model contributes to unwarranted variation in care, which leads to lower quality and higher cost (Cook et al., 2014). Creating a 'focused factory' model (characterized by a uniform approach to delivering a limited set of high-quality products) within the solution shop is a conceptual alternative that is effective in both improving quality and reducing costs (Cook et al., 2014). We therefore looked at how care should be delivered in these more applicable models, such as the more focused VAPs. Hospital managers should work on these new 'business models of care'. However, for further research we should emphasize the importance of selecting measurable, adequate (correct and appropriate) criteria to characterize the most appropriate process as early as possible, so that the patient will be allocated to the proper business model of care. For example, in the second study (chapter 3) we made use of the APR-DRG classification for the separating of care processes into iterative or sequential. But although APR-DRG classification groups are classified into clinically homogeneous groups this is on the basis of resource intensity. As for our process-related thinking this should be based on rather process related measurements (e.g., mapping the care process, segmenting the patient population) of the care process instead of resource use.

Second, individual clinicians' practices tend to go unquestioned. Despite multiple attempts over the years, huge opportunities to improve patient outcomes and lower costs still remain to be realized from benchmarking and standardizing clinical practices (Kaplan and Haas, 2014). Stimulation, motivation, and teamwork are necessary to improve care in the direction of evidence-based care and away from 'eminence-based care'. For example, physicians, nurses, and other caregivers often do not know the costs associated with the treatments they apply (Kaplan and Haas, 2014). Collaboration with administrators to develop outcome and cost measurements that would facilitate benchmarking and best-practice sharing opportunities is advised. Our study shows that hospitals can learn from each other by comparing processes to improve their processes and to meet the standards of best practice. Physicians want to improve patient care, as was confirmed by the great enthusiasm of the surgeons participating in the research. They are more than willing to search for process improvements that will lower costs while maintaining or improving the overall quality of care. It is up to the management to create the right atmosphere for this to happen.

Third, a lean concept that was again proven to show its usefulness was 'gemba' or 'management by wandering around'. In quality management, gemba means the 'working floor' (the real place where work takes place), and the idea is that if a problem occurs, the engineers (or hospital managers) must go there to understand the full impact of the problem, gathering data from all sources. With this methodological approach, applied in the final two empirical studies in this dissertation, factors disturbing flow efficiency were revealed; such knowledge can support managers and physicians in the organization and delivery of the care process. Beyond that, processes can be optimized by using the most fitting design of the operating system for sequential care. These in-depth findings were only revealed through the application of the 'gemba' method. We therefore recommend that operations managers go to the place where care is delivered and understand what causes variations in the practice of the physicians working in the same specialization.

Fourth, consider the elegantly lined up surgical instruments waiting at the beginning of an operation, with the surgical nurse ready to hand the right instrument to the surgeon at the right moment. Where did this idea and practice come from? Early pioneers in this field were Frank and Lillian Gilberth. The Gilberths' primary focus was on work performance and worker satisfaction. They conducted pioneering research in the fields of time and motion study (i.e., scientific management[6]), seeking 'the one best way' to organize and execute work flows and processes (Baumgart and Neuhauser, 2009) So, although our methodology of the 'time and motion' study is not new, it again confirms the usefulness of this approach in health care as it is practiced today.

In summary, we collected some empirical evidence that 'poor organizations can undo the work of the best physicians and great organizations can make up for mediocre ones' (Bohmer 2009, p.178). The careful design of the operating system can enhance the operational performance of physicians. For example, the third study (chapter 4) here focused on elements that cause variation in a sequential care process, and revealed some controllable and uncontrollable factors with clinical and organizational causes; examples include the severity of the illness, the level of experience of the physician, the use of a specialized nurse, and the presence of 'unwarranted' special-cause variation. Institutions that take those factors into account (i.e., manage them) and invest in factors that enhance the flow (such as designing an eye clinic or using a specialized nurse) will see efficiency boosts. The opposite effect was also witnessed: hospital managers failing to stimulate physicians to follow evidence based medicine did result in decreased flow efficiency (e.g., in terms of analgesia policy for cataract surgery). Physicians should be aware of the preferred best practice and consciously choose the

