Aus der Medizinischen Klinik für Gastroenterologie, Infektiologie und
Rheumatologie der Medizinischen Fakultät Charité – Universitätsmedizin Berlin

DISSERTATION

Analysis of complex IBD cases with regards to complications, interventions, additional charges as well as costs with distinct evaluation of center effects

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Analyse der komplexen CED-Fälle in Bezug auf Komplikationen, Intervention, Zusatzentgelte sowie Kosten mit gesonderter Evaluation von Zentrumseffekten

zur Erlangung des akademischen Grades
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Foreword

Partial results of the present work were published in Moll-von der Wettern M, Heinlein W, Rathmayer M, Koller L, Siegmund B. Ein kritischer DRG-Blick auf Fälle mit chronisch entzündlichen Darmerkrankungen. Zeitschrift für Gastroenterologie 2022; 60.
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Table of Contents

List of Tables

List of Figures

List of Abbreviations

ALOS	Average length of stay (*mittlere Verweildauer*)
BN	Billion
CAGR	Compound annual growth rate
CC	Complication or Comorbidity
DGVS	German Society for Gastroenterology, Digestive and Metabolic Diseases (*Deutsche Gesellschaft für Gastroenterologie, Verdauungs- und Stoffwechselkrankheiten*)
DKG	German Hospital Federation (*Deutschen Krankenhausgesellschaft*)
DGINA	German Society for Interdisciplinary Emergency and Acute Medicine
DRG	Diagnosis-related group
EGD	Esophago-Gastro-Duodenoscopy
ERCP	Endoscopic retrograde cholangiopancreaticography
G-DRG	German diagnosis-related group
IBD	Inflammatory bowel disease
ICD	International Classification of Diseases
InEK	Institute for reimbursement in hospitals (*Institut für das Entgeltsystem im Krankenhaus*)
IQR	Interquartile range
KHEntgG	Hospital Remuneration Act (*Krankenhausentgeltgesetz*)
KHG	German Hospital Financing Act (*Krankenhausfinanzierungsgesetz*)
KHSG	Hospital Structure Act (*Krankenhausstrukturgesetz*)
MRI	Magnetic resonance imaging
MN	Million
NHS	National Health Service
OPS	Operation and procedure code (*Operationen- und Prozedurenschlüssel*)
p.a.	Per annum
PCC	Patient Clinical Complexity Level
PSC	Primary sclerosing cholangitis
VIF	Variance Inflation Factor

Abstract

Introduction and Objectives It is assumed that inflammatory bowel disease (IBD) is partly treated in a non-cost-covering manner in German hospitals. Consequently, this paper examines the reimbursement situation of IBD in Germany. In particular, we investigate the effects of complexity on profitability and the potential differences among different hospital types.

Methods We used anonymized case data, including cost data from the Institute for reimbursement in hospitals (InEK) calculation (§21-4 Hospital Remuneration Act (KHEntgG) of the Diagnosis Related Groups (DRG) project of the German Society for Gastroenterology, Digestive and Metabolic Diseases (DGVS) from 2019. We analyzed 3,385 cases with IBD as the principal diagnosis, 1876 cases with Crohn's disease, and 1509 with ulcerative colitis. The cases are distributed across 49 hospitals.
To examine the impact of the complexity of a case on the reimbursement situation, we explored different variables, including gastroenterological complications, infections, specific procedures, admission reasons, and additional charges.
We grouped hospitals by type of care to examine potential center effects. To ensure comparability of profitability across different diagnosis groups, the standardized metric of relative profitability per case was determined.

Results We found that all types of hospitals are treating IBD in a non-cost-covering manner. Therefore, the average revenue earned per case is lower than its attributable cost. The financial loss averages 10% (€296 absolute financial loss) and varies depending on the type of hospital (primary and focus care providers: 3%, focus care providers: 10%, maximum care providers: 13%, university hospitals: 13%). The costs per case differ among the types of care; hospitals with more beds bear higher costs. On average, university hospitals incur costs €2,296 higher than those of primary care providers, with personnel costs accounting for €902 of this difference. Cases with higher complexity display higher financial losses than cases with lower complexity.

Discussion This analysis demonstrates that the costs of treating IBD in German hospitals are not recovered. A reduction of the financial loss may be achieved, for example, by adjusting the reimbursement for gastroenterological complications and infections and a

corresponding surcharge for the reason for admission (e.g., transfer). Furthermore, a surcharge could be introduced for university hospitals to account for the increased complexity and contingency costs.

Zusammenfassung

Einleitung und Ziele Es wird davon ausgegangen, dass die Behandlung von CED in deutschen Krankenhäusern teilweise nicht kostendeckend erfolgt. In dieser Arbeit untersuchen wir die Vergütungssituation von entzündlichen Darmerkrankungen (CED) in deutschen Krankenhäusern. Wir befassen uns insbesondere mit den Auswirkungen der Komplexität auf die Rentabilität und möglichen Unterschieden zwischen verschiedenen Krankenhaustypen.

Methoden Wir haben anonymisierte Falldaten, einschließlich Kostendaten, vom Institut für Krankenhausvergütung (InEK) verwendet, um Berechnungen gemäß §21-4 des Krankenhausvergütungsgesetzes (KHEntgG) der Diagnosis Related Groups (DRG) des Deutschen Gesellschaft für Gastroenterologie, Stoffwechsel- und Verdauungskrankheiten (DGVS) von 2019 durchzuführen. Es wurden 3385 Fälle mit CED als Hauptdiagnose, 1876 Fälle mit Morbus Crohn und 1509 Fälle mit Colitis ulcerosa analysiert, die sich auf 49 Krankenhäuser verteilen. Um den Einfluss der Komplexität eines Falls auf die Vergütungssituation zu untersuchen, haben wir verschiedene Variablen untersucht, darunter gastroenterologische Komplikationen, Infektionen, spezifische Prozeduren, Aufnahmegrunde und Zusatzentgelte. Um mögliche Zentrumseffekte zu untersuchen, haben wir die Krankenhäuser nach Versorgungstyp gruppiert. Um die Rentabilität zwischen verschiedenen Diagnosegruppen vergleichbar zu machen, wurde der standardisierte Metrik der relativen Rentabilität pro Fall bestimmt.

Ergebnisse Es wurde gezeigt, dass alle Versorgungstypen CED nicht kostendeckend behandeln. Folglich sind die durchschnittlichen Einnahmen pro Fall niedriger als die zugeordneten Kosten. Der finanzielle Verlust liegt im Durchschnitt bei 10% (296€ absoluter finanzieller Verlust) und variiert je nach Art des Krankenhauses (Grund- und Regelversorger: 3%, Schwerpunktversorger: 10%, Maximalversorger: 13%, Universitätskliniken: 13%). Die Kosten pro Fall unterscheiden sich zwischen den Versorgungstypen; Krankenhäuser mit mehr Betten tragen höhere Kosten. Im Durchschnitt liegen die Kosten der

Universitätskliniken um 2296€ über denen der Primärversorger, wobei 902€ auf die Personalkosten entfallen. Fälle mit höherer Komplexität weisen höhere finanzielle Verluste auf als Fälle mit geringerer Komplexität.

Diskussion Diese Analyse zeigt, dass die Kosten für die Behandlung von CED in deutschen Krankenhäusern nicht gedeckt werden. Eine Verringerung des finanziellen Verlustes kann z.B. durch eine Anpassung der Vergütung für gastroenterologische Komplikationen und Infektionen und einen entsprechenden Zuschlag für den Aufnahmegrund (z.B., Verlegung) erreicht werden. Darüber hinaus könnte ein Zuschlag für Universitätskliniken eingeführt werden, um die erhöhten Komplexitäts- und Vorhaltekosten zu berücksichtigen.

Keywords

Complex cases, Crohn's disease, G-DRG system, hospital financing, profitability, reimbursement, ulcerative colitis, university hospitals

1 Introduction

This study assesses the reimbursement status of inflammatory bowel disease (IBD) in German hospitals. To date, such an investigation has not been conducted.

IBD is a systemic disease, presenting with chronic inflammation in the gastrointestinal tract. In 2012 approximately 400,000 to 500,000 Germans suffered from IBD, with the prevalence of treated IBD increasing by 4% annually between 2001 and 2010 [1,2]. The majority of IBD patients are cared for in outpatient clinics; however, complications or severe courses of the disease may require IBD patients to be treated as inpatients [3–5]. Numerous new drug strategies have been approved over the last 20 years, with additional approvals expected in the near future. Consequently, the treating physicians must be sufficiently competent and experienced in treating the occasionally complex courses of the disease in patients with IBD [3,4].

The German hospital financing system is primarily comprised of two components: operating and investment costs [6]. Investment costs are financed by federal states, while operating costs are financed predominantly by statutory and private health insurances, and are based upon a per-case flat rate system - the German Diagnosis Related Group (G-DRG) system [7].

The reimbursement situation of select other gastroenterological conditions has been previously analyzed. In 2020, Gundling et al. analyzed the reimbursement situation of cases with liver cirrhosis, finding that, in contrast to patients with general cirrhosis, patients with hepatic encephalopathy are treated at a financial loss [8]. Furthermore, in 2020, Lerch et al. found that two-thirds of university hospitals incur financial losses, compared to 29% of non-university hospitals [9]. This is in line with the finding that aggregated annual losses faced by university hospitals have risen from €73 million in 2015 to €544 million in 2020, after adjusting for federal state subsidies [10].

In this context, the present study analyzes the reimbursement situation of inpatient IBD in Germany. Given that inpatient cases require admission, especially in instances with high disease activity and complications, this study focuses on the impact of case complexity on profitability, and on potential differences among types of care [8,9].

