UNIVERSITY OF SOUTHERN QUEENSLAND
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UNDERSTANDING THE RELATIONSHIPS BETWEEN CLINICAL QUALITY, PATIENT SATISFACTION AND FINANCIAL PERFORMANCE: EVIDENCE FROM SWISS HOSPITALS

A Thesis submitted by

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ABSTRACT

For years, hospitals have been under increasing pressure to be economically successful. Their goal is not only to provide the best possible care for patients but also to operate efficiently and optimize costs. A case-based reimbursement system ensures standardized revenues in many countries, which means hospitals can only increase profits by reducing costs. The resulting pressure to cut costs can negatively impact clinical quality and patient satisfaction. Furthermore, it is unclear how clinical quality and patient satisfaction directly and indirectly affect financial performance. It is posited that, in a free-market economy, good service quality increases customer satisfaction and loyalty, and therefore, reduces price sensitivity, leading to increased profits over time. This study aims to investigate whether this causal chain applies to the healthcare sector, thus determining whether better clinical outcomes and higher patient satisfaction lead to increased profitability in hospitals. Furthermore, it examines how the relationships between client outcomes, patient satisfaction, and profitability work in the highly regulated healthcare system.

This thesis consists of three studies (papers). The first study utilizes a systematic literature review to identify gaps in the literature and gain insights based on previous studies. It demonstrates that good and efficient clinical quality reduces costs and thus increases profits. Additionally, it finds that higher patient satisfaction positively affects patient loyalty and increases the hospital's standing in the area. Both lead to higher revenues due to the increased utilization of hospital facilities.

The second study examines the relationship between clinical quality (patient safety adverse events) and costs, using Swiss national data from 2019 covering all patients and their costs. The calculations used include propensity score matching methods and regression analyses. The core findings of the second study indicate that the examined patient safety adverse events were responsible for about 2.2% of inpatient healthcare costs and that an adverse event could generate up to CHF 137,967 excess costs per patient. Patients with an adverse event incurred costs that were 2.4 times higher, stayed 7.8 days longer in the hospital, had a 2.5 times higher readmission rate, and had approximately a 4.1 times higher mortality rate.

The third study investigates the relationship between patient satisfaction and financial performance. Therefore, an aggregated data set per hospital (2016 – 2018) was analyzed. The primary results of the third study demonstrate a positive relationship between hospital costs and patient satisfaction, which was strongest in hospitals with few emergency patients. It also found that patient satisfaction can predict patient revenue but not operating margins.

The studies demonstrate that clinical quality and patient satisfaction impact financial performance and should, therefore, be considered by hospital management. Recommendations for practice are that management should consider several moderators and should more extensively monitor the key figures discussed in this paper. Theoretically, this thesis improves the understanding of the effect mechanisms in classic service and marketing literature and how they can be applied to the healthcare sector. It explains unexplored relationships and evaluates important research gaps, providing added value for operational hospital management and the health economics literature.

Keywords: Quality, patient satisfaction, financial performance, service profit chain, costs, adverse events, patient safety

CERTIFICATION OF THESIS

I Alice Giese declare that the PhD Thesis entitled *Understanding the relationships between clinical quality, patient satisfaction and financial performance: Evidence from Swiss hospitals* is not more than 100,000 words in length including quotes and exclusive of tables, figures, appendices, bibliography, references, and footnotes.

This Thesis is the work of Alice Giese except where otherwise acknowledged, with the majority of the contribution to the papers presented as a Thesis by Publication undertaken by the Student. The work is original and has not previously been submitted for any other award, except where acknowledged.

Signed: [redacted] Date: April the 5th, 2022

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STATEMENT OF CONTRIBUTION

The following papers produced from this thesis were the agreed share of contribution between the PhD candidate and other co-authors. The details of the scientific contribution of each researcher are provided below:

Giese, A., Khanam, R., Sassenberg, A.M., Nghiem, S., Rosemann, T. (2022). Impacts of clinical quality and patient satisfaction on financial performance in hospitals: A systematic literature review. *Health Services Research* – Under review

The overall contribution of AG was 70% to the development of the concept, data extraction, analyses, interpretation, initial drafting, and revising the final submission. RK, SM, and AMS contributed to the concept, development, analysis, and editing, each providing important inputs amounting to 10% of the total work. TR proofread the final version.

Giese A., Khanam, R., Nghiem, S., Staines, A., Rosemann, T., Boes, S., Havranek, M. M. (2022). Assessing the excess costs of different in-hospital adverse events covered by the patient safety indicators. *Value in Health*– Under review

The overall contribution of AG was 70% to the development of the concept, data extraction, analyses, interpretation, initial drafting, and revising the final submission. MH and RK assisted during the whole process with a contribution of 20% and 10%, respectively. SN, SB, AS, and TR proofread the final version.

Giese, A., Khanam, R., Nghiem, S., Rosemann, T. (2022). Is patient satisfaction profitable? Evidence from Swiss hospitals. *BMJ Quality and Safety* – Under review

The overall contribution of AG was 70% to the development of the concept, data extraction, analyses, interpretation, initial drafting, and revising the final submission. RK, TR, and SN each contributed to the concept, development, and editing, each providing important inputs amounting to 10% of the total work.

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The last person I would like to thank is my friend Josefin Valentin. After having conducted a whole year of literature research (the first year) and not written a single sentence, Josefin made me confront my fear by forcing me to write my first sentence at her kitchen table in Stockholm (Sweden). Thanks to her, I took the first step, which was followed by many more small steps.

Alice Giese

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ABBREVIATIONS

AHRC	Agency for Healthcare Research and Quality
AMI	Acute myocardial infarction
ANQ	Swiss National Association for Quality Development in Hospitals and Clinics
AUC	Area under the receiver operating characteristic curve
CHF	Swiss franc
CMI	Case-mix index
COVID	Coronavirus disease
CVC	Central venous catheter
DRG	Diagnosis Related Group
EUR	Euro
FP	Financial performance
GDP	Gross domestic product
GRADE	Grading of Recommendations, Assessment, Development, and Evaluation
Km	Kilometer
LOS	length of stay
OECD	Organization for Economic Cooperation and Development
P4P	Pay for performance
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
PSI	Patient Safety Indicators
SPC	Service profit chain
USD	US Dollar
VBHC	Value-based health care
VIF	Variance inflation factor
WHO	The World Health Organization

LIST OF PAPERS (PUBLISHED / UNDER-REVIEW) INCLUDED IN THE THESIS

1. Giese, A., Khanam, R., Sassenberg, A.M., Nghiem, S. Rosemann, T. (2022). Impacts of clinical quality and patient satisfaction on financial performance in hospitals: A systematic literature review. *Health Services Research* – Under review

2. Giese A, Khanam, R., Nghiem, S., Staines, A., Rosemann, T., Boes, S., Havranek, M. M. (2022). Assessing the excess costs of different in-hospital adverse events covered by the patient safety indicators. *Value in Health* – Under review

3. Giese, A., Khanam, R., Nghiem, S., Rosemann, T. (2022). Is patient satisfaction profitable? Evidence from Swiss hospitals. *BMJ Quality and Safety* – Under review

CHAPTER 1: INTRODUCTION

1.1 Empirical Puzzle

Healthcare is supposed to be cost-efficient while being of high clinical quality and patient-centered, which economically suggests a trade-off. This thesis aims to understand the relationships between clinical quality, patient satisfaction, and financial performance and determine whether there is indeed a trade-off.

This chapter introduces the study by first considering the background and then discussing the study rationale and research problem. After explaining the research design, it summarizes the literature and discusses the main theoretical framework. Next, it defines the research question, leading to the appropriate methodology, and finishes with a discussion of the role of the researcher and the thesis structure.

Swiss Healthcare System

Switzerland is home to 8.5 million people and lies at the heart of Europe. After the US and Germany, Switzerland has the most expensive healthcare system of OECD countries (measured by healthcare spending as a share of the GDP; (OECD, 2022). The ratio of health expenditure to Swiss GDP rose from 9.6% in 2007 to 11.3% in 2019 (OECD, 2022).

In accordance with the Swiss Federal Health Insurance Act, it is compulsory for every permanent resident in Switzerland to have basic health insurance (Swiss Federal Office of Public Health, 2021), enabling everyone to have access to high-quality medical care. This compulsory insurance covers the majority of standard procedures and treatments for illnesses, and residents are able to choose the health service provider they deem most suitable. Supplementary insurance can also be added that covers, for example, single-room accommodation during hospitalization (Swiss Confederation, 1994).

According to statistics published by the OECD (2022), hospital density is comparatively high, with 4.6 beds per 1,000 inhabitants as compared to 2.8 in the US or 2.4 in the UK. Switzerland has an expensive healthcare system with above-average personnel resources and a high staffing ratio per patient (Rafferty et al., 2019). In 2019, before the COVID-19 pandemic, Switzerland ranked first among the OECD countries in the number of people working in hospitals relative to the overall size of the population (OECD, 2022). Because of this high availability and high hospital density, Switzerland has a high level of patient satisfaction with care, but the health policy has been concerned with the issue of overuse for several years (Clarfeld & Amstad, 2020).

The Swiss hospital landscape is characterized by both public organizations, owned and financed by local and regional authorities (around 80%), and private-owned organizations (around 20%) that operate under for-profit models (Girardin, 2019). Since 2012, inpatient services in Switzerland (as in many other Western countries) have been financed through a case-based remuneration scheme named Swiss Diagnosis Related Group (DRG). Switzerland does not have value-based purchasing or pay-for-performance structures, and reimbursement is not linked to quality or patient satisfaction.

Healthcare Costs

The primary goal of healthcare is not financial performance; it is to improve patients' health. Yet, good financial performance is a relevant goal for hospitals. It ensures that hospitals can have sufficient profits to cover expenditures, achieve their shareholders' economic goals, and secure investments (Steinmann et al., 2004).

Thus, hospitals must pursue different tasks and objectives (Ho & Huang, 2019). On the one hand, their central mission is to provide high-quality health care for patients. On the other hand, they must achieve economic goals to finance ongoing business operations, maintain the current level of capital (e.g., replace old tangible assets or property), and react to developing market requirements (Akinleye et al., 2019).

Healthcare costs in many countries have been significantly rising or stagnating due to factors including governments allocating more resources to health, aging populations, and technical innovations (OECD, 2020b). Politicians and society are calling for a reduction in healthcare costs without compromising the quality of care. As a result, the cost pressure on inpatient healthcare has been increasing steadily over the years. The largest share of healthcare costs is attributable to inpatient hospital costs (Jakovljevic et al., 2015). This explains why cost-cutting measures and cost pressures are mainly applied to the inpatient hospital sector, as this is where the greatest leverage can be applied with potential savings from rectifying inefficiencies and reducing overuse (Asche et al., 2009). Labor expenses account for about 70% (Ruggeri et al., 2018) of total hospital costs in Europe, while the share in the US seems to be smaller (60%) (Coughlin & Gerhardt, 2013). Many hospitals are thus facing cost pressures and trying to save where they have the greatest leverage. Since labor expenses account for the highest costs in hospitals (and are still rising), it is most effective to cut costs in this area, and increase efficiency (Ye et al., 2017a).

However, downsizing staffing levels and labor expenses reduces employee satisfaction and harms the work environment and culture, which leads to a higher turnover, absenteeism and increased workload, among other factors (Baird et al., 2019; Lu et al., 2019). Higher turnover, increased temporary staffing, a lower number of high-skilled workers and physician shortages significantly decrease the clinical quality and patient satisfaction (Aiken et al., 2017; De Simone et al., 2018; Hockenberry & Becker, 2016; E.-M. Oppel et al., 2017; Ye et al., 2017a). As the relationship between financial performance and quality is complex., studies should be conducted to determine how various quality metrics are related to financial performance and, thus, ensure that cost-cutting does not harm hospital outcomes.

Rationale for the Study

With healthcare costs continuing to rise (OECD, 2022), pressures on staffing and labor costs are expected to increase even more, which could indirectly compromise clinical quality and patient-centeredness (Avgar et al., 2011). Thus, there is a pressing need to understand how these factors directly and indirectly influence each other. To answer that need, this thesis investigates the extent to which decreased clinical quality and reduced patient satisfaction influence hospitals' financial performance. Given the need for research regarding the association between clinical quality or patient satisfaction and financial performance, this study aims to identify their relationships to answer the research question.

1.2 Literature Review

Although "health" is one of the best-researched topics in academia, the field of health economics has still not comprehensively understood the relationships between quality metrics (such as clinical quality or patient satisfaction) and financial performance (Roth et al., 2019). Healthcare managers face the challenge and trade-off of increasing quality and patient-centeredness while managing limited financial resources and reducing costs (Tajeu et al., 2015). Without deeper knowledge on this subject, there is a risk that patient care will decline as cost pressures increase. As mentioned, hospitals' quality and patient-centeredness affect their financial performance and economic turnover (Kittelsen et al., 2015; Tran et al., 2018). Thus, there exists a reciprocal relationship between a hospital's quality, patient satisfaction and financial performance (Cinaroglu & Zengul, 2019).

The literature on quality in healthcare identifies both technical quality and patient satisfaction (with the service) as relevant metrics (Marley et al., 2004). However, the literature on service and marketing clearly separates customer satisfaction from the quality of a service or product (Sureshchandar et al., 2002). In order to distinguish quality and patient satisfaction more clearly and prevent overlapping, this thesis considers clinical quality as a construct independent from patient satisfaction.

In order to be measured, clinical quality must first be defined. In broad terms, clinical quality has been described as the ability of hospitals to achieve high standards of patient health through clinical treatment (Donabedian, 1988; Kelley & Hurst, 2006; Marley et al., 2004). However, according to Endeshaw (2020), there is no single definition of clinical quality in the healthcare literature. The concept is also highly difficult to measure (Hanefeld et al., 2017). One way to address those issues is to divide quality into different dimensions. The most frequently cited model for determining the dimensions of quality is Donabedian's (1980); despite being over 40 years old, it continues to provide the basis for many other frameworks (Jolley et al., 2017). Donabedian distinguished three dimensions of quality: structure, process, and outcome, each of which can be measured using various indicators as described below.

According to Donabedian (1988), the structural dimension of quality covers the context of care and can be measured using indicators that include staffing ratios, staff availability, and the condition of hospital buildings. From the process perspective, patient safety is one of the most relevant indicators (measuring quality in the treatment process). Process quality also influences outcome quality. For example, adverse events (which are measured as an indicator of process quality) can increase mortality, which results in lower outcome quality (Hauck et al., 2017; Zhan & Miller, 2003). Other indicators related to outcome quality include patients' experiences and reported outcomes (Kingsley & Patel, 2017).

The Institute of Medicine defined quality as the degree to which services increase the likelihood of desired health outcomes and are consistent with current professional knowledge (Donaldson et al., 2000). However, the desired health outcomes depend on a set of factors, not all of which are in the clinicians' hands. Furthermore, the degree to which a service is consistent with professional knowledge is difficult to measure (Bristow et al., 2013). Relative to such potentially vague indicators, patient safety is easier to measure as it can be captured by, for example, identifying preventable adverse events. Juran's definition of quality also shows how the concept is closely related to patient safety: "Quality means freedom from deficiencies" (Juran & Godfrey, 1951, p. 21).

While clinical quality is usually not fully comprehensible from a patient's perspective (Chang et al., 2006), service quality can be judged by patients and is, therefore, related to patient satisfaction (Marley et al., 2004; Shabbir & Malik, 2016). Service quality, because of its intangibility, relies upon the healthcare service process and patients' interactions with healthcare providers (Eitan & Zvi, 2005). Donabedian (1987) divided service quality into two sub-areas: technical and interpersonal. The most popular model used to measure service quality is SERVQUAL (Parasuraman et al., 1988) which consist of 44 questions to analyze the gap between expectations and perceptions using five determinants: Tangibles, Reliability, Responsiveness, Assurance, and Empathy as the SERVQUAL scale. It provides a grading system, to support management to track quality of service over time and assist with service improvement. Despite controversies about the validity, reliability, and individual adaptions suggested for various industry-specific applications of this model (Ladhari, 2009), it can be concluded that SERVQUAL remains a useful instrument for service-quality research (Ladhari, 2009) and it is commonly used in healthcare services (Endeshaw, 2020). Although the SERVQUAL model has been adapted and widely used in health care, authors remain divided on how to measure patient reported experience with care (Wiig et al., 2013).

In addition to clinical and service quality, patient satisfaction is a relevant indicator of hospital performance (Jha et al., 2008a). In economic terms, satisfaction is defined by the utility of a service that a person purchases based on its beneficial attributes (Sofaer & Firminger, 2005). Healthcare providers need to understand the determining factors associated with patient satisfaction so that they know what patients value and how they perceive care quality; that understanding can then be used to drive service improvement (Zineldin, 2006). This is consistent with the service and marketing literature that links service quality to consumer satisfaction (Anderson & Mittal, 2000; Rust et al., 1995).

Analogous to clinical and service quality, patient satisfaction is a multi-dimensional construct that reflects patients' expectations, morals, and experiences (Naidu, 2009). In the literature, patient satisfaction is defined as the expression of the discrepancy between the expected and the perceived quality of a service (Bowling et al., 2013; Schoenfelder et al., 2011). Patient satisfaction correlates with the extent to which physicians fulfill patient expectations (Fenton et al., 2012). Drawing conclusions about patient satisfaction is, however, complicated by the fact that it depends on both expectations and experiences, meaning that we can never be sure whether the differences in individual patients' ratings are due to different expectations or experiences. For example, someone with relatively low expectations may be satisfied with a care experience whereas a person with higher expectations could find the same care completely unacceptable (Sofaer & Firminger, 2005). This is why an increasing number of patient surveys are focusing more on patient experience and less on overall patient satisfaction (Sofaer & Firminger, 2005).

Ways of conceptualizing the interactions between the above-mentioned topics are not numerous, and their relationships remain unclear. As hospital managers are increasingly exposed to the tension between higher quality and lower costs, it is unsurprising that the relationship between quality and costs has been the most studied of the mentioned areas. In that regard, Juran and Godfrey’s (1951) "cost of quality" concept should be mentioned. It defined the cost of quality as all the costs that would not exist if an organization did not have any failures. Juran and Godfrey divided those costs into two categories – "failure costs" (i.e., those caused by poor quality) and "quality costs" (i.e., those incurred to increase quality) – and recommended that companies should achieve the optimum balance between the lowest possible costs in both areas. Feigenbaum (1956) further developed the link between quality and costs with his prevention-appraisal-failure model. By going into more details, he divided costs into two major categories: The cost of conformance (the cost deliberately incurred in efforts to maintain or improve quality) and the cost of nonconformance (the cost suffered as a result of bad quality). Further, the cost of conformance were divided into appraisal and prevention costs, while the nonconformance costs were divided into internal and external failure costs. Companies that implemented “cost of quality” or “prevention-appraisal-failure” programms have been successful in reducing the costs of quality and in improving quality for the customers (Schiffauerova & Thomson, 2006).

The previously mentioned models only considered cost and quality but did not provide a complete picture of the relationships between quality, patient satisfaction, and financial performance. Berwick et al.'s (2008) triple aim framework is another attempt to address quality, patient satisfaction, and performance. It centers around three overarching goals: improving patient experience, improving health, and reducing the cost of healthcare. However, it takes a global/national view of population health that encompasses social health costs in a broader sense that goes beyond hospitals' operating costs. A clear distinction between healthcare and hospital costs must be made in the context of this thesis, which considers the financial performance of hospitals rather than the healthcare system as a whole.

Although researchers have recommended balanced performance measures for hospitals for years (Sturmberg et al., 2012), hospital administrations' performance and quality evaluation systems still primarily include economic and financial measurements (Cleven et al., 2016). Most hospitals' financial departments are still stuck in silo-thinking with a strong focus on cost and no understanding of the aforementioned relationships (Giannini, 2015). Thus, individual actions to save money risk affecting the quality of the hospital or patient satisfaction. They also risk failing to realize the full potential of improvements in quality and patient satisfaction to positively impact hospitals' financial performance. Given the increasing cost pressure under which hospitals operate and the unclear impact of such pressure on quality and patient satisfaction, it is essential to investigate these relationships more closely, especially as the literature does not provide a detailed understanding of them. To date, there is no model that situates the aforementioned areas in a broader context. Studies in the healthcare sector have considered relationships between a maximum of two areas but have not provided a larger framework that helps to understand how a broader range of factors interacts.

Research Question

Although models exist in the service literature that show the relationships between quality, satisfaction, and financial performance, these relationships have not yet been demonstrated in healthcare. Given the study's background and the overview of the research gaps (concerning the unclarity as to how quality and patient satisfaction affect financial performance), there is an opportunity to explore these relationships and influences. Hence, this thesis' primary aim is to determine how the relationships between clinical quality, patient satisfaction, and financial performance are shaped and whether there is indeed a trade-off.

Accordingly, the following research question arises:

What are the relationships between clinical quality, patient satisfaction, and financial performance?

In addition to examining the overall model, the thesis also examines the relationships separately. For this purpose, it also investigates the influence of reduced clinical quality (patient safety) on financial performance (costs). To do this, it formulates the following sub-question:

What is the impact of in-hospital patient safety events on costs?

To examine the next relationship, that between customer satisfaction and increased profitability, the thesis asks the following sub-question:

What is the impact of high patient satisfaction on financial performance?

The main research question and its sub-questions have been formulated to specifically address the research gaps discussed above, i.e., the lack of comprehensive studies addressing the relationships between clinical quality, patient satisfaction, and financial performance in healthcare settings.

To achieve this thesis' research goal, three studies were conducted. The first study examined the complete framework, while the second and third studies examined the relationships between financial performance and patient safety and satisfaction, respectively.

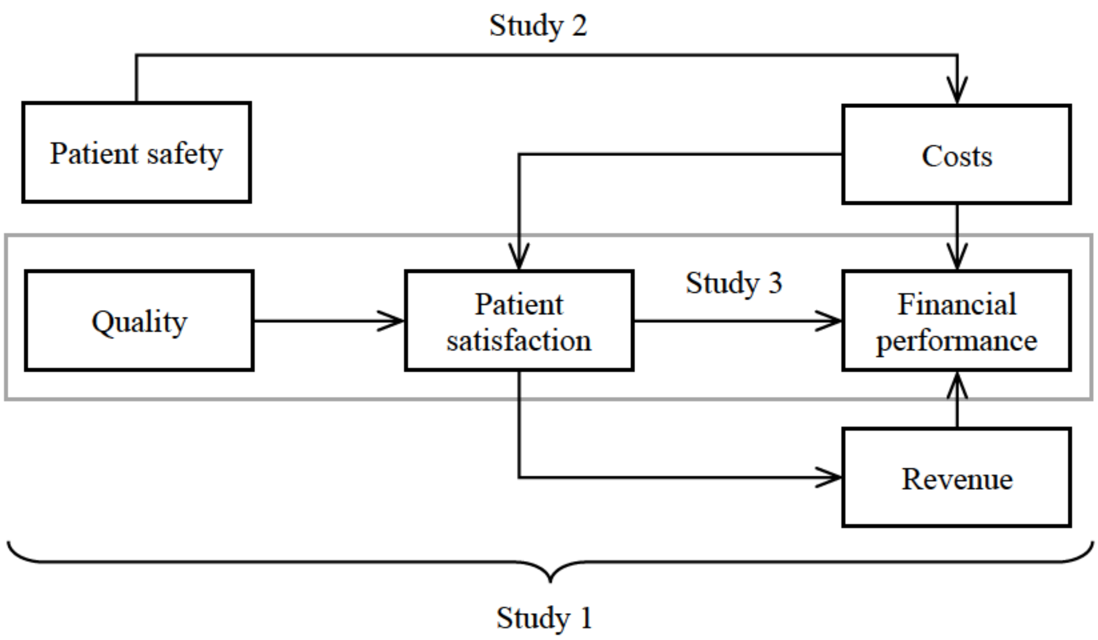

Figure 1: Relationships between the studies

1.3 Research Design

While the thesis focuses on the relationships between quality, patient satisfaction, and financial performance, I originally planned and discussed a broader research framework at the candidature confirmation, proposing the following research question:

What is the relationship between employee satisfaction, clinical outcome, patient satisfaction, profitability and efficiency in Swiss hospitals?

However, the systematic literature review (Publication 1) made it clear that the relationship between clinical quality, patient satisfaction, and financial performance is already highly complex and unexplored. A pilot study on efficiency using data envelopment analysis determined that efficiency could only be included indirectly (in the form of productivity). Furthermore, it showed that the efficiency calculation did not meet the heterogeneity of the Swiss market (with its topographically diverse situations as well as the federal healthcare structure). A literature review on the impact of working conditions and staff satisfaction on clinical quality, patient satisfaction, and financial performance revealed that the topic is of such complexity and extent that it cannot be covered in one thesis. Therefore, I chose to narrow the thesis' focus and ensure a more detailed and higher-quality assessment of the relationships.

Ontologically, I assume there is a universal framework and a single reality (Blaikie, 2000). By using data on clinical quality, patient satisfaction, and hospitals' financial performance, I could employ an objective approach to the research question (Saunders, 2011). This thesis also takes a positivist epistemological point of view, believing that reality (relationships) can be measured by collecting the right data. Thus, the thesis can ensure validity by choosing the best-suited measures and controlling all other influencing factors.

Epistemologically, a positivist approach seems best suited for the set of beliefs. Since the positivist approach believes that quantitative research methods are best suited to measure reality (Blaikie, 2000), it requires a deductive procedure, which goes from the general to the specific to test the theory (Wilson, 2014). In deductive reasoning, the cognitive process begins with a theory (in this case, the service profit chain) that can produce empirically verifiable hypotheses. The theory is criticized if these hypotheses are refuted based on the data or regarded as provisionally confirmed if they are not refuted (Wilson, 2014).

1.3.1 Theoretical Approach

The service and marketing literature examines the influence of quality and customer satisfaction on a company's financial performance, which suggests that it will provide models that can be applied to do the same in a healthcare context. One possible model that could be used from that literature is Vargo and Lusch’s (2004, 2014) new service-dominant logic for marketing. That model identifies how intangible elements of a service influence business and how the co-creation of value and relationship building with customers develop by emphasizing the interactions between the provider and the customer (Grönroos, 2006). The model can be applied to hospitals, but its emphasis on co-creation (which is less relevant when considering clinical quality instead of service quality) and value (rather than financial performance) means that the model is not suitable for the purposes of the present study.

Another well-known model in the service literature comes from Reichheld and Sasser’s (1990) work on "zero defections," which focuses on the impact that strengthening customer loyalty has on success. They estimated that a 5% increase in customer loyalty would lead to an increase in profit from 25% up to 85%. The model focuses on the quality of the service and its further development, as well as on customer value. That would be suitable for the chosen research area, especially given the impact of clinical errors on costs. However, since that model does not clearly show causalities (Silvestro & Cross, 2000), it is not suitable as a basis for the framework of the current study.Another framework is the service profit chain (SPC) (Heskett et al., 1994), a simple model that postulates that financial performance can be improved through a mechanism that links employee satisfaction, quality, customer satisfaction, and customer loyalty (Homburg et al., 2009). This thesis uses Heskett's SPC to study the effects of these interrelationships.