[6] Scientific management was a development of the 1880s and 1890s and is most closely associated with Frederick W. Taylor (1856–1915).

most appropriate treatment as a function of the patient—assuming, of course, that physicians are willing to adapt some of their practices in line with evidence-based guidelines. Checking whether the guidelines are being adhered to should not be the responsibility of the physician alone, but is a duty that must be shared with the management of the hospital. Subsequently, it is very important to differentiate between the kinds of variation and the presence of 'artificial' special-cause variation, as the goal must be to eliminate 'bad' (unwarranted, special-cause) variation and manage the warranted, common-cause variation (Appleby et al, 2011).

We note the importance of a sufficient volume when delivering care. Not only has previous research demonstrated that high volume is associated with better outcomes across a wide range of procedures and conditions (Halm et al., 2002), we also emphasize the importance that a sufficient volume (of the procedures and of physicians performing this procedure) is necessary to fully optimize the design of the operating system. For example, only having one physician performing cataract surgery to approximately five patients a week will not be sufficient to install an eye clinic within the hospital, nor will it justify hiring a specialized nurse.

Although this research did not focus on the role of the government, the results of our study deliver several relevant insights for policy makers. Most importantly, we advise policy makers to develop a more equitable system of financing hospital care as a function of the business model of care that is grounded in a specific business model of care. A solution shop model, featuring the iterative care process, requires fee-for-service financing. Payment cannot be based on outcome, as too many factors can influence the process and fixed price setting can lead to a negative effect on the care process and the outcome. On the other hand, in a VAP business model, representing the sequential care process, the process is predictable and the procedures to be taken are well known, so price setting can be fixed (Zorgnet Vlaanderen, 2013).

4. AVENUES FOR FURTHER RESEARCH

The insights we have developed in this research, based on an exploratory study, a systematic literature review, and the empirical case studies, fill some of the voids we identified in the current knowledge of care delivery optimization. Each of the studies, however, has its limitations and leaves room for additional research, or leads to new research questions. In this section, we address some of the limitations of research and provide suggestions for future research. We aim to focus on the general limitations of this research in this part and to refer to Chapter 2, 3, 4, and 5 for the individual limitations and avenues for further research of each paper.

Our research OM perspective fed a limitation of this research. OM is concerned with the design and management of operations within organizations, we focused mainly on (1) the care process as it is located (2) in hospitals. Since patient involvement comes naturally within the delivery of care, needs and demands of the patients in hospitals were therefore taken into account, though only indirectly. Even though we assume that optimizing the design of the operating system will enable providers to put their clients more at the center of care provision, we do not know whether this is the case since we did not research the demand side directly. Determining the effectiveness of a service poses significant challenges to researchers and to practitioners. At the heart of delivering excellent service lies basing decisions on what the customer wants, expects, and values. This requires an assessment of the realized service concept that customers experience (Roth and Menor, 2003). The redesign of healthcare operations and strategies should therefore include the patient's vision. Achieving patient-centered care depends on a thorough understanding of the patients' preferences at every stage of their journey through healthcare (Gooberman-Hill, 2012). To increase our understanding of what patients value in receiving health care and how their expectations and perspectives can be managed, we recommend that researchers consider patient experiences. If we want to analyze the effect of the optimization of the care process, then the opinion of the patient should be taken into account.

Additionally, it is important to acknowledge the limitation that arises from the focus of our research on sequential care processes. The inherent low variation in outcome leads to a straightforward comparison of practices between the hospitals. A significant challenge would be to look at an iterative care process where outcome must be considered in the evaluation of the design of the operating system. We recommend repeating this research in other hospital settings to continue to develop our knowledge of the impact of the design of the operating system in the different business care models.