For the data analysis, we utilized the dataset of the German Society for Gastroenterology, Digestive and Metabolic Diseases (DGVS) Diagnosis Related Groups (DRG) project. The dataset consists of annual cost data that healthcare providers share with the

Institute for the Hospital Remuneration System (IneEK) in anonymized form (2019; § 21 KHEntgG). For the purpose of this study, *cost-under recovery* is referred to as *deficit* or *financial loss* and *cost-over recovery* is referred to as *profit* or *financial gain.*

2 Theoretical Foundation and Literature Review

To evaluate the reimbursement situation of IBD in Germany, first, the definition of IBD is outlined, specifically that of Crohn's disease and ulcerative colitis. Then, an overview of the DRG system is presented. Finally, a brief summary of the stationary provider landscape in Germany is provided. The following overview aims to provide the reader with the background knowledge necessary for this study; however, it is not exhaustive.

2.1 Definition of Inflammatory Bowel Disease

IBD is a systemic, chronic disease. There are two forms of IBD: Crohn's disease and ulcerative colitis. Although IBD can spread in the intestine (intestinal manifestation), it can also cause specific inflammation of the eyes, skin, and organs such as the liver, pancreas, and kidneys (extraintestinal manifestation) [11].

In both ulcerative colitis and Crohn's disease, the inflammation likely arises due to a genetic predisposition in conjunction with environmental factors which are yet to be defined. Once initiated, the inflammatory response to bacteria is perpetuated by an abnormal inherited immune response. As a consequence, a cascade of pro-inflammatory mediators is released, which amplifies the immune response [11].

IBD is a lifelong condition characterized by a variable course of the disease. IBD patients may suffer from an alternation of acute disease episodes and remissions (i.e., symptom-free intervals) or chronically active courses [1].

2.1.1 Crohn's disease

2.1.1.1 Crohn's disease overview

Crohn's disease is a transmural disease that presents in flare-ups and affects the entire intestinal wall [11]. This inflammatory disease can affect the entire gastrointestinal tract from the mouth to the anus. About 30-40% of patients have small bowel involvement,

40-55% have small and large bowel involvement, and 15-25% have colitis only. Crohn's disease typically impacts intermittent segments of the digestive tract, with some areas of healthy mucosa between affected bowel segments. Pararectal fistulas, fissures, abscesses, and anal stenoses occur in about one-third of patients with Crohn's disease, and especially with colon involvement [11].

Crohn's disease generally presents as either acute or chronic inflammation of the bowel. During the disease course, patients usually develop either an inflammatory, a fibrostenotic obstructive, or a penetrating disease pattern. These different subtypes that are also reflected in the Montreal classification require distinct therapeutic strategies [12]. The localization of the disease within the gastrointestinal tract influences the type of clinical manifestation [11].

2.1.1.2 Crohn’s disease complications

Crohn's disease is a transmural inflammation that leads to serosal adhesions and can ultimately result in fistula formation. Over time, 10-30% of Crohn's patients develop abscesses in the abdomen or pelvis. Even with adequate drainage, resection of the corresponding bowel segment is required in most patients. Other complications that may occur include intestinal obstruction, massive hemorrhage, malabsorption, and severe perianal disease manifestations [11].

2.1.2 Ulcerative colitis

2.1.2.2 Ulcerative colitis overview

Ulcerative colitis is an inflammation of the colon that occurs in flare-ups and affects only the mucosa. This is usually confined to the colon, and most commonly starts in the rectum. The predominant symptoms of ulcerative colitis include diarrhea, rectal discharge of blood and mucus, tenesmus, and cramping abdominal pain. The severity of symptoms correlates with the extent of colonic involvement [11].

Depending on the level of involvement, the disease can be divided into different subtypes, according to anatomical localization. Examples include left-sided colitis or extensive colitis (pancolitis). In a few patients, inflammation of the terminal portion of the

small intestine (backwash ileitis) may also develop, making it difficult to distinguish ulcerative colitis from Crohn's disease. In approximately 40-50% of patients, ulcerative colitis is confined to the rectum and rectosigmoid. In 30-40%, the disease has extended beyond the sigmoid but does not involve the entire colon. Only 20% of patients present with pancolitis. The inflammatory activity in the mucosa may vary regionally, giving the impression of discontinuous involvement [11].

2.1.2.2 Ulcerative colitis complications

In 15% of patients diagnosed with ulcerative colitis, the disease manifests itself with an initial severe acute disease flare-up. In 1%, severe acute phases are accompanied by massive hemorrhaging, which can usually be stopped through the initiation of drug treatments targeting the inflammation. Toxic megacolon is defined by dilatation of the ascending or transverse colon to more than 6 cm with loss of haustration and with severe disease activity [11]. Approximately 50% of acute dilatations of the colon may be resolved with drug treatments. However, acute colectomy is indicated if drug therapy fails. Perforation is the most dangerous local complication. Although perforation is a rare complication, the high mortality rate of 15% in perforated toxic megacolon must be noted [11].

Stenoses may occur in 5-10% of patients. In this subgroup, a malignancy has to be excluded. Occasionally, anal fissures, perianal abscesses, or hemorrhoids may also occur in cases of ulcerative colitis. However, if pronounced perianal changes are observed, this may be indicative of a Crohn's disease diagnosis. [11]

2.2 Prevalence of IBD

It is estimated that in 2012, approximately 400,000 to 500,000 Germans suffered from IBD: 40% from Crohn's disease and 60% from ulcerative colitis [1]. The prevalence of treated IBD increased by about 4% annually between 2001 and 2010 [2].

IBD may be regarded as a so-called 'disease of affluence'. The prevalence of IBD is observed to be higher in locations with high sociodemographic indices than in areas with low sociodemographic indices. In countries that are increasingly adopting Western lifestyles, IBD appears to be becoming more prevalent. For example, in China, the number of cases of ulcerative colitis quadrupled between 1981 and 1990 as well as 1991 and 2000 [13].

Genetically determined predispositions and various environmental factors, such as smoking, excessive antibiotic use, and excessive hygiene, are both likely contribute to the development of the disease (see Table 1) [1,11,14]. In Caucasian populations, smoking is an important risk factor for IBD, displaying opposite effects on ulcerative colitis (odds ratio: 0.58) and Crohn's disease (odds ratio: 1.76). In 25% of patients, there is an underlying immunodeficiency. Children who received at least one course of antibiotics in their first year of life have a higher risk of developing IBD during childhood by a factor of 2.9 [11].

Furthermore, an individual's diet may contribute to the development of IBD, whereby diets that are high in animal protein, sugar, sweets, oils, fish and shellfish, and dietary fats increase the risk of developing IBD. Vitamin D has been shown to have a protective effect against Crohn's disease [11].

Table 1 Epidemiology of inflammatory bowel disease

	Ulcerative colitis	**Crohn's disease**
Prevalence (Germany), 2010	327 / 100,000	277 / 100,000
Age peak	10-40 and 60-90 years	10-50 and 60-90 years
Ratio women : men	0.51-1.58	0.34-1.65
Smoking	Can prevent (odds ratio 0.58)	Can increase (odds ratio: 1.76)
Oral contraceptive	No impact	Hazard ratio: 2.82
Appendectomy	Can reduce risk (risk reduction 13-26%)	No impact
Antibiotic use in the 1st year of life	2.9x risk in childhood	2.9x risk in childhood
Identical twins	6-18% concordance	28-58% concordance
Non-identical twins	0-2% concordance	4% concordance

Source: Harrisons Innere Medizin 2020 [11]*, Prevalence Germany: Stallmach 2012* [1]

The female-to-male ratio ranges from 0.51-1.58 in ulcerative colitis studies and 0.34-1.65 in Crohn's disease studies, indicating that the diagnosis is relatively non-gender-specific [11]. With respect to age prevalence, while Crohn's disease may occur at any age, most cases may be observed in patients between the ages of 10 and 40. Pediatric patients account for 20-25% of all patients with IBD [11]. In ulcerative colitis, the peak age of onset is between the second and fourth decade of life, with a second lower peak around the sixth decade of life.

Severe courses (here defined as courses requiring the prescription of immunosuppressants or bowel surgery) occur particularly frequently in young patients, especially up to the age of 20 (see Figure 1). This is in line with observations of the inflammatory activity, pain, and impairments in quality of life being significantly more pronounced in young patients. Inflammatory activity often decreases throughout one's life, and those who first develop the disease at an older age have milder courses on average than those who develop the disease at a younger age [1].

Figure 1 illustrates the age distribution of patients with ulcerative colitis or Crohn's disease with a severe progression. Overall, a negative relationship may be observed between the patient's age and the severity of IBD progression. Between 2008 and 2010, patients below the age of 20 were seen to be the highest risk group. This is seen by 30-35% of ulcerative colitis and 50-55% of Crohn's disease patients with a severe progression being within this age group [1]. The proportion of patients with severe progression declines steadily as age increases, with patients over the age of 80 making up only approximately 5% of all IBD cases tested. From 2008 to 2010, the proportion of severe progression observed within each age category either increased or remained constant, except in the 60-79 and 80+ age groups of ulcerative colitis patients, where a slight decline was observed in 2009 [1].