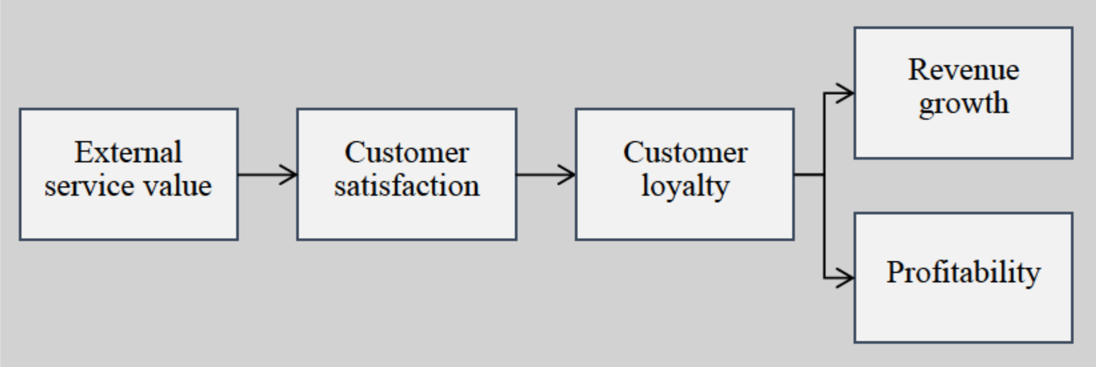

Figure 2: Second (external) part of Heskett et al.'s (1994) service profit chain.

Both academia and business practice have used the SPC (Heskett et al. 1994) as a theoretical concept to understand the mechanism of the economic success of service companies. However, the effectiveness of the SPC has not yet been empirically demonstrated (Anderson & Mittal, 2000; Homburg et al., 2009; Kamakura et al., 2002; Yee et al., 2011).

The SPC has already been used in the health literature Marley et al. (2004) used parts of the SPC to develop a structural equation model. They replaced service quality with clinical quality and process quality, both affecting patient satisfaction. However, they did not include the financial component, and their chain ends with patient satisfaction. Another US study that used the SPC as a framework to explore the link between patient experience and hospital profitability found that increased profitability is directly related to positive patient experience and vice versa (Richter & Muhlestein, 2017). A similar concept was also advanced by Harkey and Vraciu

(1992) with the quality-profitability model, which suggests that patient experience leads to hospital loyalty, which leads to increased market share and, ultimately, results in higher profits.

The SPC has an employee-centric (internal) section and a customer-centric (external) section. In the internal section, the working conditions created by the company and support from internal human resources determine employee satisfaction. Employee satisfaction, in turn, positively affects employee behavior in the form of loyalty and performance. The external section is triggered by service provision. Customers evaluate the quality of the service they receive. These quality assessments determine customer satisfaction, which in turn positively impacts customer loyalty. Customer loyalty ultimately increases the company's economic success by stimulating sales and profitability. Heskett et al. (1994; 1997) substantiate these individual impact relationships using practical examples of various service companies. While the SPC appears to be somewhat banal and thus almost oversimplified, implementing it in a company is challenging leadership work. Only managers who invest in the individual elements of the chain and increase the satisfaction level of employees and customers will achieve a competitive advantage (Heskett et al., 2008a).

This thesis uses the SPC model for orientation and organizes the more complex healthcare relationships into this overall construct to simplify the interaction paths and make them easier to understand and implement as an aspect of a hospital’s strategy. The SPC summarizes the essential mechanisms of action in service companies in an intuitively comprehensible reasoning chain and views employees and customers as important elements for generating long-term corporate success (Loveman, 1998). Thereby, the SPC provides an intuitive answer to the fundamental mechanisms through which human resource practices and customer orientation influence organizational success (Guest, 2011; Maxham III et al., 2008).

This thesis focuses on the external part of the chain, where higher service quality (value) influences customer satisfaction and, in the end, profitability. There are several drawbacks to this rather simple model. Since a portion of patients does not voluntarily seek hospital services, this study only considers loyalty as an indirect factor. It also does not focus on service quality but rather on clinical quality. Service quality (hospitality, etc.) and clinical quality belong to service performance. However, the patient primarily uses hospital services to improve their health (i.e., clinical quality) and not because of the great food or comfortable beds (i.e., service quality).

As a result of the extensive linkage of internal and external company variables, empirically validating the SPC is a significant challenge, especially in the data collection phase (Loveman, 1998). Heskett et al. (1994) have suggested that there is a causal order between employee satisfaction and loyalty, service quality, customer satisfaction and loyalty, and firm performance. However, Silvestro and Cross (2000) have criticized this model by arguing that there is no empirical validation sustaining the causality of the chain. While the direct relationship of employee satisfaction to good service quality and, thus, higher customer satisfaction is clear in the SPC, the influence of working conditions (such as wages or the number of employees) on customer satisfaction remains unclear. Other such indirect relationships have been under-researched to date.

1.3.2 Research Strategy and Methodologies

This thesis uses a deductive approach that applies a general theory (the SPC) to a specific case (healthcare, inpatients), following Wilson (2014) explanation.

Thus, part of Heskett et al. (1994) general theory was used and applied to a very specific case (hospital). The deductive explanatory model serves to evaluate the theory using the quantitative paradigm of empirical social research.

To answer the first research question, the healthcare literature was scanned to better understand the interactions between clinical quality, patient satisfaction and financial performance. A systematic literature review (SLR) was performed following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement recommendations (Moher et al., 2009). After this, existing findings on the interdependencies were compiled, discussed, and, with the help of the SPC, put into a framework.

The second research question, on the relationship between patient safety and costs, was answered and quantitatively tested by conducting a retrospective case-control study. A national administrative data set of 1.2 million inpatients from the 2019 fiscal year in Switzerland was used. With the help of a case-matching procedure as well as regression analysis, the study determined the resulting additional costs per adverse event.

The third research question, concerning the relationship between customer satisfaction (patient satisfaction) and financial performance, was also examined using a quantitative approach, namely a cross-sectional study design on a national data set covering three years (2016-2018). The data set was aggregated at the hospital level, and analyzed through regression analysis. Moderators were tested in addition to the dependent and independent variables, such as the influence of emergency patients or bed occupancy rates. The IBM SPSS Statistics 26 and 27 software was used for all statistical tests.

	Setting	Data	Method
Study 1	Literature	2008 - 2019	SLR
Study 2	Quantitative analysis, level: Patients	Administrative data from Swiss patients in 2019	Case matching, propensity score, regression analysis
Study 3	Quantitative analysis, level: Hospital	Swiss hospital data from 2016 – 2018 (costs & satisfaction)	Regression analysis

Table 1: Summary of setting, data and methods

Role of the Researcher

To reduce the researcher's influence, a PROSPERO protocol was registered in advance for the first study. In addition, a PRISMA flow chart was used to structure the process, and, besides the four-eyes principle, a standardized quality assessment was applied using the GRADE (Grade of Recommendations, Assessment, Development, and Evaluation) approach (Guyatt et al., 2008).

External validity was achieved by selecting existing national data samples for the quantitative research, therefore allowing for generalizations (Bell & Bryman, 2007). The comprehensive sample and necessary statistical tests reduced the influence of the researcher and guaranteed a value-free approach. Conservative calculations and test statistics were chosen to eliminate any bias, and several statistical approaches (like the case matching in Study 2) were performed using different matching procedures to demonstrate the resulting bias and reduce the researcher's influence.

It should also be noted that my job (quality manager of the Department of Health in the Canton of Zurich, Switzerland) does not require me to address the issue of patient safety or patient satisfaction. Therefore, the only interest guiding this research is the well-being of patients.

1.4 Structure of Thesis

This thesis consists of five chapters. The thesis chapters are presented in the logical and coherent sequence explained by the theoretical framework (Figure 1) before and are as follows:

Chapter 1 introduces the research theme and motivations to pursue this study and presents background knowledge of the core concepts employed and reported within this thesis.

Chapter 2 provides an SLR (Study 1) and focuses on the literature on the associations between clinical quality, patient satisfaction and financial performance. It investigates how studies have measured the main factors, splitting them into process and outcome measurements. In a second step, it builds a framework grounded in the SPC but adapted to the specific situation of hospitals, which and demonstrates the interactions between clinical quality, patient satisfaction and financial performance.

Chapter 3 is based on the second study and focuses on the association between clinical quality and costs by examining the costs of adverse events. The excess costs per adverse event type were estimated using a national dataset and case matching procedure. Therefore, the extra costs of lower clinical quality could be quantified and internationally compared.

Chapter 4 is based on the third study and aims to address the second research question: How does patient satisfaction influence financial performance?. A quantitative, nationwide study was used to analyze the associations between patient satisfaction and different measurements for financial performance.

Chapter 5 summarizes the key findings of the three publications, describing the contribution to the literature and proposing recommendations for future research.

First, it briefly recapitulates the objectives and research questions before discussing an overall conclusion and finally evaluating the studies through the research questions. Then, it outlines the implications of the study for management, researchers, and policymakers and discusses the limitations of this research.

CHAPTER 2: SYSTEMATIC LITERATURE REVIEWIntroduction

While Chapter 1 provided an introductory review of the research topic, Chapter 2 presents the SLR. It first demonstrates the measurability of the variables in the research model and then sets up a possible model that visualizes the relationships on the basis of the existing literature. This model is set up to create an understanding of the relationships based on the current literature and identify the research gaps.

2.2 Paper 1

Impacts of Clinical Quality and Patient Satisfaction on Financial Performance in Hospitals: A Systematic Literature Review

Paper is under review since July 2022 at: *Health Services Research*

Q1 (A)

IF (Scopus): 2.8

IF (Web of Science): 2.351

H-Index: 121

SJR: 1.706

Publisher: Blackwell Publishing Inc.

Abstract

Background and Objectives: Hospitals worldwide face many challenges, such as increasing cost pressures, enhancing their service delivery efficiency, meeting patients' human needs, and, most importantly, delivering high-quality clinical services. Yet this balancing act cannot succeed without a thorough understanding about the relationships among these challenges.

Methods: A systematic, PRISMA-guided literature review was performed using four databases (EBSCOhost, PubMed, Web of Science and Scopus) to assess the research published between 2008 and 2020. From 4,386 identified studies, sixteen were included in this review.

Results: Of the 15 studies examining clinical quality and hospital finance, 12 used outcome measures, and 10 employed process measures. The association between cost and quality depended on how quality was measured. From the research that correlated patient satisfaction and hospital finance, seven utilized outcome measures, and seven applied process measures. While research validates that patient satisfaction has a direct influence on loyalty, studies still fail to show how patient satisfaction impacts hospital finance.

Conclusion: The literature confirms that clinical quality and patient satisfaction exert both direct and indirect influences on hospitals' financial performances and infers that some of the relationships are not linear.

Keywords: Financial performance, quality, patient satisfaction, service-profit chain, systematic literature review

Introduction

Most countries are currently struggling with rising health care costs (Akinleye et al., 2019). While the real gross domestic product (GDP) in the OECD area grew marginally in 2019 by 0.4% (OECD, 2020a), 2019's increase in health care spending was six times higher, at 2.4% (OECD, 2020b). Even though the average rise in health care costs in OECD countries has decelerated, this surge is still several times higher than the GDP growth. Accordingly, health care costs are not only high but also still growing faster than the GDP.

As hospital costs in developed countries account for approximately one-third of total health care expenditures (CMS.gov, 2020), hospitals face increasing pressure to not only deliver state-of-the-art quality and service but also secure their financial performance by providing high quality at minimal costs (Akinleye et al., 2019). Although it is a common consensus that cost control and quality improvements are hospitals' central responsibilities, the relationship between health care costs and clinical quality illustrates one of the most controversial issues in health care policy (Hussey et al., 2013). Further investigation into the various measures of clinical quality, patient satisfaction, and hospital financial performance is vital for managing healthcare costs.

In the service literature, the service-profit chain (SPC) suggests that satisfied employees provide good service quality, resulting in higher customer satisfaction, which in turn leads to better financial performance (Heskett et al., 2008a). Yet research has not addressed whether part of these relationships can be applied to the health care sector and, more specifically, to hospitals.

In the context of the current pressure to save costs, our goal is to examine the extent to which specific clinical quality and patient satisfaction measures affect hospitals' financial performances.

Clinical quality

Quality, because of its subjective nature and intangible characteristics, is difficult to define. It generally relates to distinguishing attributes that meet individual requirements at the lowest cost on a continuous basis (Beattie et al., 2015). Distinct clinical quality measures such as intangibility, heterogeneity, and simultaneity stifle the ability to clearly explain and measure clinical quality (McLaughlin & Kaluzny, 2006; Naveh & Stern, 2005).

Previous studies investigating clinical quality in reference to financial performance have indicated a negative relationships between quality and cost (Beauvais et al., 2019). Poor quality leads to higher treatment costs and therefore lower profits (Akinleye et al., 2019), while excessive quality investment might be inefficient and could also reduce earnings (Jamalabadi et al., 2020). Therefore, clinical quality requires an in-depth investigation into the precise measures that affect financial performance in healthcare.

Patient satisfaction

Customer satisfaction includes customers' responses to organization-related contact (Becker & Jaakkola, 2020; Homburg et al., 2017; Lemon & Verhoef, 2016). This study uses the "patient satisfaction" to refer to the offerings that hospitals stage and manage and the patents' responses to any hospital-related contacts (Anhang Price et al., 2014). Positive patient satisfaction is linked to increased profitability (Richter & Muhlestein, 2017), but the extent to which it depends on the clinical quality remains unsure (Prabhu et al., 2018).

Financial performance

"Financial performance" is a general term that indicates the overall financial health of the hospital over a given period. The measurement of hospitals' financial performances typically employ hospital performance models that examine the operating profit margins and the net profit margins (Ly et al., 2011).

Theoretical underpinning of the study

This study is based on the service profit chain theory (SPC), which shows that financial performance relies upon satisfied and loyal customers, good service quality, satisfied employees, and favorable workplace conditions (Heskett et al., 2008a; Hogreve et al., 2017; Hong et al., 2013). According to the SPC, service providers who satisfy their customers receive a competitive advantage over those who do not. To keep the study concise, we focused only on the second (external) part of the SPC, which deals with the relationship between quality, customer satisfaction, and financial performance.

On the other hand, a popular model in the service literature may not necessarily work in the health care sector. Health care consumption is different from the consumption of other services, such as banking or cleaning; it is often less predictable and has limited choices (Harris, 2003; Viney et al., 2002). Furthermore, price sensitivity (if any) among patients also changes when their level of suffering increases, which is further aggravated by indirect financing through insurance fees. While pricing policy exerts a strong influence on a company's financial performance for regular services in the market, profits within hospitals can be increased most significantly by realizing efficiency gains, thus reducing costs (Vélez-González et al., 2011). In contrast to different services, a hospital, with its public service mission, has the responsibility not only to operate economically and control costs but also to continuously improve the quality of care and patient satisfaction (Morrisey, 2001; Porter & Teisberg, 2006).

Again, limited evidence exists to confirm a connection to these health quality measures, including patient satisfaction and financial performance. This study investigates the possible gaps that may exist within the research on clinical quality, patient satisfaction, and hospital financial performance (see Figure 3):

Figure 3: *Research model*

Methods

This systematic literature review (SLR) was performed following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement recommendations (Moher et al., 2009). A review protocol was registered with the International Prospective Register of Systematic Reviews (PROSPERO, 2020) registration number: CRD42020203800. The results of the search and screening process for the research question are shown in Figure 4 (PRISMA).

Search strategy

The search spanned from February 2020 to August 2021, and the following databases were used: EBSCOhost MegaFile Ultimate, National Institute of Health (PubMed), Web of Science Core Collection and Scopus. A manual search was additionally conducted based on selected articles' references. Synonyms were integrated for every subject to ensure full access to the available literature. The search strategy is thoroughly exhibited in the PROSPERO protocol, registration number: CRD42020203800. The search string included clinical quality, patient experience/satisfaction, and hospital financial performance (Table 1); likewise, the applied synonyms are presented in the supplementary information. The search strategy was planned using a research librarian. To manage the references, we utilized EndNote (X9) software.

Table 1: Search terms used for different relationships (without synonyms)				
Keywords	**Operator**	**Keywords**	**Operator**	**Keywords**
Clinical quality	AND	financial performance	AND	Hospital
Patient satisfaction	AND	financial performance	AND	Hospital

Table 2: Search terms used for different relationships (without synonyms)

Eligibility criteria and screening

Included journal articles embodied the following criteria: 1) the published work was peer reviewed; 2) written in the English language; 3) published between 2008-2020; and 4) examined the relationship with hospitals' financial performances. Journal articles were excluded if they adhered to these measures: 1) studies related to a specific patient group (e.g., palliative care patients) or a very specific intervention/disease (e.g., acute myocardial infarction), which made scalability to the entire hospital difficult; 2) no studies on primary care or retirement homes were used; 3) no studies from second- or third-world countries were used due to the variance in comparability of billing and financing structures (similar proportion of "out-of-pocket" costs and DRG-coded flat rates per case); 4) studies investigated relationships due to regulatory measures (e.g., influence of clinical quality on financing in a "pay-for-performance" system). The eligibility criteria are presented in the supplementary information.

Data items and charting

The examined full-text studies were categorically recorded by the research team in data-charting forms to identify review patterns within the heterogeneity of study characteristics and outcomes. Forms were then divided by the different relationships available in terms of the research question and used for data extraction by including the relevant notes and each article's keywords.

In regard to clinical quality, we have clearly distinguished it from service quality. If service quality was measured in terms of satisfaction to service aspects, then we assigned the study to the area of patient satisfaction. If, however, compliance with medical guidelines was used as a measure of service quality, then we considered it as clinical quality.

Quality assessment

The full-text-assessed studies were evaluated for quality based on the Grade of Recommendation, Assessment, Development, and Evaluation (GRADE) approach (Guyatt et al., 2008). Only articles that received a quality level of high or moderate in the GRADE approach qualified for final selection.

Synthesis of data

A meta-analysis was not possible, as significant heterogeneity was observed among the research findings, study designs, methods, and measures. Instead, a descriptive analysis was conducted on the characteristics of the included studies. The aim was to distinguish between the qualitative and quantitative measures used to investigate clinical quality, patient satisfaction, and hospital financial performance. The different categories of clinical quality were also analyzed to determine whether the studies indicated any significant variations in hospital financial performance measures.

Results

Study selection

A total of 4,386 articles were screened, and 201 full-text articles were assessed. Next, 185 were excluded for failure to meet the criteria. The remaining 16 studies were deemed as eligible for this review (Figure 4).

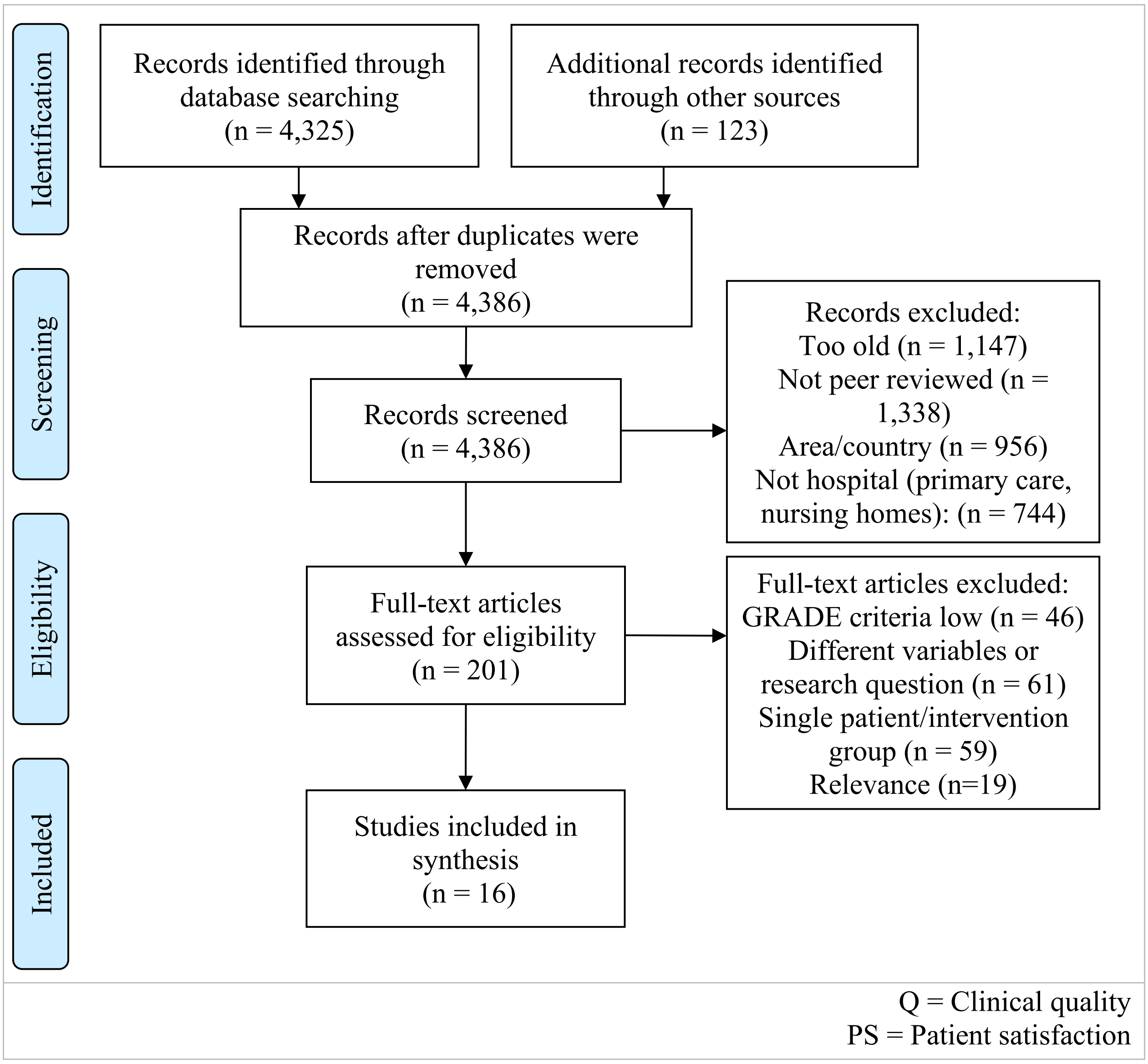

Figure 4: *PRISMA flow chart*

Characteristics of selected studies

In total, the main objective of the 16 studies was to examine clinical quality and patient satisfaction in relation to hospital finance; 12 evaluated clinical quality measures, and nine papers studied patient satisfaction and financial performance. The articles were published from 2008 to 2020. Specifically, eight studies used the Centers for Medicare and Media Services database (CMS) in the United States, and four studies were systematic literature reviews. Eleven studies were performed in the United States, one in the United Kingdom, one in Denmark, and the rest employed a worldwide perspective. Of the studies that measured the influence of clinical quality, nine analyzed the direct relationship between clinical quality and financial performance. Another six studies assessed the indirect influence of clinical quality on patient satisfaction. Only one study explored the relationship between patient satisfaction and financial performance without taking other quality measures into account.

Synthesis of Results

The purpose of this study was to outline the scope of the topical domain on clinical quality, patient satisfaction, and hospital financial performance to highlight gaps in the body of extant research. These are first presented in terms of clinical quality and hospital finance and second, in relation to patient experience and hospital finance.

3.1.1 Clinical quality and hospital finance

The measures of clinical quality and hospital finance were structured into two main categories: outcome measures (n=12) studies and process measures (n=10) studies (Jamalabadi et al., 2020). Table 2 summarizes the characteristics of the included studies.

Clinical quality and HF	n	Sources
Outcome measures	12	(Akinleye et al., 2019; Anhang Price et al., 2014; Bazzoli et al., 2008; Gutacker et al., 2013; Hvenegaard et al., 2011; Jamalabadi et al., 2020; Jha et al., 2009; Kennedy et al., 2014; Kittelsen et al., 2015; Sacks et al., 2015; Tajeu et al., 2015; Tsai et al., 2015)
Process measures	10	(Akinleye et al., 2019; Anhang Price et al., 2014; Bazzoli et al., 2008; Gutacker et al., 2013; Jamalabadi et al., 2020; Jha et al., 2009; Kennedy et al., 2014; Sacks et al., 2015; Tajeu et al., 2015; Tsai et al., 2015)

Table 3: Clinical quality and hospital finance studies

Clinical quality and hospital finance outcome measures

Outcome measures investigated in clinical quality (n=12) studies included dimensions such as inpatient mortality (n=11), patient safety indicators (n=8), readmission (n=10), morbidity (n=1), quality of life indexes (n=1), surgical process (n=7), health status postsurgery (n=1), average change in healthcare after treatment (n=1), and wound complications (n=1).

The findings indicated that outcome measures, inpatient mortality, readmission, and patient safety indicators were the most frequently examined. Six studies determined the relationship between clinical quality outcome measures and hospital finances (Akinleye et al., 2019; Bazzoli et al., 2008; Gutacker et al., 2013; Hvenegaard et al., 2011; Kittelsen et al., 2015).

The outcomes of the studies assessing clinical quality and hospital finance varied. Clinical quality measures such as inpatient mortality, patient safety indicators, readmission, and surgical processes showed evidence of a negative relationship and a possible U-related relationship with hospital finance (Akinleye et al., 2019; Gutacker et al., 2013). A study further posited that this relationship was not as strong as previously suggested (Bazzoli et al., 2008), while another source cited evidence of a positive relationship between mortality rate and hospital finance (Kittelsen et al., 2015). The study's findings contradict research that revealed a negative relationship between the mortality rate and hospital finances (Hvenegaard et al., 2011).

Clinical quality and hospital finance process measures

Clinical quality studies analyzed process measures and included dimensions such as process of care (n=8) studies, patient satisfaction of care (n=6), patient safety indicators (n-1), health status presurgery (n=1), length of stay (n=2), and surgical process score (n=6) studies.

Five studies explored the effects of clinical quality process measures on hospital finance (Akinleye et al., 2019; Bazzoli et al., 2008; Gutacker et al., 2013; Jamalabadi et al., 2020; Kennedy et al., 2014). One of the studies was a literature review, and the findings of the remaining studies showed different outcomes. Two studies indicated that the relationships between clinical quality and operating margins were not significant (Bazzoli et al., 2008; Kennedy et al., 2014), and another study suggested a U-shaped relationship between hospital cost and clinical quality (Gutacker et al., 2013).

The variations in the outcome and process measures and clinical quality may rely on the measurements of the study (Akinleye et al., 2019). Indeed, the association between cost and quality depends on how quality is measured (Hvenegaard et al., 2011).

Four studies applied patient-hospital level data. For example, the process of care was compiled using the CMS Hospital Inpatient Quality Reporting Program based on the calculation of a composite quality/safety performance score (Akinleye et al., 2019). Applying these specific safety and quality performance standards can overlook risks and obstacles within health care settings (Beauvais et al., 2019). Patient-hospital data demonstrate shortcomings in reference to data accuracy and data completeness (Bazzoli et al., 2008).

Limited empirical research, such as experiments or focus groups, have been conducted, which would have accounted for the effects of individual patients' health statuses (Hussey et al., 2013). Research therefore urges further investigation into alternative sources of quality of care data (Bazzoli et al., 2008). Limited studies have considered patients on an individual basis. Research has shown that variations in individual patient care within hospitals need to be assessed from patients' perspectives (Akinleye et al., 2019).

3.1.2 Patient satisfaction and hospital finance

The measures of patient satisfaction and hospital finance were again structured into two main categories: outcome measures (n=7) and process measures (n=7) studies (Jamalabadi et al., 2020). Table 3 summarizes the characteristics of the included studies.