This study is based on empirical evidence from the hospital sector, and we have therefore tailored our insights to the situation and practices found in this setting. Hospitals, however, are only one part of the total health care system. To improve the generalizability of our findings, we propose further research to investigate appropriate models of care with optimized operating systems in other settings, such as care for the elderly in nursing homes and psychiatric care. To contribute to an efficient health care system, future research should even go beyond focusing on small parts of the system (e.g., the efficiency of the hospital departments). A hospital may have very efficient departments, but the entire patient care trajectory may at the same time proceed quite inefficiently in the health care system. Therefore, we recommend to take the health care ecosystem into account in further research.

As for hospital care, a research project was begun in September 2014 to investigate other care processes (sequential and iterative care processes) beyond the ophthalmologic setting used as case study in this research, with the aim of broadening the empirical research findings of this dissertation. In this study, we aim to analyze the differences between two inherently different cardiological diseases (myocardial infarction and endocarditis) by using an existing database in three hospitals in Belgium and observations of the care processes. A pilot study in one Belgian university hospital in 2013 was conducted to determine whether certain protocols were followed in the processes of treating these two diseases. Retrospective analysis of medical files, structured participating observations, and semistructured interviews with physicians, coworkers, and patients were employed to this end. The results showed that care processes for myocardial patients make use of a protocol and are therefore fast and efficient. The process is mostly standardized and sequential. The approach for the endocarditis patients was less standardized and the care process more iterative, confirming our hypothesis that health care processes are different for diseases with different natures. In the current study, we wanted (1) to validate these findings in multiple hospitals, (2) to develop criteria to determine which cardiological care is appropriate for the focused factory model, and (3) to implement care protocols and standardization in order to improve efficiency for this care. We additionally aim (4) to research how care in the solution shop model can be addressed by comparing institutions.

In summary, there are different processes in health care and aligning process and structure components with the design of the operating system positively influences operational performance. As a result, a different design of the operating system is required for enhanced efficiency. Specifically, the future of affordable, rational, and reliable care lies in improved segmentation of patient populations and careful selection of care models and delivery sites prior to the initiation of the care process (Cook et al., 2014). This dissertation provides practitioners and academic with a fresh perspective on the practices of sequential care processes and the factors limiting them. It also serves as a foundation for future initiatives aimed at improving operational performance in hospitals.