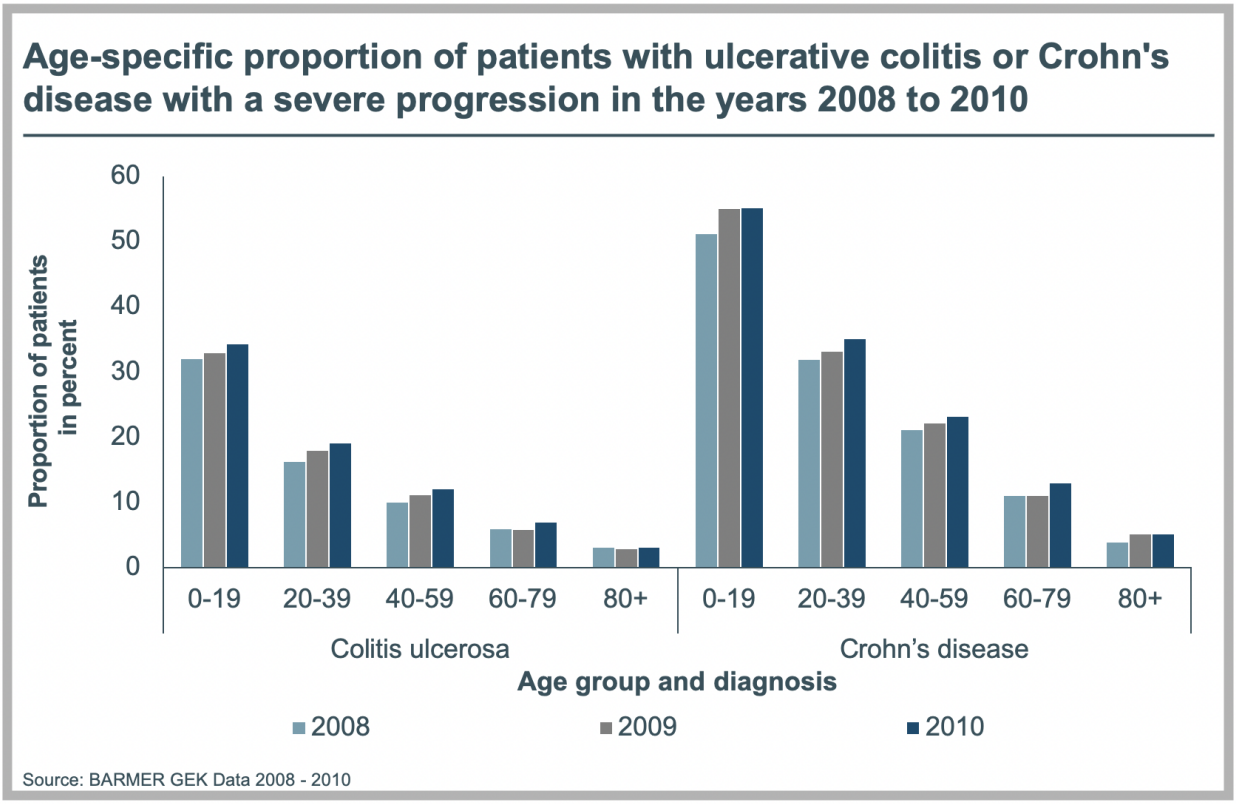

Figure 1 Severe IBD by age group 2008 to 2010

The above bar graph illustrates the proportion of patients within specified age groups presenting with severe progressions of both ulcerative colitis and Crohn's disease. Bars within each age group indicate data from 2008, 2009, and 2010 respectively (left to right).

Source: Barmer GEK Daten 2008–2010 [1]

2.3 Hospital financing in Germany

The German hospital financing system is made up primarily of two main components: operating and investment costs [6]. As shown in Figure 2, the most significant of the two are the operating costs, which made up approximately 97% of the total costs between 2016 and 2018. Investment costs are financed by federal states and comprise either individual funding schemes for specific projects (such as the construction of a new hospital) or lump sum schemes which are usually determined by the number of beds and are utilized for purposes such as replacing short-term assets. Operating costs on the other hand are financed predominantly by statutory and private health insurances and are often based on a case rate (in the case of surgery procedure respective diagnoses), a

fee-for-service (for optional services), or both (for ambulatory hospital care). The compound annual growth rate (CAGR) for investment costs and operating costs are 3.7% and 3.2% respectively.

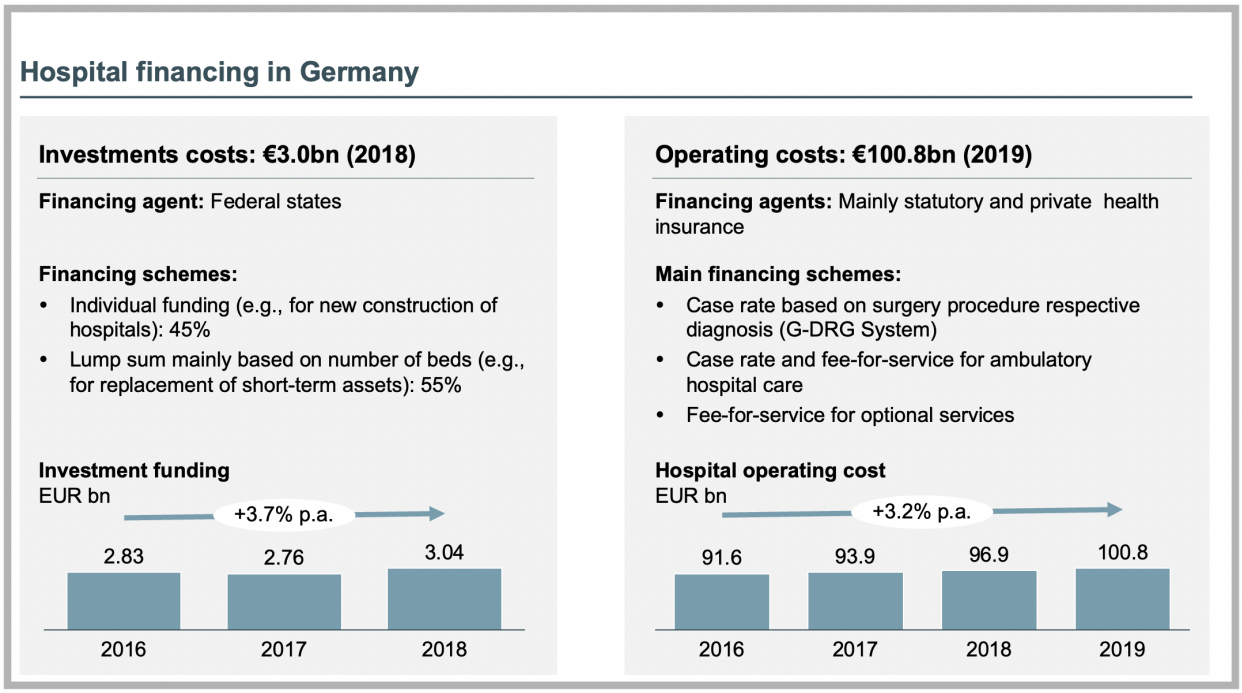

Figure 2 Hospital financing system in Germany

The above figure outlines key components of hospital financing in Germany: investment costs and operating costs. It identifies the key financing agent and financing schemes within each component. The charts at the bottom illustrate the monetary value expensed, in billions of euros, attributable to the relevant component. G-DRG. Investment costs grew at a 3.7% per annum (p.a.) between 2016 and 2018 and operation costs grew at 3.2% CAGR between 2016 and 2019. In 2018 the investment costs accumulated to €3 billion (bn), and the operation costs accumulated to €101bn.

Source: German Hospital Association 2019 [6]

2.3.1 Investment costs

The German Hospital Federation (DKG) survey from 2021 shows that there is a discrepancy between the required investments and the funding actually provided by the states. They found that the investment needs in 2020 amounted to more than six billion euros [15]. However, the states had only borne around three billion euros resulting in an investment backlog. Furthermore, the DKG found that adjusted for inflation, the funding amount has thus almost halved since 1991 [15].

The significant decline in hospital funding is also reflected in the investment ratio calculated for the hospital sector. If the adjusted costs of the hospitals as a whole are used as the reference figure for the KHG subsidies, the investment ratio for the period from 1991 to 2019 decreased from 9.7% to 3.2%. By contrast, the economic investment ratio, which is calculated as the quotient of gross fixed capital formation and gross domestic product, was 21.7% in 2019 and thus exceeded the investment ratio based on the costs of all hospitals by a factor of six (see Figure 3).

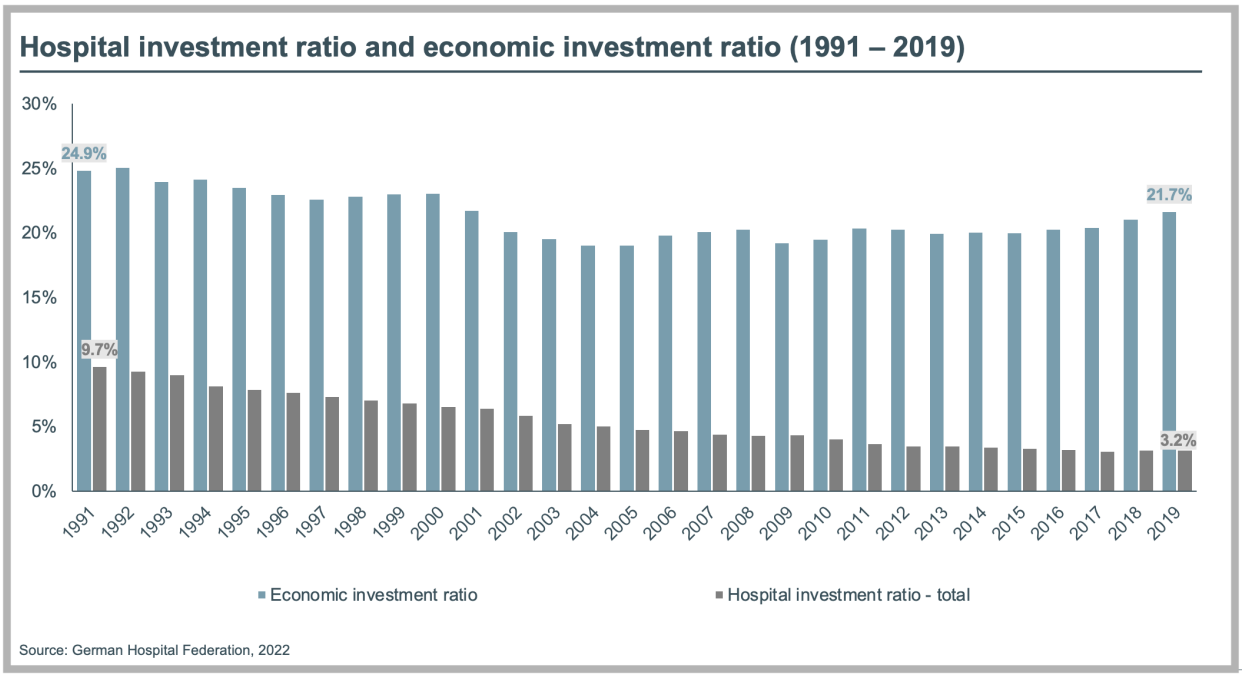

Figure 3 Hospital investment ratio compared to economic investment ratio (1991 - 2019)

This figure outlines the development of the economic investment ratio compared to the development of the hospital investment ratio between 1991 and 2019.