Patient satisfaction	**n**	**Sources**
Outcome measures	7	(Anhang Price et al., 2014; Doyle et al., 2013; Kennedy et al., 2014; Richter & Muhlestein, 2017; Sacks et al., 2015; Tajeu et al., 2015; Tsai et al., 2015)
Process measures	7	(Akinleye et al., 2019; Anhang Price et al., 2014; Doyle et al., 2013; Kennedy et al., 2014; Sacks et al., 2015; Tajeu et al., 2015; Tsai et al., 2015)

Table 4: Patient satisfaction and hospital finance

Outcome measures & patient satisfaction and hospital finance

It is important to note the difference between patient satisfaction and patient experience. Patient satisfaction referred to the gap between expectations and patient experience (Beattie et al., 2015). Patient experience outcome (n=7) studies included measures such as objective health outcomes (n=1), self-reported health and wellbeing (n=1), adherence to treatment (n=1), preventative care (n=1), healthcare resource use (n=1), recommendation of the hospital and overall satisfaction (n=5).

Five studies investigated the outcome measure, recommending hospital and overall hospital satisfaction (Kennedy et al., 2014; Sacks et al., 2015; Tajeu et al., 2015; Tsai et al., 2015). For example, Kennedy et al. (2014) found an overall positive relationship with large hospital surgical quality and overall patient satisfaction. Similarly, hospitals that were grouped in the first quartile received higher overall satisfaction than those grouped in the lowest quartile (Sacks et al., 2015). This was further confirmed with a study that showed hospitals with the highest patient satisfaction rates were on average larger than those with the lowest patient satisfaction rates (Tsai et al., 2015). Controlling hospital characteristics, patient satisfaction was found to be positively associated with three clinical quality measures and patients' willingness to recommend the hospital (Tajeu et al., 2015). These findings contribute to the current body of knowledge on clinical quality, but it is still unclear how the patient satisfaction outcome measures, such as overall satisfaction and recommending the hospital, relate to hospital finance. A study investigating patient experience and hospital finances deemed that operating income, operating margins and net patient revenue were positively related to overall patient satisfaction and willingness to recommend the hospital (Richter & Muhlestein, 2017). This study added to the current body of knowledge on patient experience but failed to show how patient satisfaction influence hospital finances. Overall satisfaction and recommendations are essential measures, as they have been previously shown to directly influence loyalty levels in healthcare (Hong & Lee, 2018).

Process measures & patient satisfaction and hospital finance

Process measures investigated in patient satisfaction (n=6) studies included dimensions such as responsiveness of staff (n=3), clean and safe environment (n=3), provide information to enable self-care (n=2), doctor-patient communication (n=2), pain management (n=2), discharge information (n=2), coordination between professionals (n=2), continuity of care (n=2) and quietness of rooms (n=2). Measures that related to only one study were not used.

Only one study determined a patient satisfaction process measure, including patient satisfaction of care being highly proportional to clinical quality and hospital profitability (Akinleye et al., 2019). However, this study did not utilize relational dimensions such as empathy, respect, and the inclusion of patients in decision making from a patient perspective. The remaining four studies established patient rational measures such as trust, empathy, respect, and inclusion of patients in decision making rather focused on the effect on clinical quality with limited determination of the effects on hospital performance (Anhang Price et al., 2014; Doyle et al., 2013; Kennedy et al., 2014; Sacks et al., 2015; Tajeu et al., 2015; Tsai et al., 2015). Process measures such as empathy, respect, and including the patient in decision making were found to have a direct association with surgical quality (Sacks et al., 2015). Doctor-patient communication, trust, and the belief that the physician has whole-person knowledge of patients positively influence patients' experiences of clinical quality (Anhang Price et al., 2014; Doyle et al., 2013). If clinical quality has a positive link with hospital finance (Akinleye et al., 2019), we argue that relational measures, such as respect, may have a direct or indirect positive influence on hospital finances. However, limited studies have investigated this phenomenon, so it is still unclear how rational process measures in the patient experience impact hospital finances.

Discussion

Even though the causality between the elements of the SPC was not the focus of this study and could not be confirmed, the literature nevertheless clearly shows that clinical quality and patient satisfaction have direct and indirect influences on hospitals' financial performances.

In Figure 5, we attempt to provide an overview of the identified relationships from the literature. Since costs and revenue both have an impact on financial performance, we divide the topics according to their influence on higher costs (negative) and their influence on higher revenues (positive).

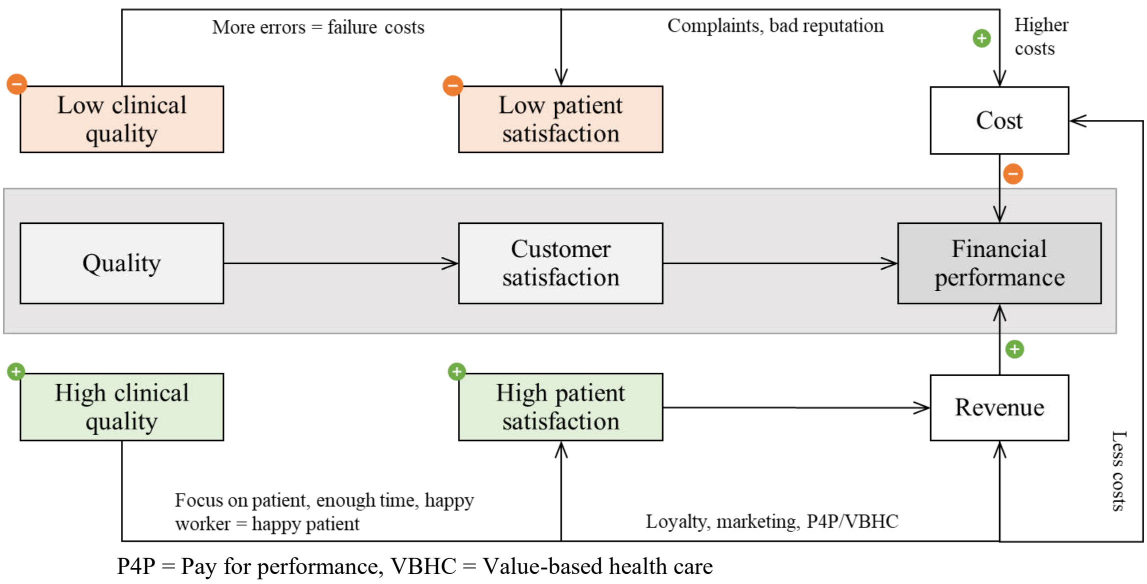

Figure 5: *Authors' Application of the SPC in Health Care*

The relationship between clinical quality and patient satisfaction is most likely not linear because patients in the health care system tend to judge service quality and patient centeredness rather than clinical quality (Anhang Price et al., 2014; Kennedy et al., 2014; Tajeu et al., 2015). However, the relationship between clinical quality and the level of costs, i.e., financial performance, is simpler to understand.

Poor quality leads to inefficiency (longer lengths of stay), lower patient safety and consequently more failures (adverse events and readmissions) (Beauvais et al., 2019; Jamalabadi et al., 2020; Kittelsen et al., 2015). In countries where inpatient services in hospitals are reimbursed through a fixed-fee funding system, low quality, and more failure therefore rapidly lead to higher costs for hospitals without higher revenues (Beauvais et al., 2019). What sounds simple in the sense of "failure costs" is more complicated in detail: several researchers assume that a U-shaped relationship exists between clinical quality and costs, whereby low clinical quality leads to failure in terms of patient safety and thus higher resource expenditure (more hospitalization days because of adverse events, more treatments, etc.), which increases costs (Gutacker et al., 2013; Hvenegaard et al., 2011; Jamalabadi et al., 2020).

Conversely, investing too much in quality can be inefficient and therefore unnecessarily expensive. The most economical and efficient point on the U-shaped curve is reached at the lowest point, when every investment in appraisal and prevention costs is balanced with a reduction in failure costs (Gutacker et al., 2013), ultimately keeping costs as low as possible. Depending on where a hospital is located on the U-shaped curve, an investment in quality can, therefore, lead to more or lower costs. Based on this correlation, a significant but nonlinear relationship between clinical quality and financial performance can be confirmed (Gutacker et al., 2013; Hvenegaard et al., 2011; Jamalabadi et al., 2020).

In the next step, the influence of patient satisfaction on financial performance was examined. Only a few studies have explored a part of the relationship between patient satisfaction and financial performance. The reason might be that high level of patient satisfaction is generally not a intent of financial interests (Richter & Muhlestein, 2017). Patient satisfaction serves as a source of continuous improvement and enhances patient centeredness, patient safety, and clinical quality (Anhang Price et al., 2014; Richter & Muhlestein, 2017).

Patient satisfaction has a positive effect on financial performance through higher returns. Satisfied patients are more likely to remain loyal and committed to a hospital, thus ensuring patient inflow (Richter & Muhlestein, 2017). Satisfied patients also result in better hospital reputations, and higher patient satisfaction can be used as a marketing tool, which in turn attracts new patients and thus secures market share (Richter & Muhlestein, 2017). The extent to which more satisfied patients link to lower complaint costs and thus to lower overall costs has not yet been considered in the health care literature but can also be an influential factor.

Limitations

The greatest strength of this study is its overview, which is also its greatest weakness. An overview containing such heterogeneous literature from the health care sector prevents a detailed investigation of the individual relationships between the variables under consideration. In this review, we do not address questions or criticisms concerning the function of the SPC itself. We only use the SPC as a model to illustrate the idea of a value chain and to systematically put the theory into order. Furthermore, studies have used widely heterogeneous methods and measures. Therefore, the review is limited by the quality of underlying studies.

From a macroeconomic perspective, we do not extend the study beyond the hospital. We did not judge studies by their impact on society but rather concentrated exclusively at the hospital level. For example, an increase in a hospital's revenue may lead to additional costs for the community or government, while lower costs for hospitals cause a positive effect not only on the hospital budget but also on the health care expenditure of society.

The comparability of health care systems has not been examined. The selection of developed countries was based on the assumption that the health care systems of these countries can be approximately compared, and thus, the related literature can be considered as sharing common aspects.

CONCLUSION AND CONTRIBUTIONS TO THE LITERATURE

While patient satisfaction seems to have only a minor impact on financial performance through loyalty or marketing effects, high and efficient clinical quality seems to have a significant impact on financial performance by lowering costs, which has a positive effect on profit for equal revenue.

Our results make a significant contribute to the literature in several ways. Using the simple model of the SPC in the service literature (Heskett et al., 2008a), the fragmented health care literature is placed into a clear and comprehensible context. By presenting these relationships in a graph and visualizing their various connections, their mutual influences become concise, and a visible framework illustrates research gaps.

Through our study, we offer empirical evidence of the influence of clinical quality and patient satisfaction on hospitals' financial performances. Our results also indicate that these variables impact each other in different ways. To illustrate, particularly high clinical quality exerts an above-average leverage effect on financial performance, as they have strong direct and indirect cost implications.

Very few studies have examined the influence of clinical quality (rather than service quality) on patient satisfaction. While there are slightly more studies on the relationship between clinical quality and cost, it is surprising that researchers are more than ambivalent about the nature of this relationship and its various determinants. There is also almost no literature regarding the relationship between patient satisfaction and financial performance, which is surprising, considering several countries' existing incentives of the "pay-for-performance" programs. In addition to the fact that very few studies have investigated the abovementioned relationships, another area of research can target to what extent a U-shaped relationship can be applied to other quality indicators (in addition to clinical quality).

From the perspective of hospital management, the (ceteris paribus) change in patient satisfaction has only a moderate influence on higher revenue. Conversely, improving clinical quality can have a significant impact on cost reduction, depending on where on the U-shaped curve between quality and costs the hospital is located. Therefore, where the most significant possible leverage can be applied, a sustainable competitive advantage can be achieved.

What kind of added value do the collected findings of this SLR offer hospital leaders? Hospital management may already be concerned about clinical quality, patient satisfaction, and financial stability. However, it is essential that management fully understands the interrelationships and connections among these elements because people can control only relationships that they clearly comprehend.

Declaration section

Ethics approval and consent to participate:

Not applicable

Consent for publication:

Not applicable.

Availability of data and materials:

Data relevant to the study are included in the article or uploaded as supplemental files. Detailed ratings of quality and satisfaction measures are available from the corresponding author upon reasonable request. Completed citations for all referenced literature are included in the reference list.

Competing interests:

The authors declare that they have no competing interests

Funding:

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Authors' contributions:

Idea for the article [AG], concept and design [AG, HSN, AMS], literature search [AG, RK], data analysis [AG, AMS, RK], drafting [AG, AMS], critically revision [RK, HSN, TR], adm. support [TR], supervision [RK, HSN, TR]. All authors read and approved the final manuscript.

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CHAPTER 3: CLINICAL QUALITY AND COSTS

3.1 Introduction

While Chapter 2 analyzed the literature and set up a framework to theorize the relevant relationships, Chapter 3 examines the first relationship, investigating the impact of lower quality (adverse events) on costs.

In a case-based reimbursement system, higher quality would not directly affect profits, since the revenue does not depend on the quality. However, lower quality would have a causal relationship with higher costs, which in turn would have a negative impact on profits.

3.2 Paper 2

Assessing the excess costs of different in-hospital adverse events covered by the patient safety indicators

Paper is under review since July 2022 at: *Value in Health*

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Statements and declarations

Ethical approval

The study is based on retrospective, de-identified, and anonymized data. According to Swiss law, the study is therefore exempted from ethical approval and informed consent.

Author contributions

All authors contributed to the study's conception and design. Alice Giese and Michael Havranek performed material preparation, data collection, and analysis. Alice Giese wrote the first draft of the manuscript; Michael Havranek revised it; and all authors commented on, read, and approved the (final) manuscript.

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Competing interests

The authors have no competing interests to declare that are relevant to the content of this article.

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Highlights

- In-hospital adverse events covered by the patient safety indicators (PSIs) caused, on average, excess costs of CHF 27,409 per patient.
- In addition, they resulted in, on average, 7.8-day longer stays, 2.5 times more readmissions, and 4.1 times higher mortality rates.
- From a national perspective, PSI 09 (postoperative hemorrhage/hematoma), PSI 04 (death after serious complications), and PSI 12 (perioperative embolism or thrombosis) generated the highest costs.
- CHF 347 million was spent nationally in Switzerland in 2019 on treating the 16 investigated PSI-related adverse events.
- This represents 2.2% of the total national inpatient expenditure.

Abstract

There exists no comprehensive and up-to date overview of the financial impact of the different adverse events covered by the patient safety indicators (PSIs). Thus, we conducted a retrospective case-control study on a national data set of one million inpatients in Switzerland. We used propensity score matching and regression analyses to control for other cost-related influences and to determine the excess costs associated with the 16 different adverse events covered by the PSIs individually and at a national level.

Average excess costs ranged from CHF 1,211 (PSI 18, obstetric trauma with instrument) to CHF 137,967 (PSI 10, postoperative acute kidney injuries) with an average of CHF 27,409 across all PSIs. At a national level, this resulted in CHF 347 million higher inpatient costs in 2019, which corresponds to about 2.2% of annual inpatient costs in Switzerland. Our results provide data to inform policymakers' decisions and prioritize investments in patient safety.

Keywords: Patient safety indicators (PSIs), adverse events, costs, mortality, length of stay (LOS), propensity score matching

JEL classification: I11, I18, I19

Word count (without references and appendix): 7,264

Introduction

In-hospital adverse events cause suffering and harm and result in longer hospitalization stays and more frequent readmissions and deaths (Tessier et al., 2019). One in ten patients (range 2.9–21.9%) suffers from at least one adverse event during hospitalization (Schwendimann et al., 2018). These are international figures, but the situation in Switzerland is no different (Halfon et al., 2017). Approximately half of these adverse events are considered potentially preventable (Hoonhout et al., 2009; Panagioti et al., 2018; Schwendimann et al., 2018; Vincent et al., 2001). In addition to causing grief, these adverse events increase costs in the healthcare system (Kjellberg et al., 2017). A conservative assumption from the 2017 Organisation for Economic Co-operation and Development (OECD) report (Slawomirski et al., 2017), as well as a Canadian study (Jackson, 2009), suggests that between 1.3% and 32% of public hospital spending is related to the treatment of adverse events. In the US, adverse events caused excess costs of approximately USD 17.1 billion in 2008, which was 0.72% of the USD 2.39 trillion spent on healthcare during that year (Van den Bos et al., 2011).

Most previous studies on the costs of in-hospital adverse events focused only on some selected adverse events such as medical errors (see, e.g., De Rezende et al., 2012; Kjellberg et al., 2017). However, to allow for comparisons of the economic consequences of various adverse events, a set of different adverse events must be measured simultaneously according to exact and agreed-upon specifications. The Agency for Healthcare Research and Quality (AHRQ) utilizes an evidence-based methodology for identifying adverse events associated with patient safety using hospital administrative data. Initially, 19 patient safety indicators (PSIs) were proposed, and these were then gradually reduced to 17 (version v2021). The remaining PSIs offer a standardized and well-structured set of indicators to assess patient safety in hospitals that is used, for example, for provider comparisons in the US and country comparisons across the OECD.

Although the PSIs were introduced nearly 20 years ago, only a few studies have analyzed their financial impact. Furthermore, most researchers who have estimated excess costs due to PSI-related adverse events either used individualized definitions or only examined a select subset of PSIs. For example, Rivard et al. (2008), calculated costs for only nine PSIs, and Encinosa and Hellinger (2008) categorized the PSIs into seven groups, which prevented these studies from analyzing the financial impact across all individual PSIs. The most comprehensive study to date was conducted by Zhan and Miller (2003) in 2003. They demonstrated that patients experiencing one of these adverse events were hospitalized up to 10.89 days longer, had excess costs of up to USD 57,727, and excess mortality of up to 21.96%. However, even Zhan and Miller (2003) did not include all PSIs in their analysis. Furthermore, they did not take the frequency of the PSIs into account when evaluating the financial impact of the different PSIs on overall national inpatient costs.

We aimed to close these research gaps and show across all individual PSIs the excess costs that result from each adverse event and how they contribute to the total national excess costs of PSI-related adverse events. Thus, by comparing the PSIs in terms of cost *and* frequency, we can draw conclusions about the national financial impact of the different PSI-related adverse events and inform policy decisions regarding patient safety priorities from an economic perspective.

Methods

Data

This retrospective cohort study was conducted in Switzerland using two national health administration and finance data sets from 2019 provided by the Swiss Federal Statistical Office. The first data set[1] contained all inpatient cases treated in Swiss hospitals in 2019 with their diagnosis codes (ICD-10-GM[2]), procedure codes (CHOP[3]), diagnosis-related group (Swiss-DRG[4]), and other clinically relevant variables such as the admission and discharge conditions as well as demographic information such as age and sex. However, this data set did not include financial information on the cases. The second data set additionally included case-related cost data that was obtained from the cost-unit accounts and consisted of a “bottom-up” cost analysis where all the direct and indirect costs (i.e., the resources spent) were attributed to the hospital stays (H+, 2020). However, this second data set was restricted to acute inpatient cases (excluding psychiatric and rehabilitation cases, which are reimbursed outside of the DRG system in Switzerland) and contained only the 84% of patients who had no private supplementary insurance coverage. This combined (second) data set (administrative health data and cost data per case) was used for our cost analyses. It included 1,012,270 cases in total, of which 331,301 (32.7%) were excluded either because they did not meet the inclusion criteria of one of the PSI samples (e.g., the patients that were under 18 years old) or because the

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[1] Variables of the Medical Statistics Specifications: https://www.bfs.admin.ch/bfsstatic/dam/assets/7066232/master
[2] German modification of the International Classification of Diseases, 10th edition (ICD-10-GM): https://www.dimdi.de/static/de/klassifikationen/icd/icd-10-gm/kode-suche/htmlgm2019/
[3] Swiss Procedure Classification (CHOP): https://www.bfs.admin.ch/bfsstatic/dam/assets/5808569/master
[4] Swiss DRG classification: https://www.swissdrg.org/de/akutsomatik/archiv-swissdrg-system/swissdrg-system-802019

patients did not receive any treatment during the hospitalization. The latter exclusion criterion was applied to prevent comparisons of cases with PSI-related adverse events to cases without any treatment (i.e., cases that naturally have much lower resource requirements). After these exclusions, 680,969 cases remained and were used in our analyses (see also Table 2, which gives the exact sample sizes of each PSI). In contrast, the other data set (which also included patients with private supplementary insurance coverage but did not contain any financial information) was used to determine the total number of PSI-related adverse events in 2019 to estimate the national financial impact of the PSIs (see Section 2.3.3 below).

PSI samples and dependent variable

Adverse events were assessed using the PSI definitions utilized by the AHRQ.[5] Of the 17 current hospital-level indicators that screen for hospitalizations with potentially preventable adverse events, PSI 15 (accidental abdominopelvic punctures or lacerations) had to be excluded from our cost analyses because of its rarity (*n*=15). The remaining 16 PSIs were included in our analyses (see Table 4):

Table 5: Patient safety indicators (PSIs)

PSI	AHRQ description	Short form used in the main text[6]
PSI 02	Death in low-mortality diagnosis-related groups	Death in low-mortality DRGs
PSI 03	Pressure ulcer	Pressure ulcer
PSI 04	Death among surgical inpatients with serious treatable complications	Death after serious complications
PSI 05	Retained surgical item or unretrieved device fragment count	Retained surgical items
PSI 06	Iatrogenic pneumothorax	Iatrogenic pneumothorax
PSI 07	Central venous catheter-related bloodstream infection	CVC bloodstream infection
PSI 08	In-hospital fall with hip fracture	Fall with hip fracture

[5] PSI specifications used by the AHRQ: https://qualityindicators.ahrq.gov/Modules/psi_resources.aspx#techspecs. These PSI definitions have been translated into the Swiss medical coding systems (ICD-10-GM and CHOP).
[6] Subsequently, we will use these abbreviations to refer to the PSIs in the main text.

PSI	AHRQ description	Short form used in the main text[6]
PSI 09	Postoperative hemorrhage or hematoma	Postoperative hemorrhage/hematoma
PSI 10	Postoperative acute kidney injury requiring dialysis	Postoperative acute kidney injury
PSI 11	Postoperative respiratory failure	Postoperative respiratory failure
PSI 12	Perioperative pulmonary embolism or deep vein thrombosis	Perioperative embolism or thrombosis
PSI 13	Postoperative sepsis	Postoperative sepsis
PSI 14	Postoperative wound dehiscence	Wound dehiscence
PSI 15	Unrecognized abdominopelvic accidental puncture or laceration (excluded from analyses, see main text)	Accidental punctures or lacerations
PSI 17	Birth trauma – injury to neonate	Birth trauma
PSI 18	Obstetric trauma – vaginal delivery with instrument	Obstetric trauma with instrument
PSI 19	Obstetric trauma – vaginal delivery without instrument	Obstetric trauma without instrument

Note. PSI 15 had an insufficient number of cases to be used for analysis but is depicted here as well for the sake of completeness.

The dependent variable we focused on was the total cost per case obtained from the bottom-up full-cost method that allocates every type of cost (even overheads) to the treated case.[7] This approach is considered appropriate for measuring excess costs due to adverse events (Carey & Stefos, 2011). Costs are subsequently provided in Swiss francs (CHF), which can be converted into US dollars (USD) with an exchange rate (June 2022) of 0.99 (USD 1 = CHF 0.99) and into euros (EUR) with an exchange rate of 1.04 (EUR 1 = CHF 1.04). In addition to our primary outcome variable costs, we also investigated several secondary outcome variables such as length of stay, mortality, and number of readmissions.

Statistical analysis

After building the PSI samples and identifying the PSI-related adverse events (based on the PSI definitions of the AHRQ[9]), we examined population characteristics, such as the number of patients per PSI sample and the PSIs' incidences. Please note that the subsequently reported incidence rates are always

[7] Statistics of diagnosis-related case costs: https://www.bfs.admin.ch/bfsstatic/dam/assets/7849/master

considered in relation to the corresponding PSI sample (rather than in comparison to the entire data set).

Matching

Similar to previous studies investigating the costs of adverse events (Encinosa & Hellinger, 2008; Hauck et al., 2017; Rivard et al., 2008; Wardle et al., 2012; Zhan & Miller, 2003), we used propensity score matching to compare PSI cases with matched control cases with similar characteristics. Caution was needed to select only control variables for the matching that predicted the occurrence of a PSI-related adverse event but that were not caused by the adverse events covered by the PSIs (Smith & Todd, 2005). For example, based on the findings of preliminary analyses, we did not include DRG codes as matching variables because, according to the grouper methodology used by the Swiss DRG system, the presence of PSI-related complications determines in which DRGs patients fall.

Propensity score matching was performed separately for each PSI. Based on recommendations from Austin (2011), we matched the samples on the logit of the propensity score using calipers of width equal to 0.2 of the standard deviation of the logit of the propensity score based on the following variables:

- age (using five-year age groups);
- sex;
- nationality (Swiss or foreign);
- admission as an emergency;
- admission from a nursing home;
- transfer from another hospital; and
- the Elixhauser Index, which was recently validated and recalculated on Swiss data (Sharma et al., 2021). .

Apart from age and the Elixhauser Index, all matching variables were coded binary. In addition, some of the utilized matching variables had to be excluded in certain PSIs. For example, the variables “sex” and “admission from a nursing home” were not relevant for obstetrical PSIs like PSI 18 (obstetric trauma with instrument) and PSI 19 (obstetric trauma without instrument). On the other hand, for PSI 17 (birth trauma), we had to include additional matching variables that were relevant to the circumstances of the newborns. These included gestational age (in days), birth weight (in grams), head size (in centimeters), and the mother’s number of previous live births (Linder et al., 2013).

We report the area under the receiver operating characteristic curve (AUC) to examine the accuracy of our propensity score models in predicting PSI cases. To ensure that the matched samples would have sufficient statistical power even though PSI-related adverse events are rare, we used a nearest neighbor 1:3 matching (instead of the more traditional 1:1 matching) (Becker & Ichino, 2002). However, since 1:1 matching has been used more frequently in previous studies, we also provide results of a 1:1 matching in the supplementary material (Supplementary File 2, Tables S33–S36) to demonstrate similar findings under different matching conditions.

Excess costs per PSI

After matching, we assessed potentially remaining differences between PSI cases and matched controls using the Mann-Whitney U and chi-squared tests. Next, we performed ordinary least squares (linear) regression analyses for each PSI sample separately as well as for all PSI cases and controls combined to investigate the influence of PSI occurrence on costs. The combined regression was estimated without distinguishing between the PSI-related adverse events to examine the average excess costs of adverse events across all PSIs. Given that certain residual differences in matching variables remained between PSI cases and matched controls, we followed the advice of Austin (2011) to additionally include the matching variables as covariates in our regression analyses to reduce potentially remaining biases.

In addition, and analogous to the approach taken by Marbus et al. (2020), we controlled for premature deaths of patients in our analyses. Dying “prematurely” was defined as deaths occurring with a length of stay below the lower-trim point set out in the respective DRG of the patient. In this manner, we allow for comparisons of the excess costs of different adverse events independent of the potential confounding effect of more frequent premature deaths in certain PSIs. This was necessary because some PSIs were previously shown (Zhan & Miller, 2003) to have higher mortality rates than others, which was hypothesized to potentially and artificially reduce costs in these PSIs if patients die prematurely and no longer receive the otherwise required treatments.