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APPENDIX

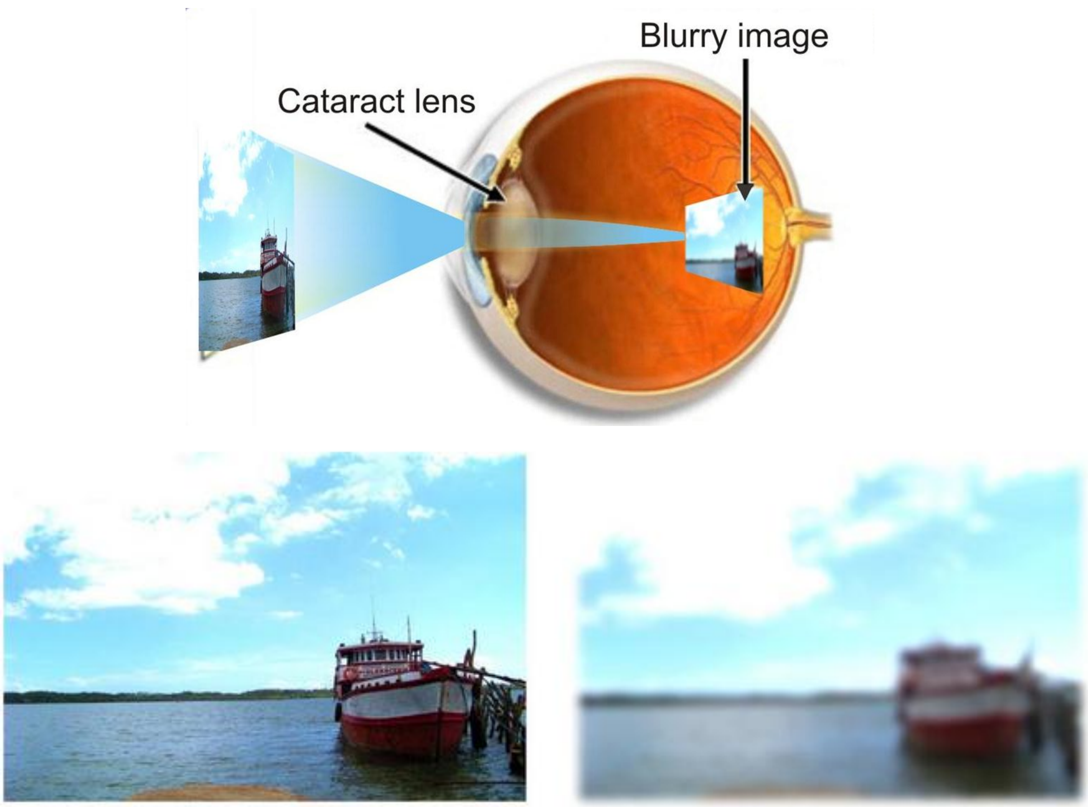
Cataract

In this appendix we introduce the disease cataract and elaborate upon the cataract surgery.

1. CATARACT

The lens of the eye is a biconvex, transparent, flexible structure that can change shape to allow precise focusing of light on the retina. In youth, the lens is perfectly transparent. However, as we age the lens becomes increasingly hard and opaque. Metabolic changes of the crystalline lens fibers over time, clouding of the lens, lead to the development of the cataract and loss of transparency, causing impairment or loss of vision (blindness) (Marieb, 2000).

Some cataracts are congenital, but most result from age-related hardening and thickening of the lens or are a secondary consequences of diabetes mellitus, smoking, steroid use or physical trauma.



Normal vision Cataract

Figure 29 Blurred or foggy vision of patients with cataract
(downloaded from Asian Eye Institute, http://www.asianeyeinstitute.com/)

Cataract has little effect on the patient’s vision in the beginning. Patients' first symptoms are strong glare from lights and small light sources at night, along with reduced acuity at low light levels. The patient will experience that their vision becomes a little bit blurred (Figure 29).

The only option to treat cataract is surgery. There are no drops or other medications that cure this age related process. The volume of cataract surgery has increased significantly around the world in the past years (WHO, 2000). In many areas cataract surgery forms over half of all ophthalmologic surgeries carried out each year (Stunevi et al., 1995) and in a number of countries cataract became the most common elective surgical procedure (Keeffe and Taylor, 1996).

2. CATARACT SURGERY

Cataract surgery is the removal of the natural lens of the eye and replacement with a synthetic intraocular lens (IOL) to restore the lens's transparency.

Cataract surgery is generally performed by an ophthalmologist (eye surgeon) in an ambulatory setting, in a surgical center or hospital, using local anesthesia (either topical, peribulbar, or retrobulbar), usually causing little or no discomfort to the patient. Well over 90% of operations are successful in restoring useful vision, with a low complication rate (Desai et al., 1999; Powe et al., 1994). Day care, high volume, minimally invasive, small incision phacoemulsification with quick post-op recovery has become the standard of care in cataract surgery all over the world.

Phacoemulsification refers to modern cataract surgery in which the eye's natural lens is emulsified with an ultrasonic device and aspirated from the eye.