Source: German Hospital Federation, 2022 [15]

2.3.2 DRG system

The concept underlying the DRG systems was developed as a collaborative project of Robert B. Fetter (Yale School of Management) and John D. Thompson (Yale School of Public Health) in the late 1970s. DRG systems are based on the idea of grouping a large number of patients with similar clinical characteristics into a limited number of medically and economically comparable case groups. In 1983 DRGs were first adopted by Medicare in the US, and the length-of-stay charges were replaced by diagnosis-related group charges [16].

The hospital receives a flat-rate remuneration for each patient based on the DRG. This remuneration to some extent disregards the individual costs incurred by the hospital for the specific case. In all DRG systems available today, patients are assigned to mutually exclusive case groups. Therefore, each case, from admission to transfer or discharge, can only be assigned to one DRG. Assignment to a DRG may be determined by the main diagnosis, the type of procedure (operations or interventions), secondary diagnoses or complications, special circumstances (e.g. transplants), and other criteria such as age and gender [17].

Several decades after the introduction of the DRG system, some negative side effects have been uncovered. Milstein and Schreyögg summarize the key criticisms and suggest several reforms in their 2022 paper [18]. The criticisms they identified include: 1) DRG reimbursement systems may lead to provider-induced demand, therefore increasing the number of procedures beyond what is medically appropriate [18,19]; 2) hospitals may favor financially profitable patients or trade off on the quality of care or discharge patients earlier than medically appropriate [18,20,21]; 3) DRG payment systems may lead to wasteful spending when hospitals classify patients as being more ill than they truly are in order to receive higher payments [18,22].

The DRG system is a reimbursement system. Therefore, the aim is to cover costs, not to generate profits.

2.3.2.1 DRG System in Germany

Introduction and purpose of the G-DRG System

In Germany, hospitals are financed on a dual basis by health insurance and the federal states, as seen previously in Figure 2. While the investment funds are covered by the federal states, the non-investment costs are to be funded by payers in a per-case flat rate system, the German-DRG (G-DRG) system [7].

The G-DRG system was introduced in 2003 for the reimbursement of inpatient hospital services. Figure 4 outlines key events in the evolution of the DRG system in Germany over time. Following its introduction in 1993, German hospitals shifted to an Australian DRG system in early 2000. Between 2000 and 2004 the ministry of health permitted hospitals to implement the DRG system on a voluntary basis, with payments being budget neutral for providers. From 2004, all hospitals were required to implement DRG systems for payment, with a transition period to account for the fact that the system was not yet ready for scale-up. Between 2007 and 2010 efforts were made to align DRGs to standardized federal state tariffs that were introduced in 2006. However, this was abolished by 2011, in favor of an “orientation value” based on real cost data due to the limitations of base rate increases. Following union agreement, in August 2013 all DRG lump sums were increased by 1% to fund cost increases. 2016 marked the start of a new 6-year convergence phase to align federal state tariffs under the Hospital Structure Act (KHSG) law. Most recently, in 2020 nursing costs were excluded from the DRG rates, requiring this to be funded out of hospital-specific annual budgets rather than DRG lump sums.

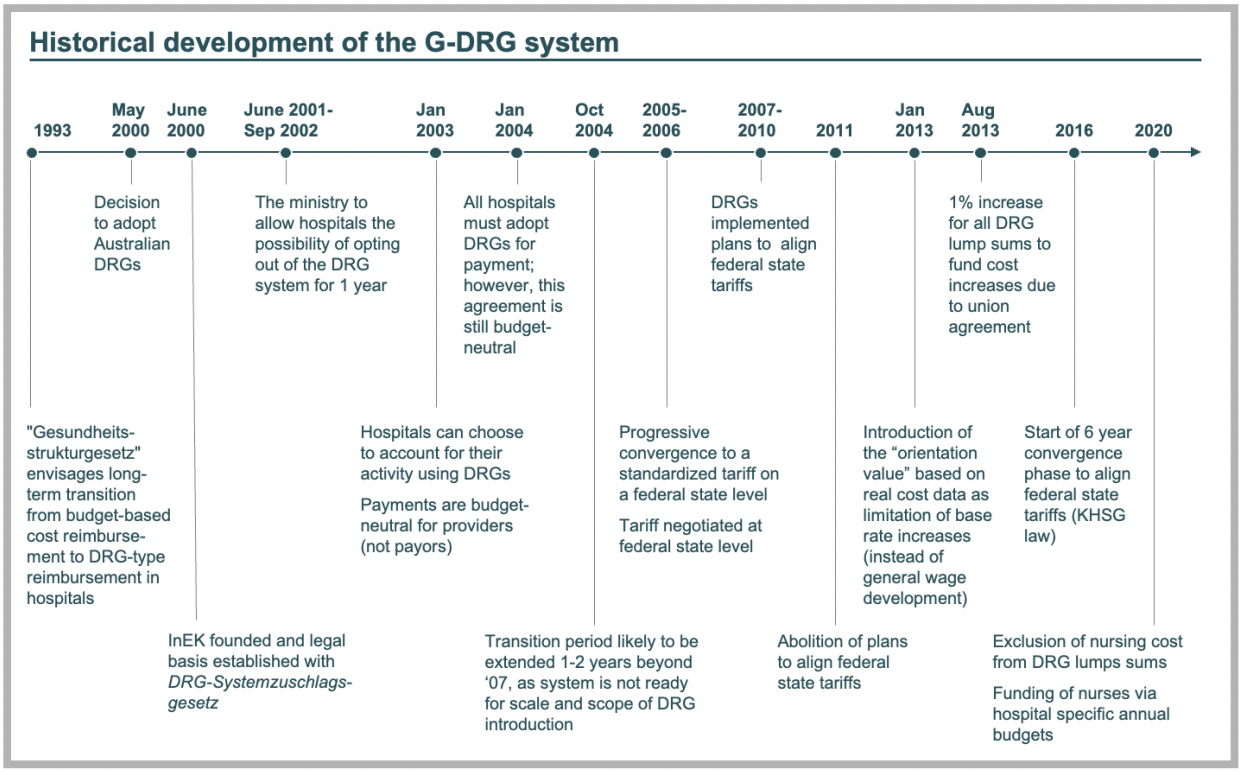

Figure 4 Historical development of the G-DRG system

This figure outlines key developments in the evolution of the German DRG system from its introduction in 1993 to the most recent exclusion of nursing costs from DRG lump sums in 2020.

Source: Hospital Report 2021 [23]

The main objective of the introduction of the G-DRG system was to enable more economical healthcare, greater transparency of hospital services and costs, and stabilization of statutory health insurance expenditures through the realization of efficiency reserves. This was expected to lead to a reduction in the length of stay of patients in hospitals, greater competition between hospitals, and the promotion of structural change. Above all, however, was the principle that "money follows performance" [24].

Figure 5 shows key hospital market metrics indexed in 2003, when the G-DRG system was first introduced. It demonstrates that between 2003 and 2019, the average length of stay decreased, and the number of cases increased, leading to reduced bed and hospital capacities. However, rising cases only partially explain the increase in hospital expenditures; prices (see Figure 6) are a driver for expenditure development.

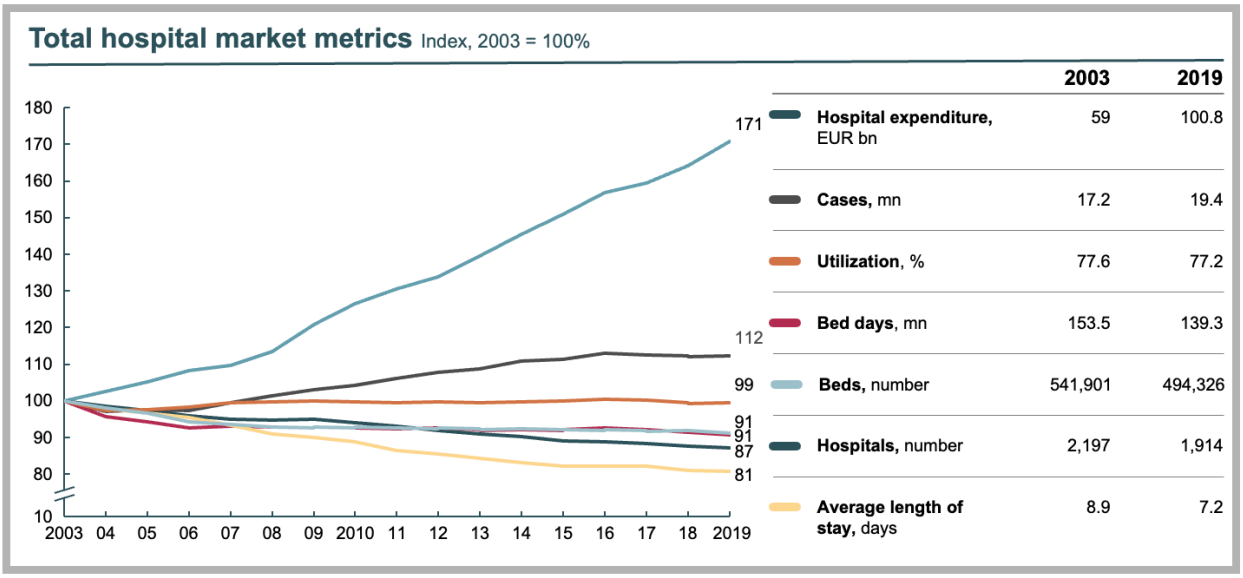

Figure 5 Overview of hospital market metrics

Figure 5 provides an overview of hospital market metrics between 2003 and 2019, with 2003 as the base year. The upper line shows the development of the total hospital expenditure from 2003 to 2019; in 2019, the total hospital expenditure was EUR 100.8bn, which is 71% higher than in 2003.