In summary, we used the following regression model to explain the total costs of patients denoted by y_i using our set of explanatory variables denoted by $x_{k,I}$:

$$y_i = \beta_0 + \beta_1 x_{1,i} + \beta_2 x_{2,i} + \beta_3 x_{3,i} + \beta_4 x_{4,i} + \beta_5 x_{5,i} + \beta_6 x_{6,i} + \beta_7 x_{7,i} + \beta_8 x_{8,i} + \beta_9 x_{9,i} + \varepsilon_i \quad (1)$$

for $i = 1, ..., N_{pat}$, where

- $x_{1,i}$ is the occurrence of the respective PSI (binary);
- $x_{2,i}$ ... $x_{8,i}$ are the included covariates (age, sex, nationality, admission as emergency; admission from a nursing home, transfer from another hospital, and the Elixhauser Index);
- $x_{9,i}$ is premature death during hospitalization (binary); and
- ε_i is the error term for patient i with heteroscedastic variance $\sigma^2_{HC,i}$.

Excess costs at the national level

To obtain an accurate cost estimate of the financial impact of the PSI-related adverse events at a national level, excess costs of adverse events covered by the PSIs were multiplied by their frequency. However, because we noticed in preliminary analyses that certain PSIs, such as PSI 10 (postoperative acute kidney injury), PSI 11 (postoperative respiratory failure), and PSI 13 (postoperative sepsis), often co-occurred, we computed an additional regression analysis for all PSI cases and their matched controls combined. In contrast to the combined regression introduced above, we also investigated the individual effect of each PSI-related adverse event by including a separate variable for each PSI in the regression model. This procedure allowed us to control for the co-occurrence of certain PSIs and avoided double-counting co-occurring PSIs in our national aggregate. Furthermore, we did not control for prematurely dying patients in this regression analysis, since our goal was to determine the most accurate estimate of the actual financial impact and adjusting the costs for prematurely deceased patients would have overestimated the national costs.

Next, the regression coefficient of each PSI (i.e., the excess costs that this adverse event generated on average per case) was multiplied by the frequency of the adverse event covered by that PSI. This frequency was, assessed on the full national data set (as was explained in Section 2.1 above). It must be noted, however, that this estimate only includes patients who met the inclusion criteria of the PSI samples, whereas certain high-risk patient groups are specifically excluded in the sample specifications of the PSIs (for further information, see the discussion in Section 4).

The only exceptions from this procedure for calculating national costs were the obstetrical PSIs 17–19. These PSIs and their samples were not included in the combined regression, because obstetrical cases require much lower resources (i.e., have lower costs) than other cases. This prevented us from computing the excess costs of the adverse events covered by PSIs 17–19 alongside the other PSIs. Their coefficients were, therefore, used from their individual regressions. We consider this correct, as these PSIs neither co-occurred with others nor did any of these patients die. For all statistical analyses, the software IBM SPSS Statistics 27 was used, and results were considered significant if $p < .05$.

Results

Study population and matching

During the observed period, 9,853 *different* PSI-related adverse events were registered among the 680,969 inpatients we investigated, and 9,109 patients had *at least one* event (see Table 5). PSI 09 (postoperative hemorrhage/hematoma) was the most common event, accounting for 27.6% of the adverse events across all PSIs, followed by PSI 12 (perioperative embolism or thrombosis), which accounted for 14.1% of the adverse events among the PSIs. The rarest PSI among the considered PSIs was PSI 02 (death in low-mortality DRGs), which, with 43 cases, accounted for only 0.4% of the measured patient safety-adverse events.

We matched 8,986 PSI cases to 26,931 control cases based on the matching variables introduced in Section 2.3.1. The predicted probabilities from our propensity score models showed good to excellent AUC values across most PSIs (see Table 5) except for PSI 18 (obstetric trauma with instrument) and PSI 19 (obstetric trauma without instrument), for which we lacked obstetrically-relevant predictor variables. Thanks to the high number of cases available, a matching rate > 95% was achieved for almost all PSIs. Lower matching rates were only registered for PSI 04 (death after serious complications) and PSI 17 (birth trauma).

Table 6: Sample characteristics and matching results

		Raw data		Incidence	After matching		Matching rate	AUC
		N (PSI = 0)	*N* (PSI = 1)	Per thousand	*N* (PSI = 0)	*N* (PSI = 1)		
PSI 02	Death in low-mortality DRGs	210,113	43	0.20	129	43	100.0%	0.919
PSI 03	Pressure ulcer	207,566	865	4.15	2,595	865	100.0%	0.744
PSI 04	Death after serious complications	6,511	1,333	169.94	1,555	524	39.3%	0.731
PSI 05	Retained surgical items	666,990	76	0.11	228	76	100.0%	0.612
PSI 06	Iatrogenic pneumothorax	557,683	310	0.56	930	310	100.0%	0.726
PSI 07	CVC bloodstream infection	467,237	553	1.18	1,659	553	100.0%	0.826
PSI 08	Fall with hip fracture	186,552	111	0.59	333	111	100.0%	0.925
PSI 09	Postoperative hemorrhage/hemato ma	303,722	2,717	8.87	8,151	2,717	100.0%	0.634
PSI 10	Postoperative acute kidney injury	230,484	227	0.98	644	217	95.6%	0.956
PSI 11	Postoperative respiratory failure	197,181	90	0.46	264	88	97.8%	0.921
PSI 12	Perioperative embolism or thrombosis	316,278	1,393	4.39	4,165	1,389	99.7%	0.861
PSI 13	Postoperative sepsis	231,525	493	2.12	1,421	474	96.1%	0.906
PSI 14	Wound dehiscence	43,545	151	3.46	453	151	100.0%	0.792
PSI 15	Accidental punctures or lacerations	43,794	15	-	-	-	-	-
PSI 17	Birth trauma	12,865	101	7.79	234	78	77.2%	0.706
PSI 18	Obstetric trauma with instrument	7,515	560	69.35	1,680	560	100.0%	0.530
PSI 19	Obstetric trauma without instrument	39,964	830	20.35	2,490	830	100.0%	0.546

Note. AUC area under the curve. The matching rate indicates the proportion of cases that met the common support assumption. PSI 15 had an insufficient number of cases to be used for analysis but is depicted here as well for the sake of completeness.

The comparisons of means and relative frequencies in the variables used for the matching are provided in the supplement (Supplementary File 1, Table S13). Rare residual differences in specific variables (mainly age and the Elixhauser Index) still existed after matching, which is why we subsequently included all matching variables as covariates in the regression models as well (see also Methods Section).

However, most comparisons of the matching variables (93%) showed no significant differences between the matched groups.

Table 6 compares the means and relative frequencies of the outcome variables between the matched groups. It shows that PSI cases have significantly higher costs (with a weighted mean of CHF 56,439 across all PSI cases) than their matched controls (with a weighted mean of CHF 23,696 across all matched non-PSI cases), resulting in a weighted mean difference of CHF 32,743. Put differently, adverse events generated between 15% excess costs in PSI 18 (obstetric trauma with instrument) and 335% excess costs in PSI 10 (postoperative acute kidney injury).

In addition to the costs, the average length of stay was 1.9 times higher[8] and, therefore, 7.8 days longer[8] in PSI-related adverse event cases compared to controls. In particular, patients with PSI 13 (postoperative sepsis) stayed 22.3 days longer, while patients with PSI 18 (obstetric trauma with instrument) or PSI 19 (obstetric trauma without instrument) only stayed several extra hours (see Table 6). Additionally, the PSI-related adverse event cases had 2.5 times higher[8] readmission rates (12.0%)[8] than their matched controls (4.8%)[8]. While, for example, patients with PSI 09 (postoperative hemorrhage/hematoma) had a seven times higher readmission rate, lower readmission rates were only found in patients who deceased in PSI 04 (death after serious complications). Furthermore, the mortality rate was 4.1 times higher[8] in cases with adverse events (16.7%)[8], compared to their controls (4.1%)[8]. While patients with a PSI 10 (postoperative acute kidney injury) had a 10.3 times higher mortality rate (36.9% instead of 3.6%) and patients with a PSI 13 (postoperative sepsis) had a 9.4 times higher mortality rate (22.4% instead of 2.4%), in the obstetrical PSIs (PSI 17–19) no patients died.

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[8] All of these values are weighted means.

Table 7: Comparisons of means and relative frequencies across outcome variables in the matched groups

PSI		Total cost in CHF		LOS		Number of readmissions		Mortality	
		0	1	0	1	0	1	0	1
PSI 02: Death in low-mortality DRGs	Mean/RF	9,432.97	16,211.84	5.05	5.81	0.03	0.02	0.00%	100.00%
	SD	7,617.84	18,100.84	5.19	6.57	0.17	0.15	-	-
	test statistic	-1.61		-0.11		-0.26		172.00	
	p	.107		.911		.794		< .001 ***	
PSI 03: Pressure ulcer	Mean/RF	22,261.30	51,792.02	12.65	23.62	0.07	0.07	5.66%	16.99%
	SD	31,696.64	77,644.00	10.13	24.21	0.27	0.26	-	-
	test statistic	-18.05		-17.95		-0.80		107.10	
	p	< .001 ***		< .001 ***		.426		< .001 ***	
PSI 04: Death after serious compli-cations	Mean/RF	85,827.49	101,459.06	25.96	16.87	0.10	0.05	0.00%	100.00%
	SD	115,484.61	128,691.57	23.62	20.07	0.31	0.23	-	-
	test statistic	-3.08		-12.40		-3.76		2079.00	
	p	.002 **		< .001 ***		< .001 ***		< .001 ***	
PSI 05: Retained surgical items	Mean/RF	13,932.12	30,748.18	5.51	10.78	0.03	0.07	2.19%	2.63%
	SD	20,026.31	47,458.73	6.65	18.54	0.19	0.25	-	-
	test statistic	-4.67		-4.01		-1.84		0.05	
	p	< .001 ***		< .001 ***		.066		>.999	
PSI 06: Iatrogenic pneumo-thorax	Mean/RF	17,998.51	43,259.37	8.43	12.71	0.05	0.05	4.62%	9.35%
	SD	31,285.92	59,343.67	11.05	12.86	0.23	0.21	-	-
	test statistic	-11.93		-6.72		-0.60		9.52	
	p	< .001 ***		< .001 ***		.551		.002 **	
PSI 07: CVC bloodstream infection	Mean/RF	25,063.80	96,456.09	10.42	28.25	0.07	0.11	6.21%	10.85%
	SD	43,110.11	120,722.84	11.05	24.59	0.27	0.32	-	-
	test statistic	-23.68		-22.64		-3.78		13.09	
	p	< .001 ***		< .001 ***		< .001 ***		< .001 ***	
PSI 08: Fall with hip fracture	Mean/RF	35,075.09	65,256.16	11.32	24.60	0.08	0.06	9.01%	17.12%
	SD	46,848.67	54,699.80	13.85	20.12	0.28	0.24	-	-
	test statistic	-7.33		-8.05		-0.53		5.57	
	p	< .001 ***		< .001 ***		.597		.018 *	
PSI 09: Post-operative hemorrhage/hematom	Mean/RF	18,145.03	35,766.92	6.20	11.84	0.04	0.25	1.36%	2.50%
	SD	29,283.71	48,453.42	9.20	14.41	0.19	0.48	-	-
	test statistic	-31.45		-30.09		-31.42		16.38	
	p	< .001 ***		< .001 ***		< .001 ***		< .001 ***	
PSI 10: Post-operative acute kidney	Mean/RF	41,325.22	179,900.37	12.38	32.29	0.05	0.06	3.57%	36.87%
	SD	49,047.81	183,709.60	13.60	31.43	0.22	0.23	-	-
	test statistic	-17.00		-11.83		-0.41		170.84	
	p	< .001 ***		< .001 ***		.679		< .001 ***	
PSI 11: Post-operative respiratory failure	Mean/RF	35,207.06	140,475.73	10.56	31.38	0.03	0.06	5.30%	23.86%
	SD	53,024.94	83,730.84	13.08	18.67	0.16	0.28	-	-
	test statistic	-11.36		-10.60		-0.90		25.39	
	p	< .001 ***		< .001 ***		.370		< .001 ***	
PSI 12: Peri-operative embolism or	Mean/RF	36,195.73	71,827.91	11.81	21.62	0.06	0.10	6.31%	10.15%
	SD	60,247.28	112,642.46	16.01	22.60	0.26	0.31	-	-
	test statistic	-23.64		-22.91		-4.57		22.73	
	p	< .001 ***		< .001 ***		< .001 ***		< .001 ***	
PSI 13: Post-operative sepsis	Mean/RF	31,497.43	124,930.27	9.90	32.14	0.04	0.11	2.39%	22.36%
	SD	41,041.90	144,215.25	12.37	27.60	0.21	0.31	-	-
	test statistic	-24.12		-23.45		-5.40		207.18	
	p	< .001 ***		< .001 ***		< .001 ***		< .001 ***	
PSI 14: Wound dehiscence	Mean/RF	33,965.91	78,382.95	12.52	26.76	0.06	0.17	5.08%	10.60%
	SD	53,418.18	63,757.46	16.75	14.48	0.25	0.40	-	-
	test statistic	-13.55		-12.80		-3.90		5.71	
	p	< .001 ***		< .001 ***		< .001 ***		.017 *	

PSI		Total cost in CHF 0	1	LOS 0	1	Number of readmissions 0	1	Mortality 0	1
PSI 17: Birth trauma	Mean/RF	5,852.45	12,615.03	4.82	6.36	0.01	0.03	-	-
	SD	14,061.31	20,300.98	4.89	5.97	0.11	0.16	-	-
	test statistic	-5.38		-2.16		-0.78		-	
	p	< .001 ***		.030 *		.436		-	
PSI 18: Obstetric trauma with instrument	Mean/RF	8,195.47	9,400.23	4.06	4.30	0.00	0.00	-	-
	SD	3,514.32	3,445.03	1.55	1.43	0.00	0.00	-	-
	test statistic	-8.80		-4.08		0.00		-	
	p	< .001 ***		< .001 ***		-		-	
PSI 19: Obstetric trauma without instrument	Mean/RF	6,415.47	7,851.62	3.47	3.83	0.00	0.00	-	-
	SD	2,450.17	2,689.39	1.23	1.18	0.02	0.00	-	-
	test statistic	-14.83		-8.45		-0.58		-	
	p	< .001 ***		< .001 ***		.564		-	

Note. *** = $p < .001$; ** = $p < 0.01$; * = $p < 0.05$; Binary variables are expressed as relative frequencies (RF) in percent (%). Continuous variables are expressed as means and standard deviations (SD). *CHF* Swiss francs, *LOS* length of stay, *p* probability value.

Excess costs across individual PSIs

We used regression analyses to examine the effects of the PSI-related adverse events on total costs per case independent of several covariates. The individual regression analyses per PSI and an overview of the individual regression analyses is provided in the supplemental material (Supplementary File 1, Tables S14–S29). In contrast, Table 7 presents the results of a regression analysis across all PSIs and matched controls (without distinguishing between PSIs) to enable a discussion of the average excess costs across all PSIs.

Table 8: Regression analysis using the occurrence of all the PSIs (without distinguishing the kind of PSI) and several covariates to explain total costs (in CHF)

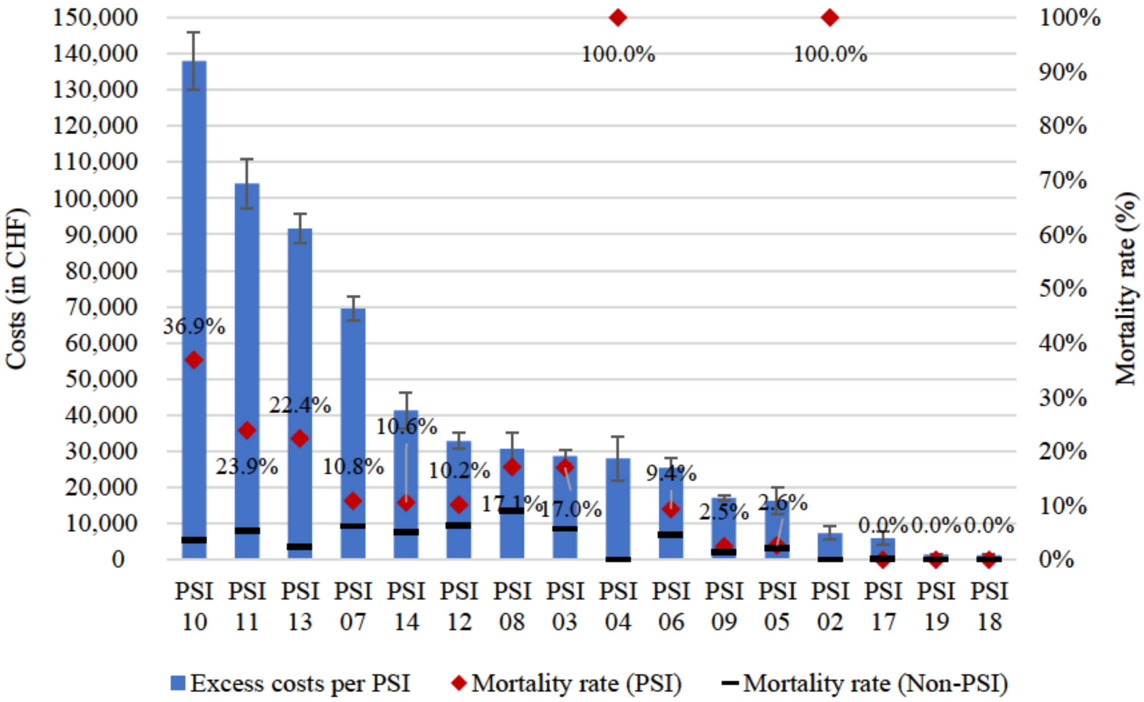
	B (in CHF)	Std. Error	t	p	
Constant	7364.61	990.39	7.436	< .001	***
PSI occurrence	27'408.85	664.91	41.222	< .001	***
Age	-65.59	15.98	-4.105	< .001	***
Sex: male	7'008.03	626.82	11.180	< .001	***
Nationality: Swiss	-1'581.37	715.02	-2.212	.027	*
Admission: Emergency	5'084.45	606.34	8.385	< .001	***
Admission: From nursing home	-3'667.48	2'478.05	-1.480	.139	
Admission: Transferred	25'242.13	1'226.06	20.588	< .001	***
Elixhauser Index	1'267.29	23.06	54.946	< .001	***
Premature death	-27'692.78	3'479.83	-7.958	< .001	***

Note. *** = $p < .001$; ** = $p < 0.01$; * = $p < 0.05$; *B* unstandardized beta coefficients (costs), *t* test statistic, *p* probability value, *CHF* Swiss francs.

Figure 6 illustrates the excess costs per PSI in descending order of magnitude (see also Supplementary File 1, Table S30) together with their mortality rates. As can be seen, excess costs vary across PSIs, and the average excess costs across all PSIs are CHF 27,409 (see Table 7). PSI 10 (postoperative acute kidney injuries), PSI 11 (postoperative respiratory failure), PSI 13 (postoperative sepsis), and PSI 07 (CVC bloodstream infection) had higher costs than the other PSIs. Apart from PSI 02 (death in low-mortality DRGs) and PSI 04 (death after serious complications), those are also the PSIs with the highest mortality rates. On the other end of the spectrum, the obstetrical PSI 17 (birth trauma), PSI 18 (obstetric trauma with instrument), and PSI 19 (obstetric trauma without instrument), together with PSI 02 (death in low-mortality DRGs) and PSI 05 (retained surgical items) show the lowest excess costs across all PSIs.

The regression results provided in the supplemental material (Supplementary File 1, Tables S13–S29 further show that premature death reduced costs in many PSIs, including PSI 02 (death in low-mortality DRGs), PSI 04 (death after serious complications), PSI 06 (iatrogenic pneumothorax), PSI 07 (CVC bloodstream infection), PSI 10 (postoperative acute kidney injury), PSI 12 (perioperative embolism or thrombosis), and PSI 13 (postoperative sepsis). In the combined sample (see Table 7), costs were, on average, CHF 27,693 ($p = < .000$) lower across all PSIs in cases of premature death.

Figure 6: Excess costs and mortality rates across the different PSIs (according to their individual regression models, see Supplementary File 1, Tables S3-29)



PSI 02	*Death in low-mortality DRGs*	*PSI 10*	*Postoperative acute kidney injury*
PSI 03	*Pressure ulcer*	*PSI 11*	*Postoperative respiratory failure*
PSI 04	*Death after serious complications*	*PSI 12*	*Perioperative embolism or thrombosis*
PSI 05	*Retained surgical items*	*PSI 13*	*Postoperative sepsis*
PSI 06	*Iatrogenic pneumothorax*	*PSI 14*	*Wound dehiscence*
PSI 07	*CVC bloodstream infection*	*PSI 17*	*Birth trauma*
PSI 08	*Fall with hip fracture*	*PSI 18*	*Obstetric trauma with instrument*
PSI 09	*Perioperative hemorrhage/hematoma*	*PSI 19*	*Obstetric trauma without instrument*

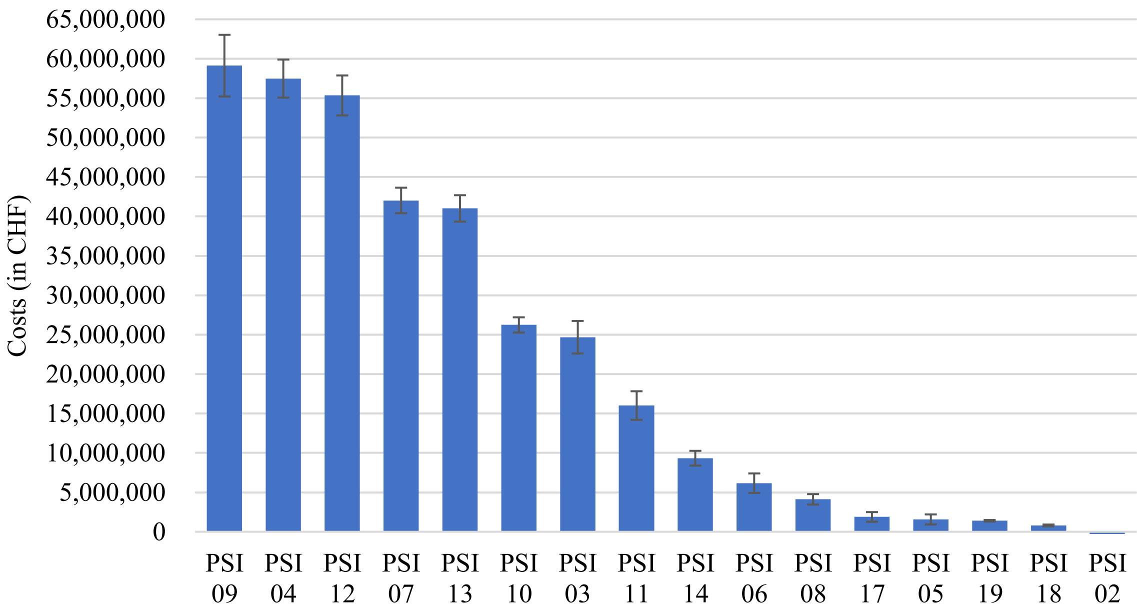
Note. Error bars illustrate standard deviations. Mortality rates are shown as averages in PSI samples vs. in the control group (non-PSI). PSI 2 (death in low-mortality DRGs) and PSI 4 (death after serious complications) have a 100% mortality rate since these PSIs assess death as outcome of interest. None of the patients in the samples of PSI 17, PSI 18, and PSI 19 died.

Excess costs at a national level

Figure 7 demonstrates the aggregated national costs per PSI in Switzerland in 2019. These costs were calculated by multiplying the excess costs per PSI by the number of adverse events per PSI (see Supplementary File 1, Tables S30-31 and Section 2.3.3). Comparing Fig. 1 and Fig. 2 reveals that, on a nationally aggregated level, PSI 07 (CVC bloodstream infection) and PSI 13 (postoperative sepsis) still show comparably high excess costs after taking their frequency into account. However, in addition, PSI 09 (postoperative hemorrhage/hematoma), PSI 04 (death after serious complications), and PSI 12 (perioperative embolism or thrombosis) are now also among the costliest adverse events when their high frequency is considered. In contrast, among the least costly PSIs, we still find the same PSIs as in Fig. 1, namely PSI 17 (birth trauma), PSI 18 (obstetric trauma with instrument), and PSI 19 (obstetric trauma without instrument), as well as PSI 02 (death in low-mortality DRGs) and PSI 05 (retained surgical items).

Finally, by summing up the total excess costs across all patient safety-adverse events (see Supplementary File 1, Table S31), the total national excess costs due to PSI-related adverse events in Switzerland in 2019 were estimated at CHF 347 million.

Figure 7: Total national costs per PSI incurred in Switzerland in the 2019 fiscal year



PSI 02	*Death in low-mortality DRGs*	*PSI 10*	*Postoperative acute kidney injury*
PSI 03	*Pressure ulcer*	*PSI 11*	*Postoperative respiratory failure*
PSI 04	*Death after serious complications*	*PSI 12*	*Perioperative embolism or thrombosis*
PSI 05	*Retained surgical items*	*PSI 13*	*Postoperative sepsis*
PSI 06	*Iatrogenic pneumothorax*	*PSI 14*	*Wound dehiscence*
PSI 07	*CVC bloodstream infection*	*PSI 17*	*Birth trauma*
PSI 08	*Fall with hip fracture*	*PSI 18*	*Obstetric trauma with instrument*
PSI 09	*Perioperative hemorrhage/hematoma*	*PSI 19*	*Obstetric trauma without instrument*

Note. Error bars illustrate standard deviations. The calculations that underlie these results can be found in the Supplementary File 1, Table S18-19.

Discussion

There are many reasons to increase patient safety and reduce in-hospital adverse events. However, instead of focusing on ethical, regulatory, or patient-centered reasons, we investigated the financial impact of patient safety-adverse events in order to motivate improvements. Across all PSIs combined, the occurrence of a PSI-related adverse event resulted in CHF 27,409 of excess costs on average. Among the specific PSI samples, PSI 10 (postoperative acute kidney injury) generated the highest excess costs per case, followed by PSI 11 (postoperative respiratory failure) and PSI 13 (postoperative sepsis). However, if the volume of the PSIs is taken into account, the highest costs resulted from PSI 09 (postoperative hemorrhage/hematoma), followed by PSI 04 (death after serious complications) and PSI 12 (perioperative embolism or thrombosis). In addition, we demonstrated that patients with a PSI-related adverse event not only generated higher costs but also remained in hospital 7.8 days longer, had a 2.5 times higher readmission rate, and demonstrated a 4.1 times higher mortality rate on average.

Comparing excess costs and incidences of PSIs with previous studies

Our analyses confirmed that both per-event excess costs as well as the volume of PSIs matter when assessing the health system impact of in-hospital adverse events. If the frequency of PSIs is taken into account, PSI 09 (postoperative hemorrhage/hematoma) causes excess costs of CHF 59 million for the Swiss healthcare system, followed by CHF 57 million from PSI 04 (death after serious complications) and CHF 55 million from PSI 12 (perioperative embolism or thrombosis). In contrast, PSI 17 (birth trauma), PSI 18 (obstetric trauma with instrument), and PSI 19 (obstetric trauma without instrument) cause relatively low excess costs of only CHF 0.8–1.9 million even though they occur quite frequently.