The pupil is dilated using drops to help better visualize the cataract. Anesthesia may be placed topically (eyedrops) or via injection next to (peribulbar) or behind (retrobulbar) the eye. Oral or intravenous sedation may also be used to reduce anxiety. General anesthesia is rarely necessary, but may be employed for children and adults with particular medical or psychiatric issues. The operation may occur on a stretcher or a reclining examination chair. The eyelids and surrounding skin will be swabbed with disinfectant. The face is covered with a cloth or sheet, with an opening for the eye to be operated on. The eyelid is held open with a speculum to minimize blinking during surgery. Pain is usually minimal in properly anesthetized eyes, though a pressure sensation and discomfort from the bright operating microscope light is common. The ocular surface is kept moist using sterile saline eye drops or methylcellulose viscoelastic. Before the phacoemulsification can be performed, one or more minimal incisions are made in the eye to allow the introduction of surgical instruments. Advantages of the smaller incision include use of few or no stitches and shortened recovery time. The surgeon then removes the anterior face of the capsule that contains the lens inside the eye. Then, the tip of the needle vibrates at ultrasonic frequency to sculpt and emulsify the cataract while the pump aspirates particles through the tip. The cataract is usually broken into two or four pieces and each piece is emulsified and aspirated out with suction. After removing the hard central lens nucleus with phacoemulsification, the softer outer lens cortex is removed with suction only. An irrigation-aspiration probe or a bimanual system is used to aspirate out the remaining peripheral cortical matter, while leaving the posterior capsule intact. Following cataract removal an intraocular lens is usually inserted into the capsular bag (Figure 30). After the IOL is inserted, the surgeon checks that the incision does not leak fluid. This is a very important step, since wound leakage increases the risk of unwanted microrganisms' gaining access into the eye and predisposes to endophthalmitis. An antibiotic/steroid combination eye drop is put in and an eye shield may be applied on the operated eye, sometimes supplemented with an eye patch. The eye quickly recovers within a week and complete recovery should be expected in about a month.

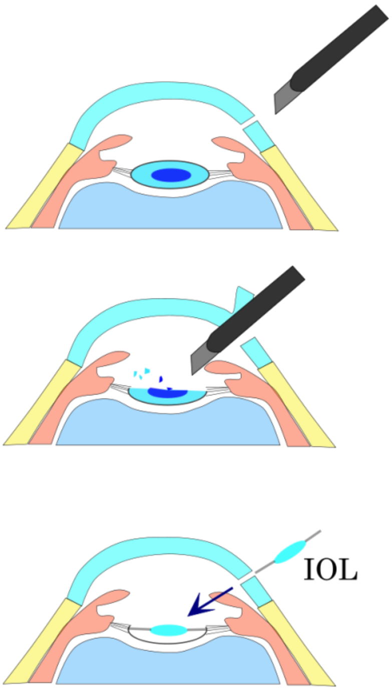


Fig 30 Phacoemulsification and insertion synthetic intraocular lens, by Takuma-sa . Licensed under CC BY-SA 3.0 via Wikimedia Commons

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Melissa De Regge (°1976, Gent) obtained the degree of Master of Science in Healthcare Management and Policy at Ghent University in 2010. Since April 2011, Melissa has been working as doctoral researcher at the Department of Innovation, Entrepreneurship, and Service Management, Ghent University and at Ghent University Hospital. Her research focuses on new business models for hospitals that link operations management, service management, and clinical experience. Aiming for a multidisciplinary research design, she collaborates with medical doctors, CNOs, CEOs, and CMOs of various Belgian hospitals and health care institutions. Melissa has experience in the working field, as she has worked for 13 years as a nurse. Her key interests include management and operational aspects of health care delivery—a domain in which she has published several peer-reviewed articles. She is a member of The Center for Service Intelligence (CSI) and the Healthcare Management Research Center, two interdisciplinary research centers at Ghent University that focuses on research topics in the domain of service management and health care management. Her work was presented at several international conferences, the Academy of Management Annual Meeting (2013), the EurOMA Conference (2014) and the Annual EHMA Conference (2012, 2013 and 2014). Melissa's research has been published in peer-reviewed international journals, such as Health Policy and Operations Management Research.

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