Source: German Federal Statistical Office 2022 [25]

In a per-case flat rate system based on Section 17b of the KHG, patients are classified into diagnosis groups based on their principal diagnosis and other medical characteristics. The diagnosis groups are intended to reflect the financial resource intensity of the specific case [3,4,26]. In 2019, there were 1318 DRGs in Germany [27]. The flat rates per case are based on cost data from calculations by the Institute for Hospital Remuneration (InEK). The remuneration from flat rates per case and additional charges are intended to cover all operating costs required for the clinical treatments that are incurred during a patient's length of stay, including personnel costs, material costs, and infrastructure costs (§ 17b KHG) [29].

Annually, a relative weight (*Relativgewicht)* per DRG is determined as well as a base flat rate (*Basisfallwert)* for each state (*Landesbasisfallwert).* To determine the reimbursement per case, the relative weight is multiplied by the base flat rate, following which surcharges and deductions are applied. The federal state base rates have increased over

time (see Figure 6). Figure 6 illustrates the convergence of the federal state base rates, followed by an increase in this rate across all federal states. The base rates of the federal states are negotiated based on a nationwide corridor. In 2019, the base flat rate varied between €3528.50 for Schleswig Holstein and €3683.97 for Rheinland Pfalz, demonstrating a federal corridor of around €155.47 [30]. As of 2020, this corridor narrowed to approximately €130.

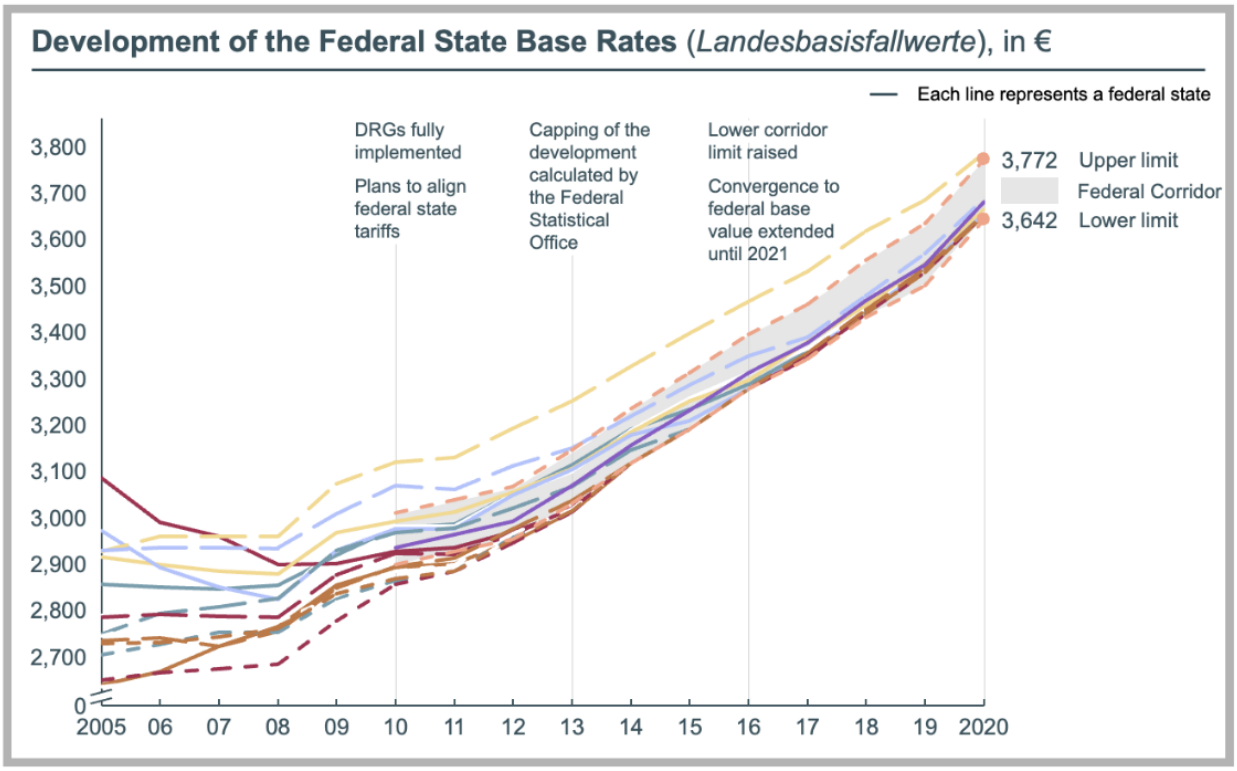

Figure 6 Development of Federal State Base Rates 2005-2020

The above graph illustrates the development of the Federal State base rates over time. Following the full implementation of DRGs in 2010, plans were formulated to align tariffs across federal states. The Federal Corridor, calculated as the difference between the upper and lower base rate limits, and seen by the shaded grey area in the graph, has narrowed over time

Source: National Association of Statutory Health Insurance Funds [30,31]

Every year, the system is adapted, with amendments coming into effect the following year, to account for any changes in the hospital system. The aim is to ensure that all inpatient services may be covered by this flat-rate payment system in a manner that is appropriate to the services provided. Calculation hospitals (*Kalkulationskrankenhäuser*) provide the actual cost data gathered for each case, as well as additional charges (*Zusatzentgelte*). In 2019, 282 hospitals submitted their data to the InEK representing approximately 20% of all cases that occurred across DRG hospitals [32].

G-DRG composition

Each DRG is assigned in an alphanumeric code comprising four digits. Figure 7 summarizes the composition of this DRG code. The first three digits of the DRG are referred to as the base DRG and provide information about the diagnostic category and the partition. Specifically, the first digit describes the primary diagnosis or the major diagnostic category. The second and third digits refer to the partition, which identifies the type of treatment. This may be surgical, medical, or other. The fourth and final digit indicates resource consumption. Some of the factors influencing resource consumption include Patient Clinical Complexity Level (PCCL), age, length of stay, ventilation, reason for discharge, primary diagnosis, secondary diagnosis, and specific procedures (see Figure 7) [33].

Furthermore, the length of stay above or below the maximum or minimum length of stay influences the reimbursement, as well as transfers and additional charges.

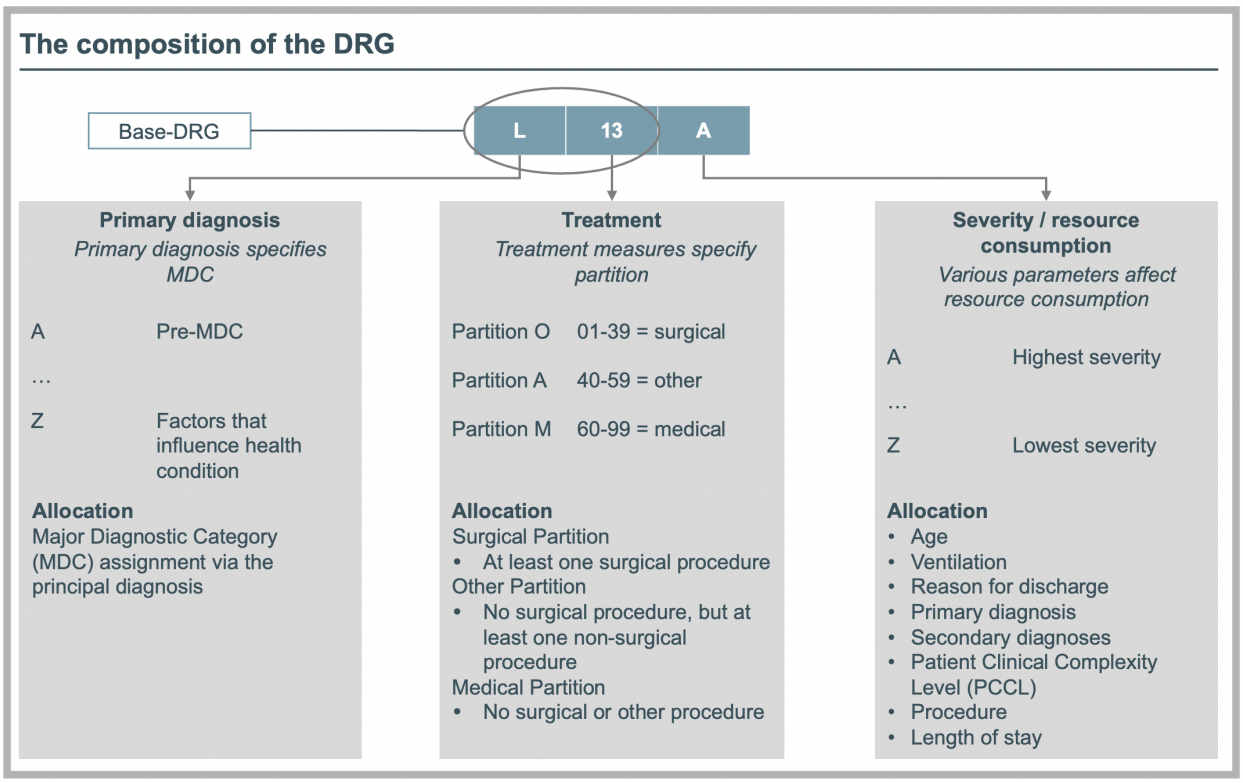

Figure 7 Definition of diagnosis-related groups in Germany

The composition of the four-digit alpha-numeric DRG code depends on the primary diagnosis, treatment measures, and resource consumption. Resource consumption is defined by several factors including reason for discharge, PCCL, and length of stay.

Source: Reimbursement Institute [33]

G-DRG Transfer deduction

The transfer deduction is a reduction (*Verlegunsabschlag*) in DRG reimbursement that takes effect in the event of a patient being transferred. A transfer is defined as a case in which less than 24 hours pass between discharge and admission to the new hospital. In the event of a transfer, each hospital that is involved in the patient's case bills according to the DRG. However, the flat rate per case is discounted depending on the patient's length of stay in the specific hospital. [34] Depending on the length of stay, the transfer deduction is applied (see Figure 8).