Comparing these findings to the selection of PSIs that the OECD annually assesses, benchmarks, and publishes for European countries reveals that its PSI selection does not match the economic relevance of the PSIs (at least for Switzerland). Although two of the PSIs that it reports, namely PSI 12 (perioperative embolism or thrombosis) and PSI 13 (postoperative sepsis), have shown an important financial impact in our study. The other four PSIs in the OECD's reports, PSI 05 (retained surgical items), PSI 14 (wound dehiscence), PSI 18 (obstetric trauma with instrument), and PSI 19 (obstetric trauma without instrument) were found to have a relatively small financial impact. However, other criteria (such as feasibility, availability of data, etc.) have, presumably, also guided the OECD's selection of PSIs for country comparisons.

Contrasting our findings with the previous results of Zhan and Miller (2003) shows various consistencies. According to Zhan and Miller (2003), the highest excess costs per case were generated by the following five PSIs (in descending order of magnitude): PSI 13 (postoperative sepsis), PSI 10 (postoperative acute kidney injury), PSI 11 (postoperative respiratory failure), PSI 14 (wound dehiscence), and PSI 07 (CVC bloodstream infection). These were also the PSIs that showed the highest per case costs in our study. Zahn and Miller (2003) did not explicitly calculate the cumulative national costs of PSIs, but they reported the frequencies of each PSI, so we were able to calculate the cumulative costs ourselves based on their results. By doing so, we found that the following three PSIs had the highest national cost impact according to Zahn and Miller (in descending order of magnitude): PSI 03 (pressure ulcer), PSI 07 (CVC bloodstream infection), and PSI 12 (perioperative embolism or thrombosis). Our findings are consistent with these previous results regarding the high financial impact of PSI 12 (perioperative embolism or thrombosis) and PSI 07 (CVC bloodstream infection). However, according to our calculations, PSI 09 (postoperative hemorrhage/hematoma) is the most expensive PSI in Switzerland, while PSI 03 (pressure ulcer) is, according to Zhan and Miller (2003), the most expensive one in the US. This disparity may arise from differing incidence rates of the PSIs in Switzerland and the US (see the next paragraph) but could also be the result of different treatment practices and coding incentives or differences in our medical coding systems (see below).

We found that in absolute terms, the highest number of patients was affected by PSI 09 (postoperative hemorrhage/hematoma) followed by PSI 12 (perioperative embolism or thrombosis). In contrast, evaluating the incidence rates within the samples of the PSIs, PSI 04 (death after serious complications) showed the highest incidence, followed by PSI 18 (obstetric trauma with instrument), and PSI 19 (obstetric trauma without instrument). Comparing these findings with the results of Zhan and Miller (2003) reveals that although they also observed the obstetrical PSIs to be the most frequent, in absolute terms, they generally found higher incidence rates for most investigated PSIs. These differences may be because they used the earlier versions of PSI definitions that were current in 2003. Since then, the PSIs have evolved considerably and now use adapted inclusion and exclusion criteria that have been improved continually over the last two decades.[9] Furthermore, the medical coding practice (i.e., what is coded) and the coding quality (i.e., how well it is coded) have also developed since then. In addition, the fact that different coding systems (ICD-10-GM) are used in Switzerland and the US (ICD-9-CM at that time) may also have impacted the differing incidence rates in our study compared to the earlier

[9] See supplemental material from the AHRQ: https://qualityindicators.ahrq.gov/Modules/psi_resources.aspx#additional

results. Alternatively, it could be argued that the quality of care has improved during the last two decades, that healthcare quality is different between Switzerland and the US, or that the health status of the Swiss population is higher (as the US has higher rates of illnesses and lower life expectancy than Switzerland) (Woolf & Aron, 2013). However, it is similarly likely, in our opinion, that the PSIs are not as frequently coded in Switzerland due to different coding practices and/or incentives or because the PSIs are currently not used in annual healthcare quality assessments and, thus, may not be as closely monitored.

Furthermore, it must be noted that the order of magnitude of the excess costs of the PSIs between the per-event costs and the nationally aggregated costs did not only change due to the frequencies of the PSIs. Rather the relative financial impact of certain PSIs also decreased at a national level because we adjusted for the co-occurrence of different PSIs in our estimation of the national costs (see Section 2.3.3). This was particularly important for PSI 10 (postoperative acute kidney injury), PSI 11 (postoperative respiratory failure), and PSI 13 (postoperative sepsis), which often co-occurred. That makes sense from a clinical perspective because PSI 13 (postoperative sepsis) often precedes PSI 10 (postoperative acute kidney injury) and/or PSI 11 (postoperative respiratory failure) in cases of multiple organ system failure due to, for example, septic shock. Therefore, the adjustment for the co-occurrence of PSIs reduced the costs of these three PSIs at a national level compared to their per-event costs (which did not include such an adjustment).

PSIs with a high risk for mortality and premature death of patients

Our study is, to the best of our knowledge, the first to provide information about the financial impact of PSI 02 (death in low-mortality DRGs) and PSI 04 (death after serious complications). We suppose that previous studies have not investigated these two PSIs because their outcome of interest is death, and they may have thus been assumed to decrease (rather than increase) costs due to a premature end of the hospitalization. However, we hypothesized that this need not necessarily be the case and included a variable for premature death as a covariate in our regression analyses to distinguish between patients that died prematurely (i.e., resulting in lower costs) and those that succumbed after several treatment attempts (i.e., resulting in higher costs). As hypothesized, our regression results revealed that costs only decrease in these PSI samples if patients deceased prematurely but, on the contrary, increase if they died at a later stage during the hospitalization. However, significantly higher costs and a trend towards higher costs for PSI 04 (death after serious complications) and PSI 02 (death in low-mortality DRGs), respectively, were already found in simple comparisons of means (without any correction for the proportion of patients that died prematurely). This demonstrates that, overall, the costs increase in patients that died within these PSI samples. These findings support the notion that excess costs arise from trying to save patients (Hvenegaard et al. (2011)). Furthermore, the cost-decreasing effects of premature deaths were also observed across many other high-mortality PSI samples, such as PSI 06 (iatrogenic pneumothorax), PSI 07 (CVC bloodstream infection), PSI 10 (postoperative acute kidney injury), PSI 12 (perioperative embolism or thrombosis), and PSI 13 (postoperative sepsis).

Practical relevance and limitations of our findings

Our study provides the most comprehensive examination of the excess costs resulting from PSI-related adverse events to date. Most previous studies investigating the excess costs of PSIs either used individualized definitions or only examined a subset of PSIs. In contrast, we calculated the costs of all PSIs and compared their financial impact per case and on a nationally aggregated level. The total excess costs across all PSIs in Switzerland were estimated as roughly CHF 347 million in 2019, which is approximately 2.2% of the annual inpatient costs of CHF 15.7 billion (Swiss Federal Statistical Office, 2020). Even though this is just an estimation, it demonstrates the potential for considerable national cost savings from reducing PSI-related adverse events. Interestingly, Hoogervorst-Schilp et al. (2015) found similar results in the Netherlands, where adverse events were estimated at approximately EUR 300 million in additional costs, corresponding to 1.3% of their national hospital costs.

It must, however, be highlighted that our study focused exclusively on the costs of adverse events covered by the PSIs. This includes only a fraction of all types of adverse events and, therefore, does not allow for a conclusive statement concerning the potential cost savings across all in-hospital adverse events. However, even if the costs of the PSIs only represent a fraction of the total excess costs of all in-hospital adverse events (Zhan & Miller, 2003), their advantage is that they enable us to measure patient safety-adverse events consistently and allow for international comparisons. The results presented in this study enable the prioritization of investments in particular aspects of patient safety that will result in the highest potential cost savings. For example, a 50% reduction in the frequency of the three most expensive adverse events, namely PSI 09 (postoperative hemorrhage/hematoma), PSI 04 (death after serious complications), and PSI 12 (perioperative embolism or thrombosis) could potentially save CHF 80 million per year in Switzerland. Our findings can thus support policymakers to select initiatives for increasing patient safety that, in addition to reducing suffering, also have the greatest potential for reducing national healthcare expenditure.

One significant limitation of our study is that we only considered costs that arose during inpatient stays. As has been pointed out (Encinosa & Hellinger, 2008), a substantial additional proportion (up to 20%) of the costs due to adverse events accrues in ambulatory settings after discharge. According to Mello et al. (2007), these additional costs could even be as high as 78%. Furthermore, we only included cases in our cost analyses that met the inclusion and exclusion criteria for the various PSI samples. However, these criteria often specifically exclude many cases at particularly high risk for adverse events in order to enable better stratification and more accurate hospital quality comparisons. As a result, however, a number of cases with additionally present PSI-related adverse events were neither included in our analyses nor in our estimation of the national costs due to these adverse events. Another important limitation of our study is the fact that there currently exists no "present on admission" (POA) indicator for secondary diagnoses in Switzerland. This introduces an important bias that, presumably, increases the number of adverse events and, thus, the nationally aggregated costs in certain PSIs (Houchens et al., 2008). Based on previous research, this incidence inflating effect of false positives is most likely to occur in PSI 03 (pressure ulcer) and PSI 08 (fall with hip fracture), where POA information has shown the greatest benefits in terms of improving positive predictive values (Narain, 2017). Finally, by only examining total costs in our study, we cannot draw conclusions about who carries these costs in the healthcare system. More specifically, it is not certain if hospitals have to bear some of the excess costs of the adverse events or if the DRG reimbursements in Switzerland contain full compensation for these complications. Future research should investigate these issues to improve our understanding of the financial implications of in-hospital adverse events.

Conclusion

Our study revealed that patients who experienced an adverse event covered by the PSIs were associated with CHF 27,409 higher costs, 7.8-day longer stays, 2.5 times more readmissions, and 4.1 times higher mortality rates. Cumulatively, we estimated that roughly CHF 347 million excess costs are generated each year in relation to the investigated PSIs in Switzerland. However, the contribution of the different PSIs to these national costs varies markedly. Three PSIs alone account for nearly half of the national excess costs: PSI 09 (postoperative hemorrhage/hematoma), PSI 04 (death after serious complications), and PSI 12 (perioperative embolism or thrombosis), which are responsible for costs of CHF 58, 57, and 55 million, respectively. Our results could inform policymakers and regulators' decisions regarding funding allocations by enabling them to consider the financial impact of these adverse events alongside the suffering they cause.

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CHAPTER 4: PATIENT SATISFACTION AND FINANCIAL PERFORMANCE

4.1 Introduction

While the previous chapter examined the relationship between clinical quality and cost, Chapter 4 turns to the relationship between patient satisfaction and financial performance. This takes the research one step further along the causal chain. Since patient satisfaction has hardly any direct influence on financial performance (because the patient does not primarily pay the hospital for its services), various financial ratios must be considered and not only costs, as in Chapter 3. Therefore, the study presented in this chapter considers not only costs but also revenues and the operating margin.

4.2 Paper 3

PATIENT SATISFACTION IS PROFITABLE – EVIDENCE FROM SWISS HOSPITALS

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Abstract

Objective: To investigate whether higher patient satisfaction is financially rewarding for hospitals.

Data Sources: Using a cross-sectional study design, we analyzed secondary national data from 135 Swiss acute care hospitals from 2016 to 2018.

Study Design: Using multiple regressions and moderating variables, we examined hospital-based financial performance measures and their associations with patient satisfaction. Financial performance was measured using net patient revenue, net operating expenses, and operating margin. Moderators included the proportion of emergency patients treated and the bed occupancy rate.

Data Collection/ Extraction methods: Data on patient satisfaction and financial performance was matched on hospital level.

Principal Findings: Our results showed a positive association between hospital costs (net operating expenses) and patient satisfaction ($r=0.143$; $p<0.00$), which was stronger in hospitals with fewer emergency patients. Patient satisfaction can be used to predict net patient revenue. These relationships were most robust in hospitals that cared for few emergency patients and had a high bed occupancy rate.

Conclusion: Even though the association between patient satisfaction and financial performance appears to be indirect and not strong, our results show that patient satisfaction is associated with not only higher revenues but also higher costs. Hospitals with few emergency patients or higher bed occupancy rates tend to profit more financially from higher patient satisfaction. This study demonstrates that more research is needed to find out why the type of admission affects patient satisfaction and to demonstrate that higher staffing costs drive up costs but also patient satisfaction.

Keyword: Patient satisfaction, healthcare financing, financial management, patient admission, bed occupancy

Abstract word count: 242

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What is known to this topic?

- Studies outside of health care demonstrate that satisfied customers drive profitability through loyalty and lower price-sensitivity.
- It remains unclear to what extant this relationship can be applied to health care.
- Only a few researchers have investigated the association considering either costs or revenues.

What this study adds?

- Hospitals with higher costs have more satisfied patients and hospitals with more satisfied patients have higher revenues, while operating margin is not affected by patient satisfaction.
- The type of admission (emergency) and the bed occupancy rate affect patient satisfaction.
- The study provides a guidance for key decision makers to publish patient satisfaction transparently and include it in the hospitals management cockpits.

Introduction

Hospitals do not usually strive for high levels of patient satisfaction for direct financial reasons (Richter & Muhlestein, 2017). Instead, patient satisfaction is an easy-to-measure proxy for service quality (Griffiths & Leaver, 2018) and a good indicator of patient-centeredness (Cosgrove et al., 2013). However, previous studies from outside of healthcare have shown that satisfied customers drive profitability. They remain loyal, speak positively about the company, and are less price-sensitive, which leads to the protection of future revenues and reduces marketing expenses (Gupta & Zeithaml, 2006; Heskett et al., 2008b; Homburg et al., 2005).

However, how does this association manifest in hospitals, where the service is not always accessed voluntarily and where the “case-based payment” is not influenced by price sensitivity? Additionally, hospitals can influence their financial performance primarily by reducing costs, whereas the relationship between cost reduction, patient satisfaction, and higher profits does not seem to be a direct one. Only a few researchers have investigated the association between patient satisfaction and financial performance, and the relationship with its influencing factors remains unclear (Richter & Muhlestein, 2017).

Therefore, this study will increase our understanding of patient satisfaction and financial performance by investigating the relationship between the two in Swiss hospitals to assess whether generating higher patient satisfaction is worthwhile from a business perspective. For hospital management, there is added value in determining how the associations are shaped and whether a trade-off exists between satisfied patients and financial performance. For researchers, this study will offer insights into the currently unknown moderators and relevant influencing variables.

Background: The Swiss health system

In Switzerland (like many Western countries), hospital inpatient services are funded by a case-based remuneration scheme. It is named the Swiss Diagnosis-Related Group (SwissDRG) and was established in 2012. Residents of Switzerland are required by law to purchase health insurance (Council, 2022). However, they can freely choose between hospitals, which makes patient loyalty an important consideration for managers (Council, 2022). Currently, Switzerland has no financial incentives that reward higher patient satisfaction or better clinical quality. Therefore, Switzerland provides a good case through which we can study the association between patient satisfaction and financial performance independent of financial incentives.

Rationale for the study

Patient satisfaction depends primarily on how well the patient's needs and expectations have been addressed (Donabedian, 1988). Thus, the association between patient satisfaction and the financial performance of a hospital appears to be indirect (Raju & Lonial, 2002). Investing in quality developments results in costs for the hospital but also has a positive effect on patient satisfaction (Huerta et al., 2016; Jha et al., 2011). Higher patient satisfaction, in turn, results in higher loyalty, (Meesala & Paul, 2018) increased utilization of inpatient services, (Fenton et al., 2012) improved financial performance, (Lim et al., 2018) and a greater willingness to recommend the hospital (Klinkenberg et al., 2011).

The concept of lifetime value (LTV) put forth by Berger and Nasr (1998) can be used to calculate the potential revenue generated for a hospital by a patient who remains loyal throughout his or her lifetime. Suppose that a married couple without children uses the same hospital throughout their lives. In that case, the hospital can charge the couple an average of US$600,00 for services, assuming a life expectancy of 85 years. In the US, one study calculated an LTV of $1.4 million per average household (Morrisey, 2012). If patients become dissatisfied and choose another healthcare provider in the future, the original hospital loses revenue. This quantifiability of loyalty may indirectly and partly account for the association between revenue and patient satisfaction. Increasing revenue (at the same cost) or decreasing costs (at the same revenue) would increase profit.

Richter and Muhlestein (2017) are among the few researchers who have investigated part of the relationship between patient satisfaction and financial performance. They examined 19,792 patient records in 3,767 US hospitals from the period 2007–12 and found that positive inpatient experience was associated with higher total profitability (net patient revenue, net income, and operating margin) and a negative inpatient experience was even more strongly associated with decreased hospital profitability. Unlike Richter and Muhlestein (2017) who focused on revenues, Fenton et al. (2012) did consider costs, but they examined societal costs rather than costs at the hospital level. Unlike the other studies, Raju and Lonial (2002) surveyed top executives from hospitals and used judgmental measures for quality context and market orientation. However, they noted that the study should be repeated with objective measures. Because of the limitations of the available literature, and because the previous authors had considered either costs or revenues and used different population sizes for their calculations, a more comprehensive study is needed.

According to Fenton et al. (2012) higher patient satisfaction is associated with less emergency department use. However, we hypothesize that the association is reversed, with patients who entered the hospital through the emergency department having different needs than other patients, which in turn results in lower patient satisfaction. Therefore, we will analyze the proportion of emergency patients as a moderator for the association between patient satisfaction and financial performance.

In several studies, the bed occupancy rate was used as a measure of financial performance (Bazzoli et al., 2007). However, according to the literature, (Lim et al., 2018; Roth et al., 2019; Ye et al., 2017b) it also influences patient satisfaction. For this reason, we decided to use the bed occupancy rate as a moderator to analyze how it influences the relationship between patient satisfaction and financial performance.

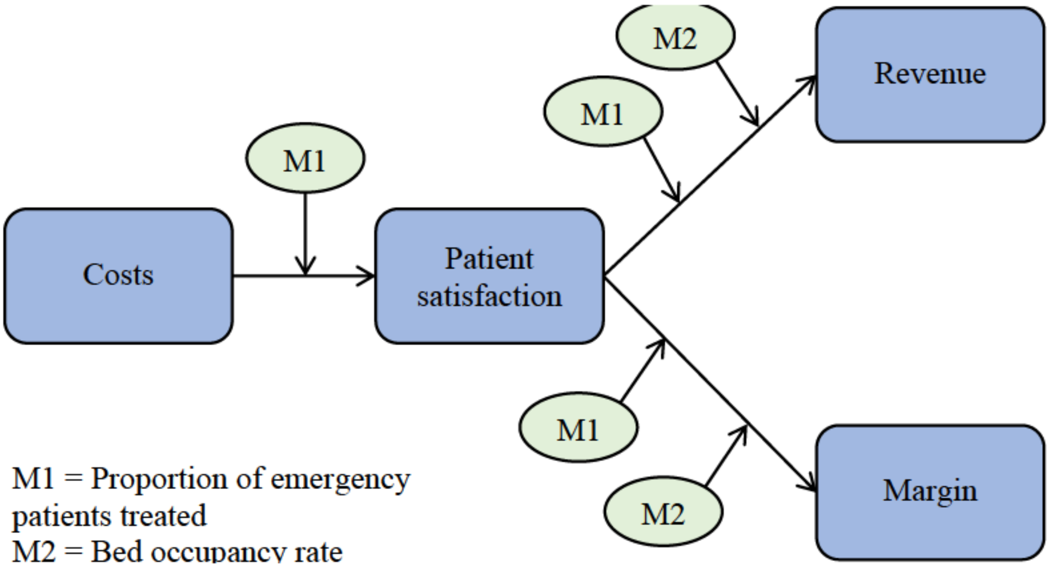
Study objectives

Consequently, the primary research questions guiding our study are as follows: (i) What is the association between patient satisfaction and financial performance? (ii) How does the proportion of emergency patients treated and the bed occupancy rate influence that relationship?

In our research model, we assessed whether higher costs have a positive association with patient satisfaction and how the proportion of emergency patients treated influences that relationship. We also investigated whether higher patient satisfaction has a positive association with revenue and operating margin and how the occupancy of beds and the proportion of emergency patients treated influence these relationships.

The proposed research model for this study is presented in Figure 8.

Figure 8: Research model



Methods

Sources

We used publicly available national data from 135 Swiss hospitals over three years, from 2016 to 2018. Data on patient satisfaction are collected via a validated survey (Barzallo et al., 2021) by the Swiss National Association for Quality Development in Hospitals and Clinics (ANQ) (ANQ, 2019b) and published annually at a hospital level. Detailed data from the patient satisfaction survey are available for research purposes upon request from the ANQ. Financial performance data and control variables for each hospital were obtained from the annually published national statistics of Swiss hospitals (based on administrative data) (Swiss Federal Statistical Office BFS, 2019b).

Variables

Patient satisfaction and experience are assessed by the ANQ with five questions, covering overall satisfaction with the quality of care, patients' experiences of having the chance to ask questions, the clarity of the answers, the explanations of medications, and the discharge process. A 5-point verbal scale is used, showing excellent reliability (Cronbach's alpha: 0.96) (Perneger et al., 2020). The ANQ (ANQ, 2019a) reports the data annually per hospital as mean values. For further calculations, the mean of the five items was calculated.

Financial performance is a broad phrase that describes a company's fiscal health. In accordance with the literature, hospitals' financial performance was measured by operating margins, (Bazzoli et al., 2008) net patient revenue, and net operating expenses (Bai & Anderson, 2016). To account for unit-specific variations (e.g., the different sizes of Swiss hospitals), we divided the variables by the number of hospital beds, a routinely used procedure to enable comparison between hospitals (Bai & Anderson, 2016). We focused on financial performance measures from inpatient business rather than overall financial conditions (Nelson et al., 1992).

The bed occupancy rate was used as a hospital utilization measure (Lim et al., 2018). Because the proportion of emergency patients treated by a hospital was not publicly available in Switzerland, we used the relative frequency of treated acute myocardial infarctions (AMI) and strokes as a proxy for common life-threatening emergency indications (Berlin et al., 2016). This information was obtained from the Swiss Federal Office of Public Health (2018) Although such a proxy has limitations, as AMI and stroke patients are just a fraction of all the emergency patients, such time-critical emergencies do require a higher level of emergency readiness and thus more resource utilization (Wong et al., 2010). To focus on two frequently occurring, time-critical, and life-threatening emergencies was previously suggested by Tataris et al. (2014). This proxy has the advantage of assessing the emergency departments of private hospitals, which show a significantly lower complexity, more equitably than they would have been if we had examined real patient numbers.

To account for each hospital's characteristics, its number of discharges, (Borah et al., 2012; Gok & Sezen, 2013) legal form (i.e., private or public), (Jha et al., 2008b) and location (Wennberg et al., 2009) were used. Healthcare institutions in Switzerland consist of general hospitals and special clinics. General hospitals were further divided into five groups, and special clinics were categorized as surgical, gynecological, and other, depending on their focus (Swiss Federal Office of Public Health, 2018) (see Table 8). To account for patient heterogeneity, we used a case-mix index (CMI), the average relative weight for a given hospital or specific patient cohort (Centers for Medicare and Medicaid Services, 2021) as proposed by Richter and Muhlestein (2017) and the percentage of patients with private or semiprivate insurance (Messina et al., 2009).

Table 9: Variables and scales

Variables	**Measurement scale**
Dependent variables	
Operating margin	(net patient revenue – net operating expenses)/net patient revenue.
Net patient revenue	Rate (Swiss Francs): revenue from medical services and care, divided by the number of hospital beds
Independent variable	
Net operating expenses	Rate (Swiss Francs): costs from medical services and care, divided by the number of hospital beds
Multiple used variables	
Patient satisfaction Dependent variable for net operation expenses Independent variable for operating margin, net patient revenue	Categorial scale, mean patient satisfaction from five patient satisfaction and experience questions: 1. overall satisfaction with the quality of care 2. chance to ask questions 3. clarity of the answers 4. explanations of medications 5. discharge process
Moderators	

Variables	Measurement scale
Proportion of emergency patients treated	Ratio: number of patients treated with acute myocardial infarction (AMI) or stroke/total number of patients treated
Bed occupancy rate	Ratio: total inpatient days/total number of beds
Control variables: Hospital characteristics	
Number of discharges	Continuous: total number of administrative cases closed in the period from January 1 to December 31
Legal form	Nominal, binary: private or public
Location	Nominal, binary: urban or rural
Hospital type	Nominal, categorical data: 1. university hospitals (level 1) 2. large central hospitals (level 2) 3. primary care hospitals (level 3) 4. primary care hospitals (level 4) 5. primary care hospitals (level 5) 6. Special clinic (surgical) 7. Special clinic (gynecological) 8. Special clinic (various)
Control variables: Patient characteristics	
Case-mix index (CMI) net	Ratio: medium degree of severity of treated inpatients (net = adjusted)
Proportion of patients with private or semiprivate insurance	Ratio: number of patients with semiprivate or private insurance/total number of patients * 100

Study design and statistical analysis

We conducted a cross-sectional analysis and matched patient satisfaction per hospital and year with their financial performance metrics. We performed descriptive analyses to compare patient satisfaction with hospital characteristics. Several econometric challenges need to be considered in the model specification. Patient satisfaction and financial performance may have undetected idiosyncratic characteristics that vary across hospitals, and patient satisfaction is not the only driver of changes in financial performance. Therefore, other variables that are not taken into account may lead to endogeneity bias (Ye et al., 2017b).

To identify the independent associations between patient satisfaction and financial performance, we used Pearson’s correlation. Regression analysis with a backward stepwise selection process was used to evaluate the effects of the independent variables on the dependent variables. Only control variables with $p < 0.1$ were considered in the model (Thompson, 1995). With histograms and the Kolmogorov-Smirnov test, the normal distribution of the data was visualized. The variance inflation factor (VIF) was used to quantify the severity of the multicollinearities (O'brien, 2007). For the slightly left-skewed financial performance data (dependent variables), a logarithmic transformation was performed (O'Hara & Kotze, 2010). In accordance with the approaches of moderation analysis, (Edwards & Lambert, 2007) an interaction term of the independent variable and moderators was included in the regression analysis. Due to the small number of hospitals in Switzerland (135 acute care hospitals), a time-lagged regression at the hospital level was not possible. For all statistical analyses, the software IBM SPSS Statistics 27 was used, and results were considered significant if $p < .05$.

Results

Descriptive statistics

The descriptive statistics are provided in Table 9. Patient satisfaction ranged from 3.64 to 4.86, with a mean of 4.39 and a standard deviation of 0.17. Our descriptive analyses showed that patient satisfaction differed the most between hospitals when they were categorized by the proportion of emergency patients treated.

58% of the hospitals were publicly owned, and 42% were private. While the occupancy rate of beds was 81% in public hospitals, it was only 65% in private hospitals. In public hospitals, an average of 17% of inpatients had complementary insurance (semiprivate or private), compared with more than twice as many in private hospitals (41%). The patient-centered costs per bed of private hospitals did not differ from those of public hospitals (0.07%), and the revenues per bed differed only marginally (2.35%).

Table 10: Descriptive statistics of study variables

Dependent and independent variables:	**N**	**Mean**	**Std. deviation**
Patient satisfaction	388	4.39	0.17
Revenue	383	721,092.17	235,525.50
Costs	387	617,250.37	167,375.71
Operating margin	383	0.12	0.12
Moderators:			
Bed occ. rate†	388	0.74	0.166
Proportion of emergency patients treated	388	0.99	1.36
Control variables:			
Discharges	388	9,447.62	10,597.54
Legal (privat)	163	42%	
Location (rural)	242	62.4%	
Hospital type (level 1)	15	3.9%	
Hospital type (level 2)	117	30.2%	
Hospital type (level 3)	45	11.6%	
Hospital type (level 4)	76	19.6%	
Hospital type (level 5)	31	8.0%	
Specialty clinic: Surgery	84	21.6%	
Specialty clinic: Gyn.‡	3	0.8%	
Specialty clinic: Various	17	4.4%	
Case-mix index (CMI§) net	371	0.95	0.20
Prop. of patients with semiprivate or private insurance	106	27.4%	

Note. † Bed occupancy rate, ‡ Gynecological

Main results

Costs and patient satisfaction

Pearson's correlation coefficient (r) between net operating expenses (independent variable) and patient satisfaction (dependent variable) was significant ($p = .005$) and showed a moderate positive relationship ($r = 0.143$). The first regression analysis (Model 1, Table 10) addressed the hypothesized effect of net operating expenses on patient satisfaction. The moderator, proportion of emergency patients treated, was considered. In the first step, Model 1 includes the predictor and moderators in the hierarchical multiple regression analysis, and Model 2 includes the control variables in a stepwise manner in addition to the variables in Model 1 (Table 10). In the results of the first block, the influence of the predictor (net operating expenses) was found to be significantly positive ($p < .001$), and all VIF values were below 3.4. The moderator variable (M1) was significant and had a positive association, while the proportion of emergency patients treated had a significant negative association.

Cost (net operating expenses) was found to be a highly significant predictor of patient satisfaction. In addition, the moderating variable of the proportion of emergency patients treated should be emphasized as a positively acting component of the hypothesis model. It should be noted that higher costs seem to be associated with an increase in patient satisfaction.

Table 11: The association between hospital costs and patient satisfaction

Model 1	**B**	**Std. error**	**Standardized coefficients**	**T**	**R^2**
Constant	2.193	0.344		6.380	
Net operating expenses	0.399	0.060	0.282***	6.698	
Proportion of emergency patients treated	-0.116	0.009	-1.000***	-13.144	
Moderator M1†	0.059	0.006	0.738***	9.706	
					0.372
Model 2 (final model)	**B**	**Std. error**	**Standardized coefficients**	**T**	**R^2**
Constant	1.880	0.315		5.961	
Net operating expenses	0.470	0.056	0.333***	8.365	
Proportion of emergency patients treated	-0.063	0.009	-0.544***	-6.832	
Moderator M1 †	0.034	0.006	0.420***	5.537	
Prop. of patients with semiprivate or private insurance	0.001	0.000	0.189***	4.402	
Hospital type (level 3)	-0.117	0.021	-0.234***	-5.626	

Model 1	B	Std. error	Standardized coefficients	T	R^2
Hospital type (level 1)	-0.254	0.035	-0.316***	-7.173	
Hospital type (level 2)	-0.119	0.016	-0.347***	-7.306	
Hospital type (level 4)	-0.067	0.017	-0.170***	-3.938	
CMI ‡	-0.119	0.041	-0.150**	-2.922	
					0.561

Notes: Dependent variable: Patient satisfaction; Significance levels are ***<1%, **<5% and *<10%. *B* unstandardized beta coefficients (patient satisfaction). Only significant control variables are reported.

† Moderator M1 = Interaction term with the proportion of emergency patients treated

‡ (net) case-mix index

Revenue and patient satisfaction

No significant Pearson correlation could be found between patient satisfaction and net patient revenue (r=0.041, p=.430). For the hierarchical multiple regression analysis (Table 11), Model 1 includes all the variables and predictor moderators, and Model 2 includes all the variables plus the stepwise control variables.

Nevertheless, patient satisfaction is identified as a highly significant and positive predictor of net patient revenue. For increasing patient satisfaction, an increase in net patient revenue per bed of CHF 230,777 (p <0.001) was expected. The VIF test indicated that there was no multicollinearity, as all VIF values were < 2.5.

While the moderating variable of bed occupancy (M2) had a highly significant positive association with the model, the proportion of emergency patients treated (M1) had a negative one. Individually, the bed occupancy rate had the strongest impact on net patient revenue (highest beta coefficient and highest t-value). All stepwise reported control variables were significant. Moreover, the beta coefficients were mostly positive (Model 2, Table 11). Thus, it can be stated that higher patient satisfaction is significantly associated with higher net patient revenue.

Table 12: The association between patient satisfaction and hospital revenue

Model 1	**B**	**Std. error**	**Standardized coefficients**	**T**	**R^2**
Constant	4.220	0.197		21.449	
Patient satisfaction	0.284	0.041	0.332***	6.855	
Moderator M1 †	-0.051	0.010	-0.219***	-4.945	
Moderator M2 ‡	0.008	0.008	0.051	1.025	
Occupancy rate of beds	0.005	0.000	0.529***	10.302	
Proportion of emergency patients treated	0.007	0.005	0.069	1.477	
					0.350
Model 2 (final model)	**B**	**Std. error**	**Standardized coefficients**	**T**	**R^2**
Constant	4.587	0.165		27.813	
Patient satisfaction	0.177	0.037	0.207***	4.782	
Moderator M1 †	-0.022	0.008	-0.095**	-2.663	
Moderator M2 ‡	0.023	0.006	0.145***	3.789	
Occupancy rate of beds	0.005	0.000	0.545***	13.046	
Proportion of emergency patients treated	0.011	0.003	0.11***	3.115	
Proportion of patients with semiprivate or private insurance	0.002	0.000	0.364***	9.805	
Hospital type (level 1)	0.200	0.029	0.291***	6.851	
Hospital type (level 6)	0.084	0.014	0.256***	5.997	
Hospital type (level 5)	-0.054	0.017	-0.109***	-3.111	
Discharges	1.711E-06	0.000	0.134**	2.679	
					0.643

Notes: Dependent variable: Net patient revenue; Significance levels are ***<1%, **<5% and *<10%. *B* unstandardized beta coefficients (net patient revenue). Only significant control variables are reported.
† Moderator M1 = Interaction term with the proportion of emergency patients treated
‡ Moderator M2 = Interaction term with the occupancy rate of beds

Operating margin and patient satisfaction

Our analysis showed a significant negative Pearson's correlation between patient satisfaction and the operating margin (ρ = -0.168, p =0.001). The regression analysis addresses the presumed effect of patient satisfaction on the operating margin. Possible moderators, such as the proportion of emergency patients treated and bed occupancy rate, must be taken into account (Model 1, Table 12). Model 1 showed that the influence of the predictor (patient satisfaction) was not statistically significant. Collinearities with a VIF value of <1.5 can be excluded. It becomes obvious that patient satisfaction was not suitable to predict operating margins. The moderator of numbers of emergency patients was not significant, whereas the moderator variable M2 and the bed occupancy rate had significantly higher standardized beta coefficients and t-values than the predictor. In particular, the coefficients suggested a higher margin when bed occupancy increases. The fact that the predictor has not become significant (initially) prompted a simple regression analysis with patient satisfaction only, which revealed a significant negative association.

In the further analysis with stepwise inclusion of the control variables, the following model emerges (Model 2, Table 12). Primarily noteworthy is that patient satisfaction now emerges as a significant predictor, albeit with a negative connotation. In addition, bed occupancy should be emphasized as a positive moderator of the hypothesis model. The proportion of emergency patients treated had no significant effect. Four of the control variables are significant, some with considerable beta coefficients. Notably, certain decreases in patient satisfaction seem to be associated with a higher operating margin. However, the operating margin is strongly influenced by several other factors.

Table 13: The association between patient satisfaction and hospital operating margin

Model 1	**B**	**Std. error**	**Standardized coefficients**	**T**	**R^2**
Constant	0.351	0.180		1.952	
Patient satisfaction	-0.074	0.038	-0.112*	-1.964	
Moderator M1 †	-0.007	0.009	-0.036	-0.689	
Moderator M2 ‡	0.016	0.007	0.128*	2.194	
Occupancy rate of beds	0.001	0.000	0.203***	3.354	
Proportion of emergency patients treated	-0.004	0.004	-0.049	-0.890	
					0.021
Model 2 (final model)	**B**	**Std. error**	**Standardized coefficients**	**T**	**R^2**
Constant	0.436	0.171		2.556	
Patient satisfaction	-0.116	0.037	-0.175***	-3.124	
Moderator M1 †	0.002	0.009	0.011	0.238	
Moderator M2 ‡	0.024	0.007	0.195***	3.622	
Occupancy rate of beds	0.002	0.000	0.248***	4.399	
Proportion of emergency patients treated	-0.003	0.004	-0.034	-0.669	
Proportion of patients with semiprivate or private insurance	0.002	0.000	0.390***	6.778	
Hospital type (level 1)	0.169	0.027	0.318***	6.340	
Hospital type (level 4)	-0.029	0.012	-0.110**	-2.366	
Location	0.044	0.011	0.201***	3.848	
					0.274

Notes: Dependent variable: Operating margin; Significance levels are ***<1%, **<5% and *<10%. *B* unstandardized beta coefficients (operating margin). Only significant control variables are reported.
† Moderator M1 = Interaction term with the proportion of emergency patients treated
‡ Moderator M2 = Interaction term with the occupancy rate of beds

Discussion

Using nationally representative hospital data from Switzerland, our results showed that higher operating costs were associated with higher patient satisfaction and the relationship was strengthened as the number of emergency patients cared for by a hospital increased. Higher patient satisfaction was associated with higher revenues, and while the proportion of emergency patients treated had a negative effect on the relationship, the level of bed occupancy strengthened it. Since the influences of costs and revenues seem to balance each other, patient satisfaction and operating margin have no notable correlation.

Impact of admission

The proportion of emergency patients treated in a hospital has a significant influence on hospital-wide patient satisfaction. The descriptive analysis demonstrated that the more emergency patients a hospital treats, the lower its patient satisfaction. According to Crow et al. (2002) the level of patient satisfaction depends on the nature of their needs and expectations and how they are met. Therefore, based on our results, we conclude that the urgency of care strongly influences patients' needs. This finding has not yet been considered in the patient satisfaction literature and needs to be further studied in the future.

Costs and patient satisfaction

Higher costs are indirectly associated with higher patient satisfaction. While Huerta et al. (2016) were able to demonstrate this using nonrepresentative data, we were able to confirm this on the basis of specific patient costs. In the context of research on the introduction of pay for performance, Stanowski et al. (2015) were able to demonstrate an association between higher costs and higher patient satisfaction ($R^2 = 0.23$). In our study, we have been able to prove this association even without such an incentive system.

The positive association between cost and patient satisfaction was strengthened when a hospital cared for many emergency patients. Our model with the proportion of emergency patients treated explained significantly more patient satisfaction than Stanowski et al. (2015) model without that moderating factor.

Since a large portion of the hospital costs can be attributed to labor expenses, an explanation could be that patients are generally more satisfied when more staff are available to care for them. In contrast, a reduction in personnel expenses could decrease costs; however, in that case, it would also be associated with reduced patient satisfaction. This association between staffing and patient satisfaction was confirmed by E. M. Oppel et al. (2017) and Hockenberry and Becker (2016) who demonstrated that the higher the staffing ratio is, the higher the patient satisfaction.

Revenue and patient satisfaction

Our results demonstrate that an increase in patient satisfaction was associated with an increase in revenue. One explanation for this positive association might be that Switzerland's high hospital density (OECD, 2022) and residents' freedom to choose their hospital (Council, 2022) make patient loyalty, which is majorly influenced by patient satisfaction, an important factor. Besides loyalty, marketing or indirect connections, such as higher process competence, better medical quality, or even higher employee satisfaction, might also influence that association.

The proportion of emergency patients treated and the bed occupancy rate influenced the strength of the association between patient satisfaction and revenue. The strongest association was found for hospitals that did not care for any emergency patients and had a high bed occupancy rate. In such cases, the increase in patient satisfaction (from the lowest to the highest third) would predict a 27% increase in revenue. While in other countries, such as the US, high patient satisfaction is incentivized, there is no value-based payment or reimbursement in Switzerland. Nevertheless, surprisingly, a positive association between patient satisfaction and revenues was still demonstrated.

Our results are in accordance with those of Richter and Muhlestein (2017) who demonstrated that the percentage of patients who definitely recommend a hospital was positively associated with that hospital's net patient revenue ($\beta = 1072$, *p* < .001). However, they did not examine moderator effects. One explanation for the aforementioned association could be that smaller hospitals, in which the majority of the procedures are not emergencies, are increasingly dependent on patients' voluntary choice of hospital and, therefore, pay more attention to facilitating a high degree of patient-centeredness. As a result, for small hospitals with fewer emergency patients, patient satisfaction and, therefore, loyalty is a more relevant financial performance factor than it is for larger hospitals with more emergency patients. The strong impact of the bed occupancy rate on the association of patient satisfaction and revenue is consistent with the findings of Roth et al. (2019) and Ye et al. (2017b) which indicated that a higher bed occupancy rate is associated with higher revenue but a reduction in patient satisfaction.

Operating margin and patient satisfaction

Within our results, a significant negative but small correlation between patient satisfaction and operating margin was demonstrated. However, as the regression analysis was not highly significant, patient satisfaction could not be used to predict the operating margin. Therefore, our results disagree with those of Richter and Muhlestein (2017) While they reported a regression coefficient of $\beta=0.04$ ($p < 0.05$), our regression coefficient was $\beta= -0.087$ ($p=0.07$). Both beta values are small and approximately similar in size. However, while Richter and Muhlestein (2017) interpreted the small beta value as indicating a positive association, we are more cautious and conclude that patient satisfaction has no (or a marginally negative) influence on the operating margin. From our point of view, this result is reasonable since the association between costs and revenues is approximately equal.

Limitations and future research directions

This study has limitations that offer opportunities for future research. Although we were able to use Switzerland's complete national dataset, patient satisfaction was only available per hospital and year. Future studies should investigate this topic at the patient level. A hospital with higher revenues could provide better patient care, which would increase costs and patient satisfaction. This inverse causality was not additionally considered in our calculations. Another limitation is the fact that the actual number of inpatients who were admitted by emergency was not known. The proxy used, which was based on the ratio of AMI and stroke patients cared for, allows an approximation, but no more.

Future studies should examine the extent to which staffing structures directly affect costs and indirectly affect patient satisfaction. While the isolated relationships have already been examined, no study has investigated both relationships in the same framework. As we used a cross-sectional study design, we could not exclude a cohort effect. Conversely, a longer time horizon would have allowed for time-lagged regressions and, thus, for better causal inferences.

Nevertheless, our research provides several insights that expand on the existing literature. We demonstrate that admission type (emergency) has a significant impact on patient satisfaction and, therefore, is an important aspect to consider. Investigating the interaction chain between costs, patient satisfaction, and revenue and margin provides further insight into the known associations. Because there is limited research on the association between patient satisfaction and financial performance, this study provides a better understanding of the specific relationships and influencing factors. In the future, the relationship between specific aspects of financial performance and patient satisfaction should be studied in more detail to gain a better understanding of the causal relationships. We consider the influence of admission type on patient satisfaction and the impact of the proportion of emergency patients treated on hospitals' financial performance to be relevant factors that should be investigated further.

Practical implications

Our research suggests that patient-centered care, for which patient satisfaction is an appropriate metric, (Cosgrove et al., 2013) is worthwhile from a business perspective. Therefore, patient satisfaction should be published more transparently and included in the management cockpits. On the one hand, it reflects customer satisfaction and, on the other hand, it also plays an indirect role in the financial context. However, the financial incentive is more significant in hospitals that care for a small proportion of emergency patients and have a higher bed occupancy rate. Since emergency patients have significantly lower patient satisfaction, our research suggests that emergency departments and hospital units that admit mostly emergency patients (e.g., internal medicine units) should take a close look at what separates the needs of emergency patients from those of regularly admitted patients to be able to respond to such specific needs in the future (e.g., the desire for more safety and compassion).

Conclusion

The aim of our study was to investigate whether high patient satisfaction is financially rewarding for hospitals. Our results show that patient satisfaction is associated not only with higher revenues but also with higher costs, with no highly significant association with the operating margin. Our research demonstrates that these relationships are most robust in hospitals that care for few emergency patients and have a high bed occupancy rate.

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CHAPTER 5: CONCLUSION

5.1 Thesis Summary

This thesis empirically investigates the relationships between clinical quality, patient satisfaction and financial performance. To do so, it builds on the basic model of the SPC, which explains how the service industry can generate sustainable profits.

The research question guiding this thesis is the following: *What are the relationships between clinical quality, patient satisfaction and financial performance?*

This thesis' main objectives were to create an overview model showing the functioning of the relationships and then use Swiss data to test that model (see Figure 9). To answer the research question and achieve the research objectives, an SLR was conducted followed by two quantitative research studies. It became clear through the systematic analysis of the relevant literature that the SPC cannot be directly applied to the healthcare sector as several parameters of the free market, namely price sensitivity and voluntary consumption, do not apply (Porter & Guth, 2012). It also became clear that the relationship between quality and financial performance depends on how quality is measured (process or outcome quality) (Jamalabadi et al., 2020). The measurement methodology used for patient satisfaction appeared to have less of an influence on the relationships. However, due to the dearth of research in this context, no reliable statement can be made on that matter. Different theories have been presented on the relationship between quality and financial performance. The most evident relationship proposed is a U-curve between quality and costs, which (on the left, decreasing half) proposes there are cost reductions with quality improvements and (on the right, increasing half) indicates a trade-off between costs and quality improvement (Jamalabadi et al., 2020; Søgaard & Enemark, 2017). Since almost no research exists that considered the relationship between patient satisfaction and financial performance, no reliable statement can be made However, it can be assumed that higher patient loyalty (based on higher satisfaction) positively impacts profitability (Klinkenberg et al., 2011). The two quantitative studies tested these findings in detail.

Study 2 examined the left side of the U-curve of the relationship between quality and cost, which proposes that an improvement in quality (patient safety) leads to a reduction in cost (Jamalabadi et al., 2020). The 16 patient safety adverse events studied confirmed this relationship. The adverse events caused cost increases between CHF 1,211 and CHF 137,967 per patient, which led to additional national expenditures of CHF 347 million for the events studied alone. Furthermore, these adverse events led patients to stay in the hospital for 7.8 days more and have a 2.5 times higher readmission rate and a 4.1 times higher mortality rate. The calculation of the cost of all AHRQ PSIs was new, as was the methodology to eliminate the cost-reducing effect of patients who died prematurely.

The third study investigated the relationship between patient satisfaction and several financial ratios. Although the results were less clear than in the previous study, this study demonstrated that higher (net) operation expenses (mostly labor costs) are associated with higher patient satisfaction. This relationship is strongest in hospitals that had to care for a low number of emergency patients. Conversely, higher patient satisfaction is associated with higher net patient revenue. This relationship is strongest in hospitals with high bed occupancy rates and few emergency patients. However, the study found no relationship between patient satisfaction and operating margin, which might be due to a counterbalancing effect. The described relationships of the two quantitative studies (Studiesy 2 and 3) based on the findings of the SPC (Study 1) are visualized in Figure 9.

5.2 Response to Research Questions

These chapters have explored the main research question:

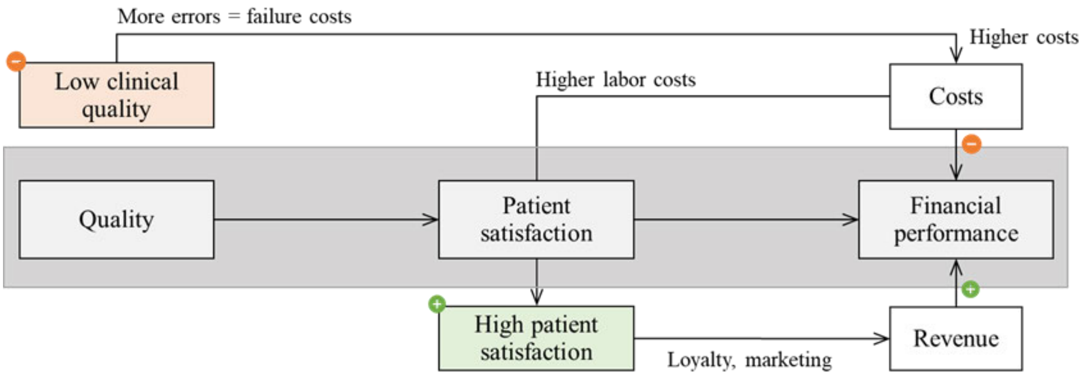

Figure 9: Thesis summary

- *What are the relationships between clinical quality, patient satisfaction, and financial performance?*

The three studies show that there are relationships between clinical quality, patient satisfaction, and financial performance. However, these relationships are different from those posited in Heskett's SPC theory and thus cannot be extrapolated from the marketing and service literature. In detail, it can be concluded that poor quality in hospitals primarily and directly increases costs. Investments (higher costs, primarily those related to labor) lead to higher patient satisfaction, which, in turn, is associated with higher revenues through an indirect relationship. While the causal chain of the SPC cannot be directly reproduced in the healthcare system, it nevertheless provides a useful basis to explore individual relationships.

This thesis' results suggest that a hospital could be particularly successful if it prioritizes quality and customer orientation in the long term rather than deprioritizing them due to short-term pressures to save money. A hospital risks undermining its long-term success if it cuts resources to guarantee short-term efficiency gains as those cuts will directly or indirectly diminish clinical quality and patient satisfaction.

5.3 Contributions of the Thesis

This work has extended previous research and made several important contributions to understanding the relationships between clinical quality, patient satisfaction and financial performance. The research (Study 1) showed for the first time that there are several direct and indirect relationships between a hospital's quality, patient satisfaction and financial performance. Based on the existing literature on the SPC (Heskett et al., 2008a), it was possible to develop a framework that visualized these relationships for the first time in the healthcare literature. By developing the framework, gaps in the literature could be identified. Even though some of the relationships are common sense, many parts of them are still under-researched. That confirmed the applicability of Harkey and Vraciu (1992) quality-profitability model in healthcare.

Prior to the start of Study 2, there was little evidence of any research on the costs of PSI-related adverse events (Kuo et al., 2020). Even though Zhan and Miller (2003) already examined part of the PSIs in terms of their costs, there was a lack of comprehensive research from the past 20 years to demonstrating the individual excess costs caused by all the different PSIs. The study makes it now possible to more effectively compare PSIs internationally, not only in terms of their incidence and costs but also in terms of additional outcome measures. Thus, it provides a relevant contribution to the patient safety literature by informing researchers and practitioners' efforts to develop evidence-based business plans for patient safety activities.

Another contribution to the literature and methodology is the approach developed to eliminate the cost reduction of patients who died prematurely. Their cost-reducing effect has rarely been reported in the literature (Hvenegaard et al., 2011), and Study 2 is the first study that proposes a procedure to control for this bias.

Furthermore, the thesis evaluated a relevant factor that had not yet been considered in the literature on patient satisfaction: the influence of the type of admission (e.g., emergency) on patient satisfaction. To date, patient satisfaction has primarily been adjusted for subjective disease severity(Fenton et al., 2012). The finding that the type of admission shapes patient needs and thus indirectly influences satisfaction is a new one and should be studied in more depth in the future.

Another new contribution to the health economics literature is the development of a relationship model between patient satisfaction and financial performance. The model demonstrates that higher costs are associated with higher patient satisfaction, highlighting a previously unknown trade-off. Previous studies have demonstrated that higher employee satisfaction leads to higher patient satisfaction, indirectly addressing higher wages (i.e., higher costs) (De Simone et al., 2018). However, the indirect relationship between total costs and patient satisfaction had not been previously studied. Therefore, the present study contributes further insights to the HR literature.

Furthermore, it shows that higher revenues compensate for higher costs, which is also a new finding that offers further insights for the health economic literature as it highlights unknown interactions and demonstrates how to influence financial performance through patient satisfaction.

The thesis contributes primarily by showing that hospitals' financial performance is influenced by numerous factors beyond those that have been the subjects of previous studies. Demonstrating the interrelationships between these factors shows that some issues that were not previously considered to be financially oriented (such as quality or patient satisfaction) also impact financial performance. This adds more influencing factors to the field of finance literature and will allow for further research to demonstrate more clearly that investments in patient satisfaction can have financial returns.

This thesis as a whole contributes to the service literature by applying classical service models to healthcare, thus showing that service models can be specifically adapted and "harnessed" for that sector and suggesting that the same models could similarly be applied in other sectors. Overall, the thesis also contributes by proving that "doing the right thing" can also pay off financially. Thus, this thesis supports the linking of research on total quality management with the literature on service/marketing and finance.

5.4 Limitations of the Thesis

Despite using two nationwide datasets, this PhD thesis has several limitations. Empirical service research does not yet support the confidence that many managers place in the causality of the SPC given its intuitively comprehensible structure (Silvestro & Cross, 2000). Despite the unclear causality, the SPC offers exciting insights into the interrelationships and was used in this thesis to create an overarching framework for healthcare relationships. Another limiting factor of this thesis' application of the SPC is that it did not investigate the causality of the relationships but rather the direct relationship of two factors with financial performance. Thus, it remains unclear whether a statement on causality can be made for the healthcare sector. Another limiting factor is that the thesis did not consider the internal part of the SPC (employee-oriented part), nor did it directly consider the influence of loyalty; this influence was only assessed indirectly as a possible reason for increased bed occupancy and revenue. The reason for this is that patient loyalty is only conditionally relevant for the utilization of hospital services (Lei & Jolibert, 2012), and, in contrast to the recommendation rate, it is difficult to measure (Klinkenberg et al., 2011).

Finally, the COVID-19 pandemic placed limitations on this thesis. The pandemic affected the content of the work by making it impossible to include the originally planned extension of the model to include employee satisfaction. This was partly because data collection was only 80% complete at the start of the pandemic, and the last 20% could not be collected anymore due to the otherwise high demands on hospital resources.

5.5 Future Research Directions

As this PhD thesis demonstrates, the literature has overlooked associations between clinical quality, patient satisfaction, and financial performance in healthcare; thus, the study offers meaningful insights and directions for future academic research. Not only does the framework provide an approach for future researchers to follow but it also identifies gaps that urgently need to be addressed. Considering similar research questions and objectives, researchers could, for example, conduct a nationwide longitudinal study that allows year-to-year comparisons at the patient and hospital levels, thereby also revealing time-lagged effects. Furthermore, there is still a limitation to the statement of causality. Future research could investigate the causal relationships in more detail.

As stated, this thesis did not consider the internal part of the SPC, and future research could focus on the topic of employee satisfaction and work culture. The latter is at the beginning of the chain of effects and thus influences quality and patient satisfaction. If there is more research on this, there could be more regulation in this area. Currently, as evidenced by the literature underpinning this study, the topic is not given enough attention in practice and in the literature.

5.6 Practical Recommendations

By conducting the SLR, this thesis proposed a simple model that can provide practical support for hospital management. Hospital managers can be made aware of further possibilities to influence financial performance by visualizing these relationships. For example, the model shows how good quality positively influences financial performance and how patient satisfaction interacts with financial performance. It also demonstrates how poor quality not only leads directly to higher costs (longer length of stay, more resources) but might also indirectly lead to the reduction of patient satisfaction and thus market share. By understanding these relationships, hospital managers might better estimate the under-reported interactions and consequences of their short-term cost-cutting measures (in staffing, for example).