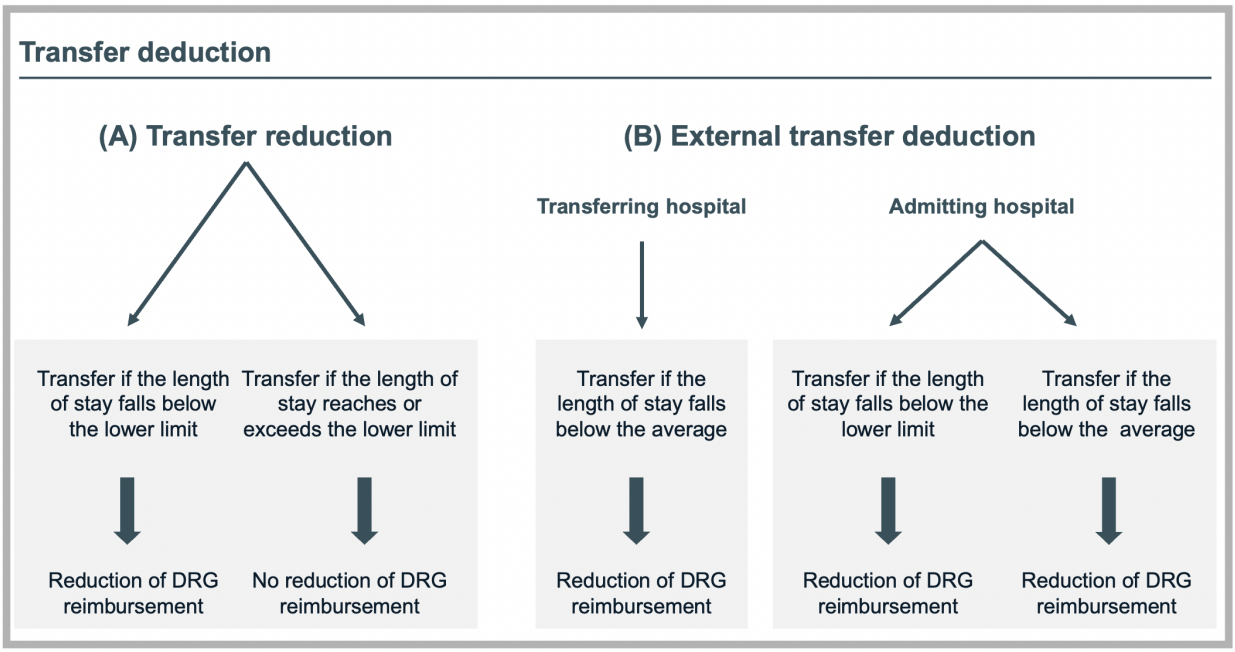

Figure 8 Transfer deduction based on length of stay

The transfer deduction is determined by two main factors. First, it must be differentiated whether the flat rate per case is (A) a transfer flat rate per case or (B) a flat rate with an external transfer discount. In the case of the latter, an additional distinction must be made as to whether the calculation is made from the perspective of the transferring or the admitting hospital.

Source: Reimbursement institute, 2022 [35]

2.3.2.2 DRG System in other countries

Austria

In Austria, the DRG system – the performance-oriented hospital financing (*Leistungsorientierte Krankenanstaltenfinanzierung*) – was introduced in 1997. It includes both a geographic component and a type of care component. Austria differentiates between four different types of care:

- Centralized care provision (e.g., a large university hospital),
- Specialized care focus (e.g., a large hospital with many departments),
- Specialized professional care functions (e.g., an orthopedic hospital)
- Specialized regional care functions (e.g., hospitals in tourist regions of the Alps) [36]

Every state defines factors for each type of care. For example, Steiermark assigns a factor of 1.3 to the per-case flat rates for its university hospitals and a factor of 1.05 to the per-case flat rates for its focus-care hospitals. Tirol chooses an additional factor of 1.2 for its university hospitals [37].

United Kingdom

The United Kingdom pays surcharges to small hospitals based on "unavoidable smallness due to remote location" and takes into account a market forces factor, which is intended to compensate hospitals for unavoidable costs beyond their control [38]. Five factors enter into the weighting of the market forces factor: non-medical staff, medical staff, land costs, building costs, business costs, and other factors [39].

Furthermore, the United Kingdom also introduced the best-practice tariffs in 2011, differentiating between a basic tariff, which a hospital receives for the normal treatment of patients, and the higher best-practice tariff, for the additional fulfillment of defined quality parameters. The targets are set by the National Health Service (NHS) in conjunction with the relevant professional societies. The link between financial incentives and the quality of treatment is intended to promote the implementation of the guidelines, and thus improve the quality of treatment [40].

In addition, the United Kingdom finances outpatient and inpatient surgery identically, aiming to replace per-case payments with a combination of budgets and quality-based remuneration. Clinical Commissioning Groups have already changed their remuneration from flat rates to annual budgets. According to them, flat rate systems do not have the right incentive structure to achieve their goals [41]. In 2019, England announced a deviation from DRGs in its NHS Long-Term Plan [41]. As of 2022, England is shifting to a reimbursement system consisting of three building blocks: (1) a variable component largely based on DRGs, (2) a quality-related component, and (3) a fixed payment. Furthermore, England has organized its healthcare providers into 42 Integrated Care Systems, which are supposed to come together to plan and deliver harmonized health and care services. These Integrated Care Systems now determine which combination of the reimbursement block is appropriate for their region.

2.4 Inpatient Treatment in Germany

In 2019, there were 1914 hospitals in Germany with a total of 494,326 beds available for the treatment of 19.4 million patients [25,42,43]. The majority of hospitals in Germany are small to medium-sized. As shown in Figure 9, around 70% of hospitals have less than 300 beds, 25% have between 300 and 799 beds, and 5% of hospitals have more than 800 beds. Out of the 96 hospitals that have more than 800 beds, 36 hospitals are university hospitals. As per Figure 9, the 96 largest hospitals which hold over 800 beds account for 24% of the total beds available in Germany. Conversely, the smallest 652 hospitals hold only 5% of the total beds in the country [25].

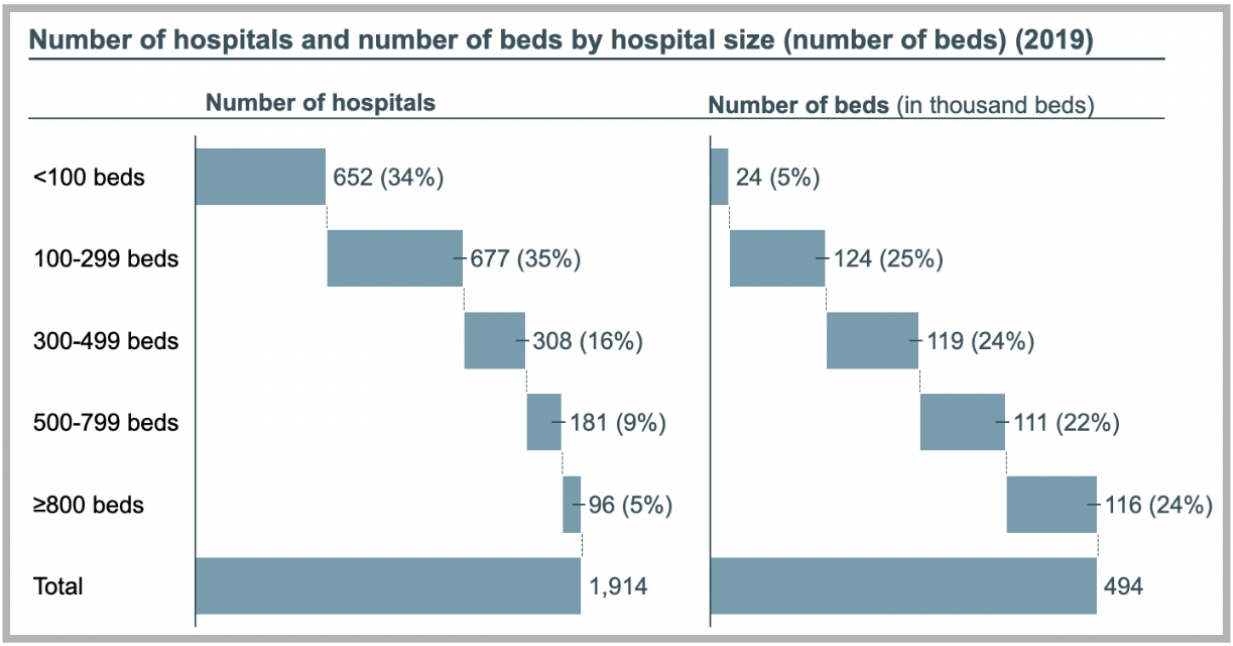

Figure 9 Number of hospitals and number of beds by hospital size

Figure 9 illustrates (1) the number of hospitals classified by the number of beds they hold (left-hand side), and (2) the number of beds classified by the hospital size (right-hand side). For example, out of the total 1,914 hospitals in Germany in 2019, 5% (96 hospitals) had over 800 beds. These 96 hospitals house 24% of the total 494,326 beds available for treatment in the same year (corresponding to 116,000 beds).

Source: German Federal Statistical Office 2022 [25]

Compared to other EU countries, Germany has a high number of hospital beds per inhabitant. This is seen by the presence of 6 hospital beds per 1000 inhabitants in Germany, compared to only 2.1 hospital beds per 1000 inhabitants in Sweden for example. While Germany's number of general practitioners per inhabitant is lower than in France or Switzerland, it is higher than in Denmark, UK, and Sweden. Furthermore, the number of medical specialists per inhabitant is high, seen by there being 1.39 medical specialists per 1000 inhabitants in Germany, compared to just 0.99 in Sweden or 0.79 in France. These comparisons are illustrated in Figure 10 below.