The additional costs of adverse events identified in Study 2 may motivate hospital managers to invest in improving patient safety. Therefore, it is recommended to measure PSIs nationwide. Based on the administrative data that is already available, the identification of PSIs is simple and provides useful insights into patient safety. For Switzerland, the additional coding of the present-on-admission suffix is recommended at this point (Houchens et al., 2008). This would allow the PSIs to be identified even more accurately.

The correlations between patient satisfaction and financial performance shown in Study 3 may encourage hospital managers of private hospitals (which have few emergency patients) to measure and increase their patient satisfaction. A hospital has limited instruments to change the type of patient admission, but it can be aware of patients' different needs and discuss how their expectations can be met or managed. The application of such a procedures in healthcare practice is still in its infancy. Finally, it can be concluded that developing valid measurements of patient safety, clinical quality in general, and patient satisfaction (as well as employee satisfaction due to the SPC) is worthwhile. Such measurements will provide hospital management with essential evidence upon which they can base their strategic plans and actions.

5.7 Policy Implications

In view of the effects studied, hospitals might profit from standardized measurements of clinical quality and patient satisfaction and of the influencing factors of the workplace environment and employee satisfaction. However, unlike Switzerland's ANQ survey which only runs for one month a year, measurements of satisfaction should be ongoing and nationally consistent at the clinic and station levels so that timely comparisons can be made between hospitals at those two levels.

Furthermore, patient safety measurements should be conducted using the PSIs nationally. In addition, present-on-admission coding with the ICD 10 GM should be used to sharpen individual PSIs and promote further use of routine data. For risk adjustment (see Study 2), the Elixhauser diagnoses and score (Sharma et al., 2021) are suitable and are also recommended for Switzerland. Government institutions must ensure that hospitals always have the up-to-date data on clinical quality and patient satisfaction that they require (without any delays).

If hospitals are to measure adverse events (which is recommended because of the suffering and costs they cause and the fact that they are potentially avoidable), they should select internationally comparable metrics such as the PSIs from the AHRQ. They should be transparent about the results of nationally or even internationally comparable measurements as this would serve good hospitals from a marketing perspective and allow hospitals to develop and improve their quality and patient satisfaction.

5.8 Reflection

I have chosen this topic for my thesis because I have observed that Swiss hospitals are pursuing partly undifferentiated and hard cost savings, which primarily affect human resources, in turn affecting clinical quality and patient satisfaction. Instead, they could be saving elsewhere in areas that would less directly affect the patient. By investigating these relationships, I found avenues through which hospitals can avoid harming quality and patient satisfaction while cutting costs. If it is not enough to avoid these harms for ethical reasons, this work demonstrates there are also economic reasons to do so. Thus, my future work (as a healthcare worker in Switzerland) will focus even more on influencing factors such as work environment, culture, staffing, and employee satisfaction.

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APPENDICES

APPENDIX A (SUPPLEMENTARY FILE 1, PAPER 2)

Comparisons of means and relative frequencies in the variables used for the 1:3 matching:

Table S14 Comparisons of means and relative frequencies across the matching variables

		Age[a]		Sex[b]		Nationality		Emergency		Nursing home		Transferred		Elixhauser Index	
	PSI	**0**	**1**	**0**	**1**	**0**	**1**	**0**	**1**	**0**	**1**	**0**	**1**	**0**	**1**
PSI 02: Death in low-mortality DRGs	Mean/RF	76.59	77.56	49.61%	51.16%	79.84%	79.07%	79.07%	74.42%	14.73%	16.28%	8.53%	11.63%	7.25	6.98
	SD	15.62	19.71	-	-	-	-	-	-	-	-	-	-	10.13	11.40
	test stat.	-0.91		0.03		0.01		0.41		0.06		0.37		-0.42	
	p	.362		.860		.913		.524		.806		.551		.675	
PSI 03: Pressure ulcer[d]	Mean/RF	77.82	78.35	53.03%	53.53%	81.73%	80.92%	82.08%	82.89%	-	-	-	-	15.43	17.46
	SD	12.61	13.26	-	-	-	-	-	-	-	-	-	-	14.77	15.45
	test stat.	-1.79		0.07		0.28		0.29		-		-		-3.44	
	p	.073		.798		.595		.589		-		-		.001 **	
PSI 04: Death after serious compli-cations	Mean/RF	69.93	70.68	61.80%	64.50%	79.61%	76.91%	64.76%	63.93%	3.15%	3.63%	11.77%	16.03%	18.97	20.58
	SD	14.20	14.68	-	-	-	-	-	-	-	-	-	-	15.40	15.77
	test stat.	-1.35		1.22		1.73		0.12		0.28		6.36		-2.06	
	p	.177		.269		.189		.732		.597		.012 *		.039 *	
PSI 05: Retained surgical items	Mean/RF	58.57	56.51	39.91%	40.79%	71.93%	72.37%	30.26%	28.95%	2.19%	1.32%	1.32%	2.63%	4.66	4.61
	SD	18.55	18.92	-	-	-	-	-	-	-	-	-	-	10.76	11.45
	test stat.	-0.76		0.02		0.01		0.05		0.23		0.61		-0.07	
	p	.448		.893		.941		.828		> .999		.602		.941	
PSI 06: Iatrogenic pneumo-thorax	Mean/RF	68.36	67.13	49.57%	49.68%	84.19%	83.55%	53.66%	49.68%	2.37%	1.61%	10.86%	12.58%	13.42	13.84
	SD	17.97	15.92	-	-	-	-	-	-	-	-	-	-	14.06	13.28
	test stat.	-1.81		0.00		0.07		1.48		0.62		0.69		-1.06	
	p	.071		.974		.788		.224		.432		.407		.288	
PSI 07: CVC bloodstream infectio	Mean/RF	65.50	65.40	71.91%	71.07%	78.66%	78.48%	71.55%	70.71%	1.93%	2.17%	20.74%	21.34%	14.39	15.44
	SD	20.35	15.74	-	-	-	-	-	-	-	-	-	-	14.75	14.64
	test stat.	-1.81		0.15		0.01		0.14		0.12		0.09		-1.94	

	PSI	Age[a] 0	Age[a] 1	Sex[b] 0	Sex[b] 1	Nationality 0	Nationality 1	Emergency 0	Emergency 1	Nursing home 0	Nursing home 1	Transferred 0	Transferred 1	Elixhauser Index 0	Elixhauser Index 1
	p	.070		.703		.928		.704		.725		.763		.053	
PSI 08: Fall with hip fracture	Mean/RF	78.17	79.32	54.65%	49.55%	86.49%	85.59%	80.78%	78.38%	8.41%	14.41%	20.12%	18.02%	12.70	13.25
	SD	10.77	12.09	-	-	-	-	-	-	-	-	-	-	13.91	12.78
	test stat.	-1.48		0.87		0.06		0.30		3.36		0.23		-0.96	
	p	.139		.350		.811		.582		.067		.629		.336	
PSI 09: Post-operative hemorrhag e/hematom	Mean/RF	60.12	59.63	55.63%	56.86%	77.33%	77.22%	26.49%	27.02%	0.92%	0.96%	5.34%	5.26%	6.29	6.87
	SD	18.59	19.68	-	-	-	-	-	-	-	-	-	-	11.48	11.50
	test stat.	-0.43		1.27		0.01		0.29		0.03		0.02		-3.74	
	p	.667		.260		.905		.590		.863		.882		< .001 ***	
PSI 10: Post-operative acute kidney	Mean/RF	70.43	68.69	68.48%	66.82%	71.43%	72.35%	3.42%	2.76%	0.00%	0.00%	8.07%	9.68%	30.44	31.89
	SD	13.53	13.39	-	-	-	-	-	-	-	-	-	-	16.03	16.32
	test stat.	-1.67		0.21		0.07		0.22		-		0.54		-1.01	
	p	.095		.651		.794		.640		-		.464		.311	
PSI 11: Post-operative respiratory failure	Mean/RF	69.77	67.05	82.95%	82.95%	83.33%	79.55%	2.27%	2.27%	1.52%	1.14%	4.55%	5.68%	25.23	25.60
	SD	15.53	11.54	-	-	-	-	-	-	-	-	-	-	17.68	18.05
	test stat.	-2.59		0.00		0.65		0.00		0.07		0.19		-0.13	
	p	.010 *		> .999		.419		> .999		> .999		.774		.894	
PSI 12: Peri-operative embolism or	Mean/RF	70.21	69.16	52.44%	53.35%	82.91%	82.94%	56.16%	54.64%	3.58%	3.17%	11.91%	13.03%	17.73	19.39
	SD	15.87	15.40	-	-	-	-	-	-	-	-	-	-	16.37	16.38
	test stat.	-2.79		0.35		0.00		0.97		0.52		1.23		-3.74	
	p	.005 **		.556		.978		.325		.470		.268		< .001 ***	
PSI 13: Post-operative sepsis	Mean/RF	71.47	70.18	68.82%	66.24%	80.58%	80.17%	1.41%	1.48%	1.20%	1.27%	4.93%	6.96%	22.54	23.33
	SD	13.29	13.28	-	-	-	-	-	-	-	-	-	-	16.12	16.33
	test stat.	-1.59		1.09		0.04		0.01		0.01		2.87		-0.94	
	p	.111		.296		.846		.912		.905		.090		.347	
PSI 14: Wound dehiscence	Mean/RF	70.36	69.77	66.67%	66.23%	80.57%	82.78%	51.66%	49.01%	1.55%	0.66%	6.18%	8.61%	12.85	14.82
	SD	13.91	13.59	-	-	-	-	-	-	-	-	-	-	14.64	13.24
	test stat.	-0.47		0.01		0.36		0.32		0.68		1.06		-2.14	
	p	.642		.921		.548		.573		.686		.304		.032	
PSI 18: Obstetric trauma with instrument[e]	Mean/RF	33.27	33.12	-	-	55.95%	55.54%	56.19%	56.43%	-	-	0.48%	0.71%	-0.59	-0.59
	SD	4.96	4.75	-	-	-	-	-	-	-	-	-	-	2.88	2.91
	test stat.	-0.61		-		0.03		0.01		-		0.45		-0.24	
	p	.544		-		.863		.922		-		.509		.808	
PSI 19: O	Mean/RF	32.62	32.64	-	-	59.08%	59.04%	55.82%	56.14%	-	-	0.16%	0.36%	-0.53	-0.57

	PSI	Age[a]		Sex[b]		Nationality		Emergency		Nursing home		Transferred		Elixhauser Index	
		0	**1**	**0**	**1**	**0**	**1**	**0**	**1**	**0**	**1**	**0**	**1**	**0**	**1**
	SD	4.88	4.77	-	-	-	-	-	-	-	-	-	-	2.81	2.73
	test stat.	-0.08		-		0.00		0.03		-		1.19		-0.27	
	p	.935		-		.984		.872		-		.377		.784	
		Age (G)[c]		Sex		Nationality: Swiss		Birth weight		Head size		No. prev. live births[f]		Elixhauser Index	
		0	1	0	1	0	1	0	1	0	1	0	1	0	1
PSI 17: Birth traum	Mean/RF	390.32	389.67	64.10%	67.95%	50.43%	51.28%	3469.44	3460.05	34.17	34.09	0.31	0.32	0.21	0.42
	SD	17.83	19.45	-	-	-	-	549.27	582.28	5.74	5.78	0.55	0.65	1.36	1.99
	test stat.	-0.09		0.38		0.02		-0.36		-0.23		-0.55		-0.89	
	p	.931		.537		.896		.715		.819		.584		.374	

Note. *** = $p < .001$; ** = $p < 0.01$; * = $p < 0.05$. Binary variables are expressed as relative frequencies (RF) in percent (%). Continuous variables are expressed as means and standard deviations (SD). [a] Rounded up to 5 years. [b] 1 = male. [c] Gestational age. [d] In PSI 3, patients were excluded from the sample if they were transferred from another hospital or were admitted from a nursing home. [e] The variables sex and admission from a nursing home were excluded in PSIs 18 and 19 because of missing relevance. *p* probability value. [f] Number of all previous live births of the mother.

Individual regression analyses across all PSIs:

Table S15: Regression analysis using the occurrence of PSI 02 (death in low-mortality DRGs) and several covariates to explain total costs (in CHF)

	B (in CHF)	*Std. Error*	*t*	*p*	
Constant	17,981.11	4,335.57	4.147	< .001	***
PSI 02 occurrence	7,333.19	1,877.50	3.906	< .001	***
Age	-24.60	53.33	-0.461	.645	
Sex: male	-2,532.50	1,630.18	-1.554	.122	
Nationality: Swiss	-1,719.14	2,061.08	-0.834	.405	
Admission: Emergency	-7,815.18	2,072.80	-3.770	< .001	***
Admission: From nursing home	-2,425.66	2,345.60	-1.034	.303	
Admission: Transferred	-1,450.00	2,855.70	-0.508	.612	
Elixhauser Index	362.26	83.25	4.351	< .001	***
Premature death	-14,774.58	7,921.39	-1.865	.064	

Note. *** = $p < .001$; ** = $p < 0.01$; * = $p < 0.05$; *B* unstandardized beta coefficients (costs), *t* test statistic, *p* probability value, *CHF* Swiss francs.

Table S16: Regression analysis using the occurrence of PSI 03 (pressure ulcer) and several covariates to explain total costs (in CHF)

	B (in CHF)	*Std. Error*	*t*	*p*	
Constant	58,990.75	5,285.83	11.160	< .001	***
PSI 03 occurrence	28,642.17	1,807.62	15.845	< .001	***
Age	-562.33	62.89	-8.941	< .001	***
Sex: male	3,187.70	1,593.49	2.000	.046	*
Nationality: Swiss	-1,248.64	2,041.24	-0.612	.541	
Admission: Emergency	-3,765.00	2,068.61	-1.820	.069	
Elixhauser Index	609.61	52.70	11.567	< .001	***
Premature death	57,897.99	32,530.15	1.780	.075	

Note. *** = $p < .001$; ** = $p < 0.01$; * = $p < 0.05$; *B* unstandardized beta coefficients (costs), *t* test statistic, *p* probability value, *CHF* Swiss francs. In PSI 3, patients were excluded from the sample if they were transferred from another hospital or were admitted from a nursing home. Because of this, these two variables are not included here.

Table S17: Regression analysis using the occurrence of PSI 04 (death after serious complications) and several covariates to explain total costs (in CHF)

	B (in CHF)	*Std. Error*	*t*	*p*	
Constant	171,222.63	14,200.94	12.057	< .001	***
PSI 04 occurrence	27,962.38	6,152.62	4.545	< .001	***
Age	-1,723.89	176.90	-9.745	< .001	***
Sex: male	7,704.53	5,069.15	1.520	.129	
Nationality: Swiss	-10,578.35	6,123.29	-1.728	.084	
Admission: Emergency	7,686.42	5,170.27	1.487	.137	
Admission: From nursing home	-11,476.32	13,980.21	-0.821	.412	
Admission: Transferred	30,698.19	7,411.42	4.142	< .001	***
Elixhauser Index	1,612.22	159.15	10.130	< .001	***
Premature death	-77,166.33	12,229.28	-6.310	< .001	***

Note. *** = $p < .001$; ** = $p < 0.01$; * = $p < 0.05$; *B* unstandardized beta coefficients (costs), *t* test statistic, *p* probability value, *CHF* Swiss francs.

Table S18: Regression analysis using the occurrence of PSI 05 (retained surgical item) and several covariates to explain total costs (in CHF)

	B (in CHF)	*Std. Error*	*t*	*p*	
Constant	5,366.66	5,826.11	0.921	.358	
PSI 05 occurrence	16,303.89	3,599.20	4.530	< .001	***
Age	9.50	91.12	0.104	.917	
Sex: male	6,479.09	3,232.65	2.004	.046	*
Nationality: Swiss	944.26	3,552.98	0.266	.791	
Admission: Emergency	430.82	3,539.75	0.122	.903	
Admission: From nursing home	-2,295.13	11,586.47	-0.198	.843	
Admission: Transferred	35,857.14	12,344.78	2.905	.004	**
Elixhauser Index	906.87	155.62	5.828	< .001	***
Premature death	-7,353.27	27,406.66	-0.268	.789	

Note. *** = $p < .001$; ** = $p < 0.01$; * = $p < 0.05$; *B* unstandardized beta coefficients (costs), *t* test statistic, *p* probability value, *CHF* Swiss francs.

Table S19: Regression analysis using the occurrence of PSI 06 (iatrogenic pneumothorax) and several covariates to explain total costs (in CHF)

	B (in CHF)	***Std. Error***	***t***	***p***	
Constant	5,366.66	5,826.11	0.921	.358	
PSI 06 occurrence	25,405.86	2,581.84	9.840	< .001	***
Age	-65.37	66.50	-0.983	.326	
Sex: male	1,422.02	2,253.18	0.631	.528	
Nationality: Swiss	-7,367.24	3,081.84	-2.391	.017	*
Admission: Emergency	4,509.32	2,317.18	1.946	.052	
Admission: From nursing home	-1,806.42	7,686.99	-0.235	.814	
Admission: Transferred	17,896.63	3,573.42	5.008	< .001	***
Elixhauser Index	446.18	83.72	5.329	< .001	***
Premature death	-28,230.22	11,479.41	-2.459	.014	*

Note. *** = $p < .001$; ** = $p < 0.01$; * = $p < 0.05$; *B* unstandardized beta coefficients (costs), *t* test statistic, *p* probability value, *CHF* Swiss francs.

Table S20: Regression analysis using the occurrence of PSI 07 (CVC bloodstream infection) and several covariates to explain total costs (in CHF)

	B (in CHF)	***Std. Error***	***t***	***p***	
Constant	28,141.17	6,177.19	4.556	< .001	***
PSI 07 occurrence	69,462.52	3,266.90	21.263	< .001	***
Age	-508.07	79.54	-6.388	< .001	***
Sex: male	2,317.93	3,162.54	0.733	.464	
Nationality: Swiss	-4,008.47	3,513.54	-1.141	.254	
Admission: Emergency	6,791.05	3,277.13	2.072	.038	*
Admission: From nursing home	-14,957.76	10,234.20	-1.462	.144	
Admission: Transferred	18,179.77	3,654.25	4.975	< .001	***
Elixhauser Index	1,641.73	105.40	15.576	< .001	***
Premature death	-33,145.95	16,827.54	-1.970	.049	*

Note. *** = $p < .001$; ** = $p < 0.01$; * = $p < 0.05$; *B* unstandardized beta coefficients (costs), *t* test statistic, *p* probability value, *CHF* Swiss francs.

Table S21: Regression analysis using the occurrence of PSI 08 (fall with hip fracture) and several covariates to explain total costs (in CHF)

	B (in CHF)	***Std. Error***	***t***	***p***	
Constant	75,683.45	16,970.60	4.460	< .001	***
PSI 08 occurrence	30,607.06	4,719.56	6.485	< .001	***
Age	-785.74	195.07	-4.028	< .001	***
Sex: male	1,626.02	4,192.63	0.388	.698	
Nationality: Swiss	-6,638.75	6,025.11	-1.102	.271	
Admission: Emergency	5,013.03	5,238.91	0.957	.339	
Admission: From nursing home	-283.81	7,225.27	-0.039	.969	
Admission: Transferred	10,442.57	5,285.19	1.976	.049	*
Elixhauser Index	1,552.75	152.52	10.181	< .001	***
Premature death	-19,681.05	21,697.72	-0.907	.365	

Note. *** = $p < .001$; ** = $p < 0.01$; * = $p < 0.05$; *B* unstandardized beta coefficients (costs), *t* test statistic, *p* probability value, *CHF* Swiss francs.

Table S22: Regression analysis using the occurrence of PSI 09 (postoperative hemorrhage/hematoma) and several covariates to explain total costs (in CHF)

	B (in CHF)	***Std. Error***	***t***	***p***	
Constant	5,797.75	1,190.02	4.872	< .001	***
PSI 09 occurrence	17,073.58	717.78	23.787	< .001	***
Age	65.23	17.76	3.674	< .001	***
Sex: male	828.77	628.28	1.319	.187	
Nationality: Swiss	-1,710.51	754.91	-2.266	.023	*
Admission: Emergency	10,076.47	717.67	14.040	< .001	***
Admission: From nursing home	-4,713.64	3,270.21	-1.441	.150	
Admission: Transferred	16,964.77	1,405.81	12.068	< .001	***
Elixhauser Index	918.18	28.78	31.901	< .001	***
Premature death	-5,051.83	5,290.92	-0.955	.340	

Note. *** = $p < .001$; ** = $p < 0.01$; * = $p < 0.05$; *B* unstandardized beta coefficients (costs), *t* test statistic, *p* probability value, *CHF* Swiss francs.

Table S23: Regression analysis using the occurrence of PSI 10 (postoperative acute kidney injury) and several covariates to explain total costs (in CHF)

	B (in CHF)	***Std. Error***	***t***	***p***	
Constant	73,272.93	18,658.81	3.927	< .001	***
PSI 10 occurrence	137,967.66	7,774.29	17.747	< .001	***
Age	-1,240.80	253.44	-4.896	< .001	***
Sex: male	7,403.49	7,132.42	1.038	.300	
Nationality: Swiss	582.15	7,511.07	0.078	.938	
Admission: Emergency	-5,810.09	21,400.45	-0.271	.786	
Admission: Transferred	24,395.65	13,677.90	1.784	.075	
Elixhauser Index	1,597.74	209.67	7.620	< .001	***
Premature death	-71,816.65	23,598.13	-3.043	.002	**

Note. *** = $p < .001$; ** = $p < 0.01$; * = $p < 0.05$; *B* unstandardized beta coefficients (costs), *t* test statistic, *p* probability value, *CHF* Swiss francs. The variable admission from nursing home is not included here because there were no admissions from nursing homes within the PSI 10 cases of this sample.

Table S24: Regression analysis using the occurrence of PSI 11 (postoperative respiratory failure) and several covariates to explain total costs (in CHF)

	B (in CHF)	***Std. Error***	***t***	***p***	
Constant	11,040.48	17,183.94	0.642	.521	
PSI 11 occurrence	104,000.42	6,981.65	14.896	< .001	***
Age	-61.30	211.23	-0.290	.7772	
Sex: male	1,603.28	8,111.93	0.198	.843	
Nationality: Swiss	-11,947.67	7,972.36	-1.499	.135	
Admission: emergency	3,050.86	22,923.88	0.133	.894	
Admission: From nursing home	-14,938.98	26,597.16	-0.562	.575	
Admission: transferred	21,111.39	15,587.01	1.354	.176	
Elixhauser Index	1,452.93	174.23	8.339	< .001	***
Premature death	-50,913.25	34,654.90	-1.469	.143	

Note. *** = $p < .001$; ** = $p < 0.01$; * = $p < 0.05$; *B* unstandardized beta coefficients (costs), *t* test statistic, *p* probability value, *CHF* Swiss francs.

Table S25: Regression analysis using the occurrence of PSI 12 (perioperative embolism or thrombosis) and several covariates to explain total costs (in CHF)

	B (in CHF)	***Std. Error***	***t***	***p***	
Constant	35,782.02	4,970.14	7.199	< .001	***
PSI 12 occurrence	32,815.55	2,219.60	14.784	< .001	***
Age	-540.54	64.29	-8.408	< .001	***
Sex: male	7,327.68	1,950.19	3.757	< .001	***
Nationality: Swiss	-2,771.81	2,592.60	-1.069	.285	
Admission: Emergency	16,092.59	1,955.37	8.230	< .001	***
Admission: From nursing home	-5,015.80	5,394.79	-0.930	.353	
Admission: Transferred	28,352.01	2,970.41	9.545	< .001	***
Elixhauser Index	1,408.06	60.38	23.319	< .001	***
Premature death	-33,012.46	8,443.48	-3.910	< .001	***

Note. *** = $p < .001$; ** = $p < 0.01$; * = $p < 0.05$; *B* unstandardized beta coefficients (costs), *t* test statistic, *p* probability value, *CHF* Swiss francs.

Table S26: Regression analysis using the occurrence of PSI 13 (postoperative sepsis) and several covariates to explain total costs (in CHF)

	B (in CHF)	***Std. Error***	***t***	***p***	
Constant	46,403.55	10,186.56	4.555	< .001	***
PSI 13 occurrence	91,568.15	4,064.36	22.530	< .001	***
Age	-696.22	135.25	-5.148	< .001	***
Sex: male	5,558.30	3,774.34	1.473	.141	
Nationality: Swiss	-3,487.24	4,474.11	-0.779	.436	
Admission: emergency	-23,699.87	15,985.00	-1.483	.138	
Admission: From nursing home	7,608.12	16,307.08	0.467	.641	
Admission: Transferred	37,545.39	8,282.39	4.533	< .001	***
Elixhauser Index	1,435.09	109.06	13.159	< .001	***
Premature death	-42,874.46	20,560.97	-2.085	.037	*

Note. *** = $p < .001$; ** = $p < 0.01$; * = $p < 0.05$; *B* unstandardized beta coefficients (costs), *t* test statistic, *p* probability value, *CHF* Swiss francs.

Table S27: Regression analysis using the occurrence of PSI 14 (wound dehiscence) and several covariates to explain total costs (in CHF)

	B (in CHF)	***Std. Error***	***t***	***p***	
Constant	28,776.95	12,005.43	2.397	.017	*
PSI 14 occurrence	41,283.12	4,910.31	8.407	< .001	***
Age	-165.18	161.40	-1.023	.307	
Sex: male	276.12	4,518.86	0.061	.951	
Nationality: Swiss	-5,213.13	5,544.65	-0.940	.347	
Admission: Emergency	10,442.61	4,310.56	2.423	.016	*
Admission: From nursing home	-12,348.72	18,901.80	-0.653	.514	
Admission: Transferred	58,325.40	8,504.57	6.858	< .001	***
Elixhauser Index	939.38	153.02	6.139	< .001	***
Premature death	-25,100.83	52,387.66	-0.479	.632	

Note. *** = $p < .001$; ** = $p < 0.01$; * = $p < 0.05$; *B* unstandardized beta coefficients (costs), *t* test statistic, *p* probability value, *CHF* Swiss francs.

Table S28: Regression analysis using the occurrence of PSI 17 (birth trauma) and several covariates to explain total costs (in CHF)

	B (in CHF)	***Std. Error***	***t***	***p***	
Constant	77,072.28	18,239.37	4.226	< .001	***
PSI 17 occurrence	5,819.57	1,876.75	3.101	.002	**
Sex: male	1,712.02	1,725.77	0.992	.322	
Nationality: Swiss	-2,795.70	1,635.11	-1.710	.088	
Admission: Transferred	-2,791.75	5,505.73	-0.507	.612	
Elixhauser Index	3,691.46	531.19	6.949	< .001	***
No. previous live births	-206.42	1,463.11	-0.141	.888	
Birth weight	-1.98	1.74	-1.139	.256	
Gestational age	-173.34	51.42	-3.371	.001	**
Head size	87.08	147.46	0.591	.555	

Note. *** = $p < .001$; ** = $p < 0.01$; * = $p < 0.05$; *B* unstandardized beta coefficients (costs), *t* test statistic, *p* probability value, *CHF* Swiss francs. No patients died; therefore, we did not control for premature deaths.

Table S29: Regression analysis using the occurrence of PSI 18 (obstetric trauma with instrument) and several covariates to explain total costs (in CHF)

	B (in CHF)	*Std. Error*	*t*	*p*	
Constant	7,868.90	519.11	15.158	< .001	***
PSI 18 occurrence	1,211.15	170.37	7.109	< .001	***
Age	20.69	15.15	1.365	.172	
Nationality: Swiss	-187.82	149.51	-1.256	.209	
Admission: Emergency	-429.82	148.95	-2.886	.004	**
Admission: Transferred	-1,225.85	1,013.01	-1.210	.226	
Elixhauser Index	15.98	25.60	0.624	.533	

Note. *** = $p < .001$; ** = $p < 0.01$; * = $p < 0.05$; *B* unstandardized beta coefficients (costs), *t* test statistic, *p* probability value, *CHF* Swiss francs. No patients died; therefore, we did not control for premature deaths. Similarly, the variables sex and admission from nursing home are not included here because no patients were male or admitted from a nursing home.

Table S30: Regression analysis using the occurrence of PSI 19 (obstetric trauma without instrument) and several covariates to explain total costs (in CHF)

	B (in CHF)	*Std. Error*	*t*	*p*	
Constant	7,275.55	303.20	23.996	< .001	***
PSI 19 occurrence	1,440.25	100.38	14.349	< .001	***
Age	-18.40	8.99	-2.047	.041	*
Nationality: Swiss	-50.89	88.90	-0.572	.567	
Admission: Emergency	-403.74	87.73	-4.602	< .001	***
Admission: Transferred	-1,192.51	947.95	-1.258	.208	
Elixhauser Index	4.30	15.59	0.276	.782	

Note. *** = $p < .001$; ** = $p < 0.01$; * = $p < 0.05$; *B* unstandardized beta coefficients (costs), *t* test statistic, *p* probability value, *CHF* Swiss francs. No patients died; therefore, we did not control for premature deaths. Similarly, the variables sex and admission from nursing home are not included here because no patients were male or admitted from a nursing home.

Table S31: Overview of the excess costs of PSI-related adverse events from the individual regression analyses presented above

		B (in CHF)	***Std. Error***	***t***	***p***	
PSI 02	Death in low-mortality DRGs	7,333.19	1,877.50	3.906	< .001	***
PSI 03	Pressure ulcer	28,642.17	1,807.62	15.845	< .001	***
PSI 04	Death after serious complications	27,962.38	6,152.62	4.545	< .001	***
PSI 05	Retained surgical items	16,303.89	3,599.20	4.530	< .001	***
PSI 06	Iatrogenic pneumothorax	25,405.86	2,581.84	9.840	< .001	***
PSI 07	CVC bloodstream infection	69,462.52	3,266.90	21.263	< .001	***
PSI 08	Fall with hip fracture	30,607.06	4,719.56	6.485	< .001	***
PSI 09	Perioperative hemorrhage/hematoma	17,073.58	717.78	23.787	< .001	***
PSI 10	Postoperative acute kidney injury	137,967.66	7,774.29	17.747	< .001	***
PSI 11	Postoperative respiratory failure	104,000.42	6,981.65	14.896	< .001	***
PSI 12	Perioperative embolism or thrombosis	32,815.55	2,219.60	14.784	< .001	***
PSI 13	Postoperative sepsis	91,568.15	4,064.36	22.530	< .001	***
PSI 14	Wound dehiscence	41,283.12	4,910.31	8.407	< .001	***
PSI 17	Birth trauma	5,819.57	1,876.75	3.101	.002	**
PSI 18	Obstetric trauma with instrument	1,211.15	170.37	7.109	< .001	***
PSI 19	Obstetric trauma without instrument	1,440.25	100.38	14.349	< .001	***

Note. *** = $p < .001$; ** = $p < 0.01$; *B* unstandardized beta coefficients (costs), *t* test statistic, *p* probability value, *CHF* Swiss francs.

Estimation of the total national costs of PSI-related adverse events in Switzerland:

Table S32: Regression analysis using the occurrence of all non-obstetrical PSIs and several covariates to explain total costs (in CHF)

		B (in CHF)	*Std. Error*	*t*	*p*	
Constant		13,795.93	989.81	13.938	< .001	***
PSI 02	Death in low-mortality DRGs	-9,015.84	7,621.49	-1.183	0.237	
PSI 03	Pressure ulcer	21,037.08	1,761.53	11.943	< .001	***
PSI 04	Death after serious complications	43,118.33	1,810.40	23.817	< .001	***
PSI 05	Retained surgical items	14,186.64	5,726.63	2.477	0.013	*
PSI 06	Iatrogenic pneumothorax	14,217.42	2,850.87	4.987	< .001	***
PSI 07	CVC bloodstream infection	56,178.95	2,156.36	26.053	< .001	***
PSI 08	Fall with hip fracture	29,632.88	4,759.48	6.226	< .001	***
PSI 09	Perioperative hemorrhage/hematoma	15,422.67	1,019.65	15.125	< .001	***
PSI 10	Postoperative acute kidney injury	95,061.65	3,511.04	27.075	< .001	***
PSI 11	Postoperative respiratory failure	47,239.14	5,358.20	8.816	< .001	***
PSI 12	Perioperative embolism or thrombosis	30,356.67	1,390.51	21.831	< .001	***
PSI 13	Postoperative sepsis	58,504.80	2,393.97	24.438	< .001	***
PSI 14	Wound dehiscence	40,760.01	4,070.07	10.015	< .001	***
Age		-136.77	16.23	-8.426	< .001	***
Sex: Male		5,310.00	613.55	8.655	< .001	***
Nationality: Swiss		-1,376.59	694.01	-1.984	0.047	*
Admission: Emergency		6,820.51	602.86	11.314	< .001	***
Admission: From nursing home		-4,280.90	2,397.22	-1.786	0.074	
Admission: Transferred		22,709.20	1,189.27	19.095	< .001	***
Elixhauser Index		1,027.72	22.86	44.966	< .001	***

Note. *** = $p < .001$; ** = $p < 0.01$; * = $p < 0.05$; *B* unstandardized beta coefficients (costs), *t* test statistic, *p* probability value, *CHF* Swiss francs. For the estimation of the total national costs, the covariate "premature death" and adverse events from the obstetrical PSIs 17–PSI 19 were not included (see Section 2.3.3).

Table S33: Sample characteristics of the complete national PSI data set and estimation of the total national costs due to adverse events covered by the PSIs in Switzerland in 2019.

		Raw data		**Incidence**	**Costs (in CHF)**	**Sum (in CHF)**
		N (PSI = 0)	*N* (PSI = 1)	Per thousand		
PSI 02	Death in low-mortality DRGs	390,479	62	0.16	-9,015.84	-558,982.08
PSI 03	Pressure ulcer	355,488	1,173	3.29	21,037.08	24,676,494.84
PSI 04	Death after serious complications	6,511	1,333	186.51	43,118.33	57,476,733.89
PSI 05	Retained surgical items	978,794	111	0.11	14,186.64	1,574,717.04
PSI 06	Iatrogenic pneumothorax	929,319	434	0.47	14,217.42	6,170,360.28
PSI 07	CVC bloodstream infection	679,179	748	1.10	56,178.95	42,021,854.60
PSI 08	Fall with hip fracture	405,592	139	0.34	29,632.88	4,118,970.32
PSI 09	Postoperative hemorrhage/hematoma	469,713	3,833	8.09	15,422.67	59,115,094.11
PSI 10	Postoperative acute kidney injury	366,428	276	0.75	95,061.65	26,237,015.40
PSI 11	Postoperative respiratory failure	354,828	339	0.95	47,239.14	16,014,068.46
PSI 12	Perioperative embolism or thrombosis	491,524	1,823	3.70	30,356.67	55,340,209.41
PSI 13	Postoperative sepsis	368,121	701	1.90	58,504.80	41,011,864.80
PSI 14	Wound dehiscence	62,036	229	3.68	40,760.01	9,334,042.29
PSI 15	Accidental punctures or lacerations	73,957	26	0.35		
PSI 17	Birth trauma	81,343	325	3.98	5,819.57	1,891,360.25
PSI 18	Obstetric trauma with instrument	8,694	668	71.35	1,211.15	809,048.20
PSI 19	Obstetric trauma without instrument	47,146	975	20.26	1,440.25	1,404,243.75
Sum (Switzerland)						**346,637,095.56**

Note. The full data set (see Section 2.3.3) was used here to include patients with private supplementary insurance coverage as well. The total national costs were calculated by multiplying the number of PSI-related adverse events by their costs per case (extracted from Supplementary File 1, Tables S15–S17 and S19). PSI 15 had an insufficient number of cases to be used for cost analysis but is depicted here as well for the sake of completeness.

APPENDIX B (SUPPLEMENTARY FILE 2)

Results of the 1:1 matching in contrast to the 1:3 matching reported in the manuscript:

Table S34: Sample characteristics and matching results

		Raw Data		Incidence	After matching		Matching rate	AUC
		N (PSI=0)	*N* (PSI=1)	Per thousand	*N* (PSI=0)	*N* (PSI=1)		
PSI 02	Death in low-mortality DRGs	210,113	43	0.2	41	43	100%	0.919
PSI 03	Pressure ulcer	207,566	865	4.17	865	865	100%	0.744
PSI 04	Death after serious complications	6,511	1,333	204.73	1,328	1333	100%	0.731
PSI 05	Retained surgical item	666,990	76	0.11	76	76	100%	0.612
PSI 06	Iatrogenic pneumothorax	557,683	310	0.56	310	310	100%	0.726
PSI 07	CVC bloodstream infection	467,237	553	1.18	551	553	100%	0.826
PSI 08	Fall with hip fracture	186,552	111	0.6	110	111	100%	0.925
PSI 09	Postoperative hemorrhage/hematoma	303,722	2,717	8.95	2,717	2,717	100%	0.634
PSI 10	Postoperative acute kidney injury	230,484	227	0.98	217	227	100%	0.956
PSI 11	Postoperative respiratory failure	197,181	90	0.46	87	90	100%	0.921
PSI 12	Perioperative embolism or thrombosis	316,278	1,393	4.4	1,391	1,393	100%	0.861
PSI 13	Postoperative sepsis	231,525	493	2.13	484	493	100%	0.906
PSI 14	Wound dehiscence	43,545	151	3.47	151	151	100%	0.792
PSI 15	Accidental punctures or lacerations	43,794	15	-	-	-	-	-
PSI 17	Birth trauma	12,865	101	7.85	77	101	100%	0.706
PSI 18	Obstetric trauma with instrument	7,515	560	74.52	560	560	100%	0.530
PSI 19	Obstetric trauma without instrument	39,964	830	20.77	830	830	100%	0.546

Note. AUC area under the curve. The matching rate indicates the proportion of cases that met the common support assumption. PSI 15 had an insufficient number of cases to be used for analysis but is depicted here as well for the sake of completeness.

Table S35: Comparisons of means and relative frequencies across matching variables

		Age[a]		**Sex**[b]		**Nationality**		**Emergency**		**Nursing home**		**Transferred**		**Elixhauser Index**	
Group	PSI	0	1	0	1	0	1	0	1	0	1	0	1	0	1
PSI 02: Death in low-mortality DRGs	Mean/RF	72.68	77.56	56.10%	51.16%	63.41%	79.07%	65.85%	74.42%	14.63%	16.28%	4.88%	11.63%	8.27	6.98
	SD	21.88	19.71	-	-	-	-	-	-	-	-	-	-	11.12	11.40
	test stat.	-0.78		0.21		2.52		0.74		0.04		1.25		-0.58	
	p	.436		.650		.112		.391		.835		.434		.560	
PSI 03: Pressure ulcer[d]	Mean/RF	77.72	78.35	53.76%	53.53%	81.27%	80.92%	80.92%	82.89%	-	-	-	-	15.74	17.46
	SD	13.34	13.26	-	-	-	-	-	-	-	-	-	-	15.02	15.45
	test stat.	-1.25		0.01		0.03		41.54		-	-	-	-	-2.40	
	p	.213		.923		.854		<.001 ***		-	-	-	-	.016 *	
PSI 04: Death after serious compli-cations	Mean/RF	72.75	73.08	64.61%	64.97%	79.59%	81.85%	76.36%	76.52%	4.67%	4.58%	13.70%	16.88%	25.17	27.07
	SD	12.90	13.33	-	-	-	-	-	-	-	-	-	-	16.59	16.48
	test stat.	-1.13		0.04		2.17		0.01		0.01		5.17		-2.80	
	p	.259		0.847		.141		.921		.910		.023*		.005 **	
PSI 05: Retained surgical items	Mean/RF	59.74	56.51	40.79%	40.79%	71.05%	72.37%	27.63%	28.95%	3.95%	1.32%	2.63%	2.63%	4.42	4.61
	SD	17.94	18.92	-	-	-	-	-	-	-	-	-	-	9.19	11.45
	test stat.	-0.94		0.00		0.03		0.03		1.03		0.00		-0.15	
	p	.348		> .999		.857		.857		.311		> .999		.884	
PSI 06: Iatrogenic pneumo-thorax	Mean/RF	67.94	67.13	50.00%	49.68%	80.65%	83.55%	49.03%	49.68%	2.26%	1.61%	11.29%	12.58%	12.46	13.84
	SD	16.85	15.92	-	-	-	-	-	-	-	-	-	-	14.73	13.28
	test stat.	-0.98		0.01		0.89		0.03		0.34		0.25		-2.25	
	p	.326		.936		.346		.872		.560		.620		.024 *	
PSI 07: CVC bloodstream infection	Mean/RF	65.30	65.40	67.33%	71.07%	77.68%	78.48%	64.43%	70.71%	3.09%	2.17%	20.51%	21.34%	13.38	15.44
	SD	18.91	15.74	-	-	-	-	-	-	-	-	-	-	15.01	14.64
	test stat.	-0.87		1.81		0.10		4.96		0.90		0.12		-2.94	
	p	.386		0.179		.747		.026		.342		.735		.003 **	
PSI 08: Fall with hip fracture	Mean/RF	76.55	79.32	61.82%	49.55%	78.18%	85.59%	75.45%	78.38%	10.91%	14.41%	23.64%	18.02%	11.81	13.25
	SD	14.24	12.09	-	-	-	-	-	-	-	-	-	-	11.78	12.78
	test stat.	-1.37		3.37		2.04		0.27		0.61		1.06		-1.09	
	p	.170		.067		.153		.610		.433		.304		.277	
PSI 09: Post-operative hemorrhage /hematoma	Mean/RF	60.01	59.63	53.70%	56.86%	78.40%	77.22%	25.76%	27.02%	1.10%	0.96%	5.15%	5.26%	6.09	6.87
	SD	18.41	19.68	-	-	-	-	-	-	-	-	-	-	11.75	11.50
	test stat.	-0.11		5.51		1.09		1.10		0.29		0.03		-4.63	
	p	.912		.019*		.296		.295		.591		.855		< .001 ***	
PSI 10: Post-operative acute kidney injury	Mean/RF	68.55	69.07	62.67%	66.52%	72.81%	71.81%	2.76%	2.64%	0.00%	0.00%	6.91%	10.13%	28.36	33.03
	SD	14.33	13.27	-	-	-	-	-	-	-	-	-	-	19.36	16.86
	test stat.	-0.45		0.72		0.06		0.01		-		1.09		-2.10	

		Age[a]		Sex[b]		Nationality		Emergency		Nursing home		Transferred		Elixhauser Index	
	PSI	0	1	0	1	0	1	0	1	0	1	0	1	0	1
	p	.650		.397		.813		.937		-		.297		.036 *	
PSI 11: Post-operative respiratory failure	Mean/RF	68.56	67.17	72.41%	83.33%	74.71%	78.89%	0.00%	2.22%	0.00%	1.11%	6.90%	6.67%	21.68	26.77
	SD	15.17	11.44	-	-	-	-	-	-	-	-	-	-	19.05	19.59
	test stat.	-1.46		3.07		0.43		1.96		0.97		0.00		-1.55	
	p	.145		.080		.510		.497		.244		.952		.121	
PSI 12: Peri-operative embolism or thrombosis	Mean/RF	68.07	69.15	53.20%	53.41%	81.09%	82.91%	49.32%	54.70%	2.59%	3.16%	12.65%	13.14%	16.63	19.53
	SD	16.87	15.39	-	-	-	-	-	-	-	-	-	-	17.39	16.59
	test stat.	-0.97		0.01		1.57		8.09		0.81		0.15		-5.77	
	p	0.331		.911		.211		.004**		.368		.703		< .001 ***	
PSI 13: Post-operative sepsis	Mean/RF	68.51	70.26	63.84%	66.33%	77.48%	79.51%	1.65%	1.62%	1.45%	1.22%	7.23%	7.30%	20.73	24.70
	SD	15.91	13.21	-	-	-	-	-	-	-	-	-	-	18.10	17.52
	test stat.	-1.17		0.66		0.60		0.00		0.10		0.00		-3.41	
	p	.242		.415		.439		.970		.755		.966		.001 **	
PSI 14: Wound dehiscence	Mean/RF	69.44	69.77	56.95%	66.23%	78.81%	82.78%	47.68%	49.01%	1.32%	0.66%	7.95%	8.61%	14.34	14.82
	SD	16.40	13.59	-	-	-	-	-	-	-	-	-	-	14.93	13.24
	test stat.	-10.83		2.74		0.77		0.05		0.34		0.04		-0.39	
	p	<.001 ***		.098		.381		.818		> .999		.835		.696	
PSI 18: Obstetric trauma with instrument[e]	Mean/RF	33.38	33.12	-	-	54.46%	55.54%	56.25%	56.43%	-	-	1.07%	0.71%	-0.38	-0.59
	SD	4.92	4.75	-	-	-	-	-	-	-	-	-	-	3.15	2.91
	test stat.	-0.90		-		0.13		0.00		-		0.40		-1.50	
	p	.371		-		.719		.952		-		.525		.133	
PSI 19: Obstetric trauma without instrument[e]	Mean/RF	32.67	32.64	-	-	61.45%	59.04%	54.46%	56.14%	-	-	0.12%	0.36%	-0.51	-0.57
	SD	4.69	4.77	-	-	-	-	-	-	-	-	-	-	2.82	2.73
	test stat.	-0.21		-		1.01		0.48		-		1.00		-0.11	
	p	.833		-		.316		.489		-		.625		.911	
		Age (G)[c]		**Sex**		**Nationality: Swiss**		**Birth weight**		**Head size**		**No. prev. live births[f]**		**Elixhauser Index**	
		0	1	0	1	0	1	0	1	0	1	0	1	0	1
PSI 17: Birth traum	Mean/RF	388.39	388.55	53.25%	67.33%	54.55%	53.47%	3,449.81	3,432.56	34.30	34.33	0.39	0.34	0.26	0.38
	SD	19.13	19.90	-	-	-	-	517.27	577.34	5.83	5.15	0.61	0.66	1.34	1.82
	test stat.	-0.20		3.65		0.02		-0.28		-0.75		-0.84		-0.34	
	p	.839		.056		.886		.780		.451		.402		.737	

Note. *** = $p < .001$; ** = $p < 0.01$; * = $p < 0.05$. Binary variables are expressed as relative frequencies (RF) in percent (%). Continuous variables are expressed as means and standard deviations (SD). [a] Rounded up to 5 years. [b] 1 = male. [c] Gestational age. [d] In PSI 3, patients were excluded from the samples if they were transferred from another hospital or were admitted from a nursing home. [e] The variables sex and admission from a nursing home were excluded in PSI 18 and 19 because of missing relevance. *p* probability value. [f] Number of all previous live births of the mother.

Table S36: Comparisons of means and relative frequencies across outcome variables

		Total cost in CHF		LOS		Number of readmissions		Mortality	
	PSI	0	1	0	1	0	1	0	1
PSI 02: Death in low-mortality DRGs	Mean/RF	10,103.29	16,211.84	5.41	5.81	0.07	0.02	0.00%	100.00%
	SD	9,274.51	18,100.84	6.66	6.57	0.26	0.15		-
	test statistic	-0.92		-0.23		-1.07		84.00	
	p	.359		.819		.286		< .001 ***	
PSI 03: Pressure ulcer	Mean/RF	23,596.97	51,792.02	13.07	23.62	0.09	0.07	6.94%	16.99%
	SD	31,424.85	77,644.00	10.92	24.21	0.31	0.26	-	-
	test statistic	-14.07		-14.17		-0.50		41.54	
	p	< .001 ***		< .001 ***		.619		< .001 ***	
PSI 04: Death after serious compli-cations	Mean/RF	90,929.44	103,948.48	28.08	18.45	0.08	0.03	0.00%	100.00%
	SD	101,175.76	121,130.00	24.83	20.52	0.28	0.19	-	-
	test statistic	-2.55		-16.48		-4.88		2661.00	
	p	.011 *		< .001 ***		< .001 ***		< .001	
PSI 05: Retained surgical items	Mean/RF	14,159.43	30,748.18	5.83	10.78	0.04	0.07	1.32%	2.63%
	SD	19,585.80	47,458.73	7.58	18.54	0.20	0.25	-	-
	test statistic	-3.44		-3.14		-0.72		0.34	
	p	.001 *		.002 **		.469		.560	
PSI 06: Iatrogenic pneumo-thorax	Mean/RF	17,450.86	43,259.37	7.91	12.71	0.05	0.05	5.48%	9.35%
	SD	26,675.60	59,343.67	8.75	12.86	0.22	0.21	-	-
	test statistic	-10.35		-6.11		-0.19		3.38	
	p	< .001 ***		< .001 ***		.851		.066	
PSI 07: CVC bloodstream infection	Mean/RF	21,975.91	96,456.09	9.58	28.25	0.07	0.11	5.08%	10.85%
	SD	28,551.27	120,722.84	9.75	24.59	0.29	0.32	-	-
	test statistic	-20.10		-19.42		-2.79		12.52	
	p	< .001 ***		< .001 ***		.005 **		< .001***	
PSI 08: Fall with hip fracture	Mean/RF	34,597.71	65,256.16	12.35	24.60	0.10	0.06	4.55%	17.12%
	SD	41,064.17	54,699.80	13.69	20.12	0.36	0.24	-	-
	test statistic	-5.98		-6.09		-0.57		9.02	
	p	< .001 ***		< .001 ***		.569		.003**	
PSI 09: Post-operative hemorrhage/hematom	Mean/RF	17,438.13	35,766.92	5.96	11.84	0.03	0.25	1.36%	2.50%
	SD	23,929.17	48,453.42	8.62	14.41	0.19	0.48	-	-
	test statistic	-26.75		-25.58		-21.16		9.33	
	p	< .001 ***		< .001 ***		< .001 ***		.002**	
PSI 10: Post-operative acute kidney	Mean/RF	43,208.13	184,824.96	11.70	33.07	0.03	0.05	4.15%	38.77%
	SD	68,334.41	190,533.89	14.48	31.70	0.18	0.22	-	-
	test statistic	-14.04		-10.50		-1.07		77.88	
	p	< .001 ***		< .001 ***		.284		< .001***	
PSI 11: Post-operative respiratory failure	Mean/RF	30,761.25	140,710.77	9.41	31.54	0.02	0.06	4.60%	25.56%
	SD	49,089.90	83,918.77	11.56	18.65	0.15	0.27	-	-
	test statistic	-9.62		-8.99		-0.80		15.03	
	p	< .001 ***		< .001 ***		.426		< .001***	
PSI 12: Peri-operative embolism or	Mean/RF	35,672.24	72,030.42	11.49	21.65	0.06	0.10	7.05%	10.19%
	SD	56,429.19	112,568.59	14.38	22.59	0.26	0.31	-	-
	test statistic	-20.11		-19.36		-3.93		8.76	
	p	< .001 ***		< .001 ***		< .001 ***		.003**	
PSI 13: Post-operative sepsis	Mean/RF	30,759.35	127,730.62	8.88	32.46	0.04	0.10	2.27%	23.33%
	SD	54,551.51	147,951.07	12.14	27.79	0.21	0.30	-	-
	test statistic	-20.86		-20.54		-3.78		96.37	
	p	< .001 ***		< .001 ***		< .001 ***		< .001***	
PSI 14: Wound dehiscence	Mean/RF	33,367.01	78,382.95	12.18	26.76	0.06	0.17	5.30%	10.60%
	SD	40,476.75	63,757.46	14.67	14.48	0.24	0.40	-	-
	test statistic	-10.83		-10.67		-2.92		2.90	
	p	< .001 ***		< .001 ***		.004 **		.089	
PSI 17: Bi	Mean/RF	5,352.52	14,611.43	4.65	6.93	0.04	0.02	-	-

		Total cost in CHF		LOS		Number of readmissions		Mortality	
	PSI	0	1	0	1	0	1	0	1
	SD	9,169.26	20,723.45	3.34	6.35	0.19	0.14	-	-
	test statistic	-5.53		-2.63		-0.76		-	
	p	< .001 ***		.009 **		.445		-	
PSI 18: Obstetric trauma with instrument	Mean/RF	8,203.21	9,400.23	4.03	4.30	0.00	0.00	-	-
	SD	4,178.72	3,445.03	1.35	1.43	0.00	0.00	-	-
	test statistic	-7.63		-3.61		0.00		-	
	p	< .001 ***		< .001 ***		-		-	
PSI 19: Obstetric trauma without instrument	Mean/RF	6,618.26	7,851.62	3.45	3.83	0.00	0.00	-	-
	SD	2,622.01	2,689.39	1.22	1.18	0.02	0.00	-	-
	test statistic	-10.43		-7.21		-1.00		-	
	p	< .001 ***		< .001 ***		.317		-	

Note. *** = $p < .001$; ** = $p < 0.01$; * = $p < 0.05$; Binary variables are expressed as relative frequencies (RF) in percent (%). Continuous variables are expressed as means and standard deviations (SD). *CHF* Swiss francs, *LOS* length of stay, *p* probability value.

Table S37: Overview of the excess costs of PSI-related adverse events from the individual regression analyses using 1:1 matching

		B (in CHF)	***Std. Error***	***t***	***p***	
PSI 02	Death in low-mortality DRGs	8,271.76	3,238.43	2.554	.013	*
PSI 03	Pressure ulcer	27,419.96	2,730.19	10.043	< .001	***
PSI 04	Death after serious complications	23,767.24	4,208.20	5.648	< .001	***
PSI 05	Retained surgical item	15,424.33	5,303.46	2.908	< .001	***
PSI 06	Iatrogenic pneumothorax	25,502.31	3,637.86	7.010	< .001	***
PSI 07	CVC bloodstream infection	69,763.31	5,000.20	13.952	< .001	***
PSI 08	Fall with hip fracture	29,743.94	5,941.70	5.006	< .001	***
PSI 09	Perioperative hemorrhage/hematoma	17,284.63	940.38	18.381	< .001	***
PSI 10	Postoperative acute kidney injury	137,984.64	13,340.60	10.343	< .001	***
PSI 11	Postoperative respiratory failure	104,678.38	10,055.08	10.410	< .001	***
PSI 12	Perioperative embolism or thrombosis	32,226.37	3,173.08	10.156	< .001	***
PSI 13	Postoperative sepsis	92,699.76	6,844.87	13.543	< .001	***
PSI 14	Wound dehiscence	44,126.61	5,810.23	7.595	< .001	***
PSI 17	Birth trauma	7,664.09	2,384.71	3.214	.002	**
PSI 18	Obstetric trauma with instrument	1,201.98	22 8.70	5.256	< .001	***
PSI 19	Obstetric trauma without instrument	1,245.88	130.01	9.583	< .001	***

Note. *** = $p < .001$; ** = $p < 0.01$; B unstandardized beta coefficients (costs), t test statistic, p probability value, *CHF* Swiss francs.