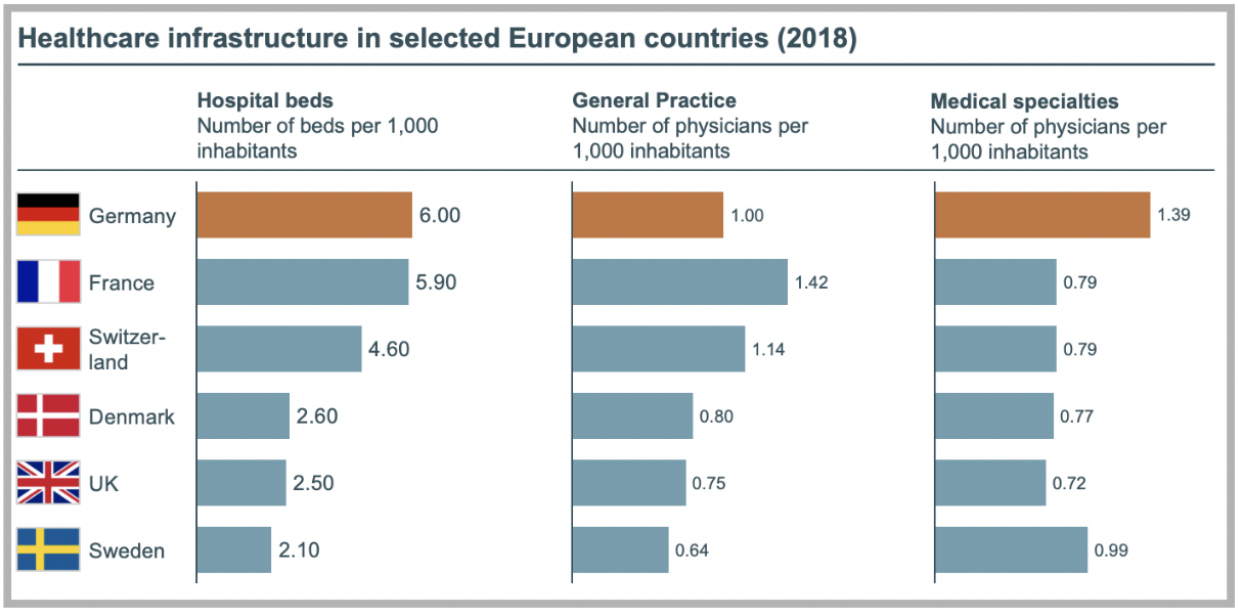

Figure 10 Healthcare infrastructure in selected European countries (2018)

The number of hospital beds, general practitioners, and specialized physicians per 1000 inhabitants varies across different European countries. Germany has an especially high number of hospital beds and specialty physicians compared to its peers. It is also above the average in this sample of general practitioners per 1000 inhabitants.

Source: OECD 2022 [44]

Demand planning in Germany is carried out separately for outpatient and inpatient capacities. Outpatient demand planning is based on doctor-patient ratios determined throughout the country which are set for various specialties. Inpatient planning is carried out at the federal state level with each state drawing up a hospital plan [45].

In line with the high number of hospital beds per inhabitant in Germany, Klauber et al. found that for planned admission cases, many procedures currently performed as inpatient treatments may also be provided as outpatient treatments [23]. Furthermore, Gerlach et al. suggested that performance management can be implemented by linking the allocation of outpatient clinics and hospital beds to the provision of a specific range of services, thereby improving medical and economic outcomes [45].

In Germany, healthcare expenditure has been growing constantly over the past 50 years. As shown in Figure 11, the total expenditure increased by 177% between 1992 and 2020.

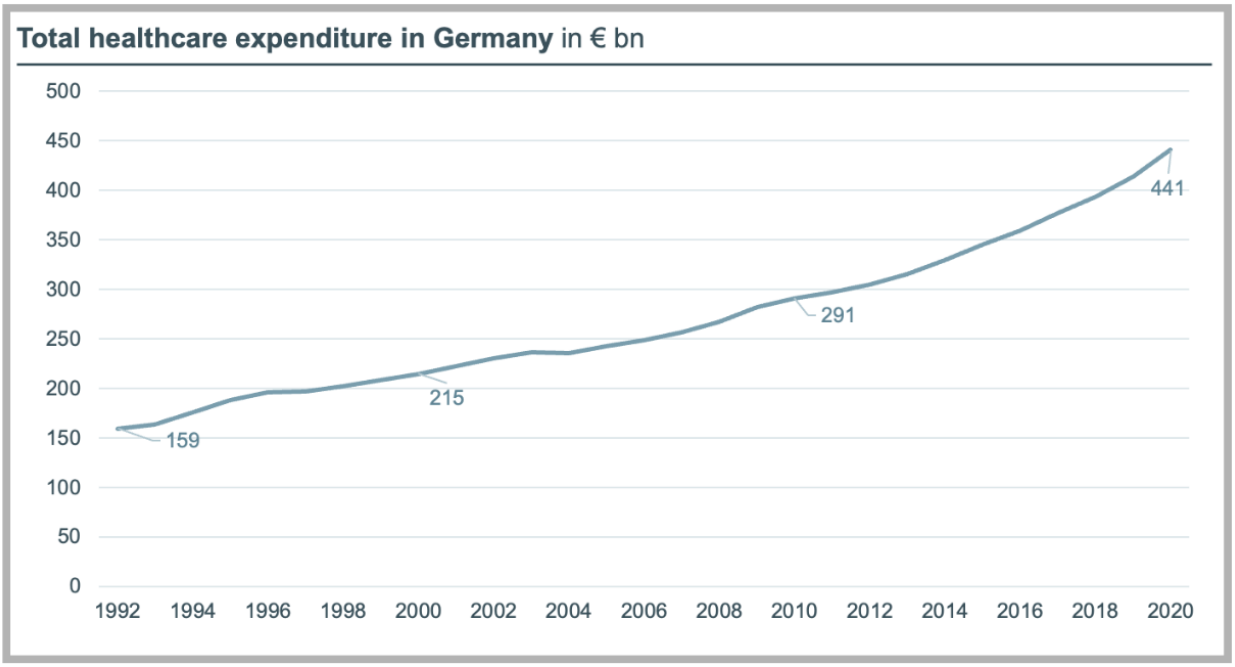

Figure 11 Total healthcare expenditure in Germany 1992-2020

Total healthcare expenditure in billions of euros in Germany has consistently increased over the last 40 years. Expenditure in 1992 stood at approximately €159 bn, and this reached around €441 bn by 2020.

Source: German Federal Statistical Office 2022 [46]

The financial conditions of German hospitals have been deteriorating, as costs are rising faster than revenues; this decline is visualized in Figure 12. In 2012 we can see a drop in the number of hospitals booking surpluses from 68% to 43%. Specifically, the number of hospitals booking deficits increased significantly, from 21% to 51%. From 2012

to 2016, we observe a slight increase in the number of surpluses, and conversely a decline in deficits. However, from 2016 onwards, the hospitals generating surpluses once again declines, reaching levels close to those seen in 2012 by 2019. This indicates a serious risk of insolvency, with public and charitable hospitals being affected worse than privately held ones [47].

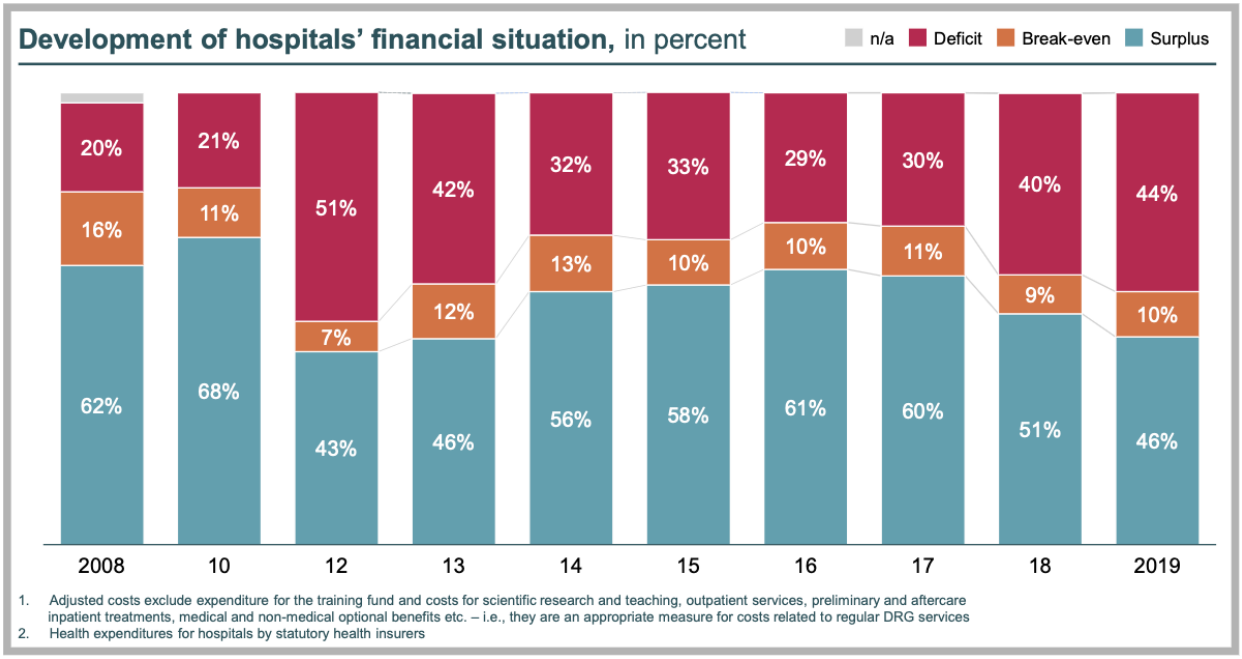

Figure 12 Development of hospitals' financial situation 2008-2019

The trend in hospitals generating financial deficits illustrates a significant deterioration in 2012, followed by a slight recovery until 2016. This once again began worsening from 2017 onwards. Costs captured in this graph are related to regular DRG services. As such, they exclude costs pertaining to training, scientific research, teaching, outpatient services, preliminary care, aftercare, inpatient treatment, and medical and non-medical optional benefits.

Source: RWI Hospital Rating Report, 2020 [47]

The growth of healthcare expenditure relative to GDP was largely driven by distinct political events in the last few decades. As shown in Figure 13, long periods of sustainable expenditure growth have been demonstrated, with previous deliberate political decisions inducing abnormal expenditure growth.

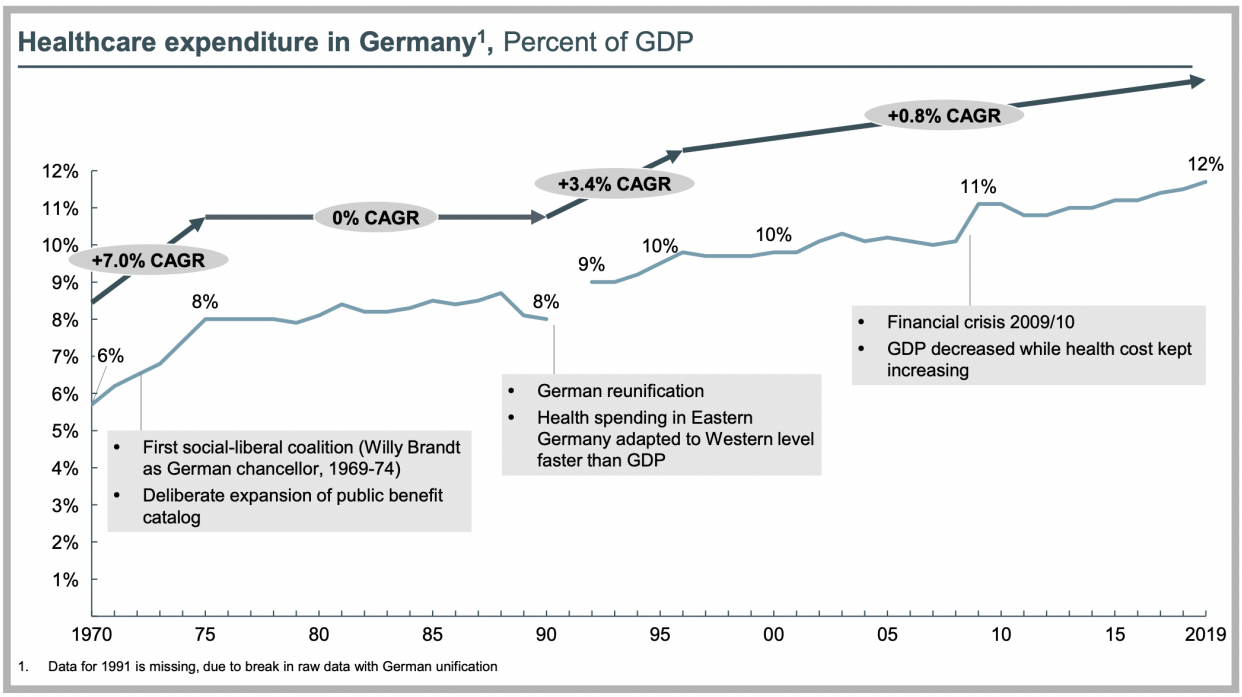

Figure 13 Healthcare expenditure in Germany as a fraction of GDP

The above graph shows healthcare expenditure as a percentage of GDP, and the compound annual growth rates of healthcare expenditure in Germany, for selected periods between 1970 and 2019. The high CAGR of 7% in the first 5 years was stimulated by a deliberate expansion of the public benefit catalog under German chancellor Willy Brandt. A gap in the data is observed in 1991, attributable to the German unification, during which time health spending in East Germany adapted to Western levels faster than GDP. This resulted in a 0% CAGR. The 2009 global financial crisis resulted in a drop in GDP. However, healthcare costs continued to rise, resulting in higher healthcare expenditure as a percentage of GDP, reaching 12% by 2019.

Source: German Federal Statistical Office 2022 [46,48]

2.5 University hospitals

University medicine is shaped by the interconnected tasks of research, teaching, and healthcare. These three tasks are pursued in an organizational construct consisting of a medical faculty and a university hospital. Fourteen out of the 20 largest hospitals in Germany are university hospitals (see Figure 32).

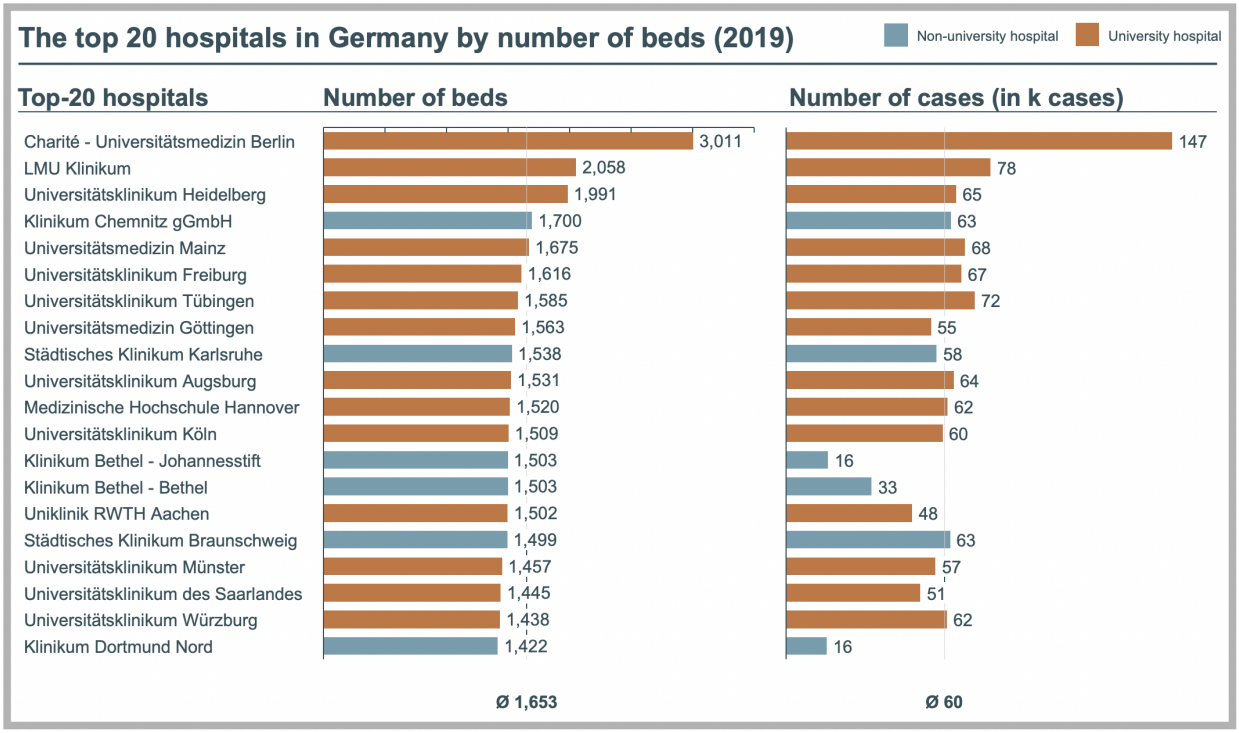

Figure 14 Top 20 hospitals in Germany by size

Fourteen out of the largest 20 hospitals by number of beds in Germany are university hospitals. On average, the 20 largest hospitals have 1653 beds and 60 thousand (k) cases. The Charité held 3,011 beds and housed the largest number of cases for a single hospital in the top 20, amounting to approximately 12% of the total cases in 2019 (147,000 out of the total 1,205,000).

Source: Hospital quality reports 2019 [49]

In 2019, there were 1914 hospitals out of which 36 were university hospitals, yet university hospitals provide care for about 10% of all inpatients. Additionally, Figure 15 shows that university hospitals require 1.4 times the number of nurses and 2 times the number of physicians per case.

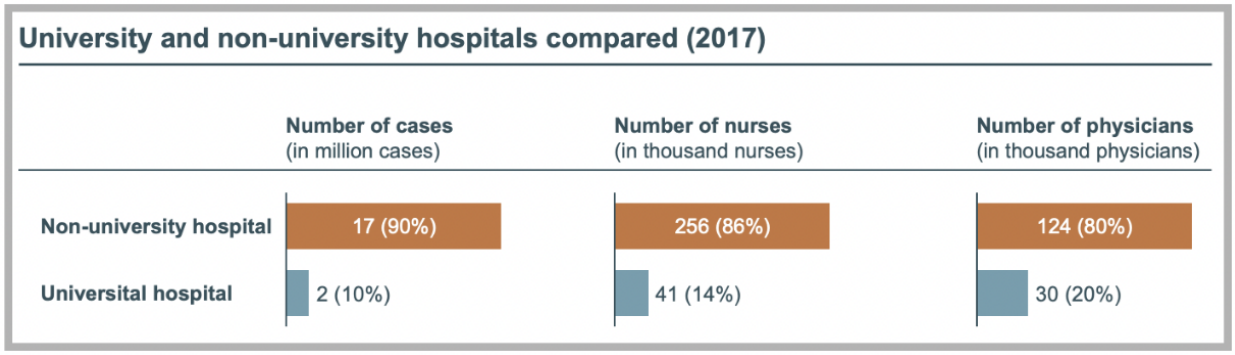

Figure 15 University hospitals and non-university hospitals compared

University hospitals make up 10% of all cases, 14% of all nurses, and 20% of all physicians. Given this, university hospitals require 1.4 times as many nurses and 2 times as many physicians as other hospitals.

Source: German Federal Statistical Office [25]

Lerch et al. compared the reimbursement situation of university and non-university hospitals; they found that 67% of university hospitals incur a financial loss, compared with 29% of non-university hospitals [9]. Furthermore, the aggregated annual losses of university hospitals rose from €73 million in 2015 to €544 in 2020 after adjusting for federal state subsidies. Without considering federal state subsidies, university hospitals' losses amounted to €952m [10].

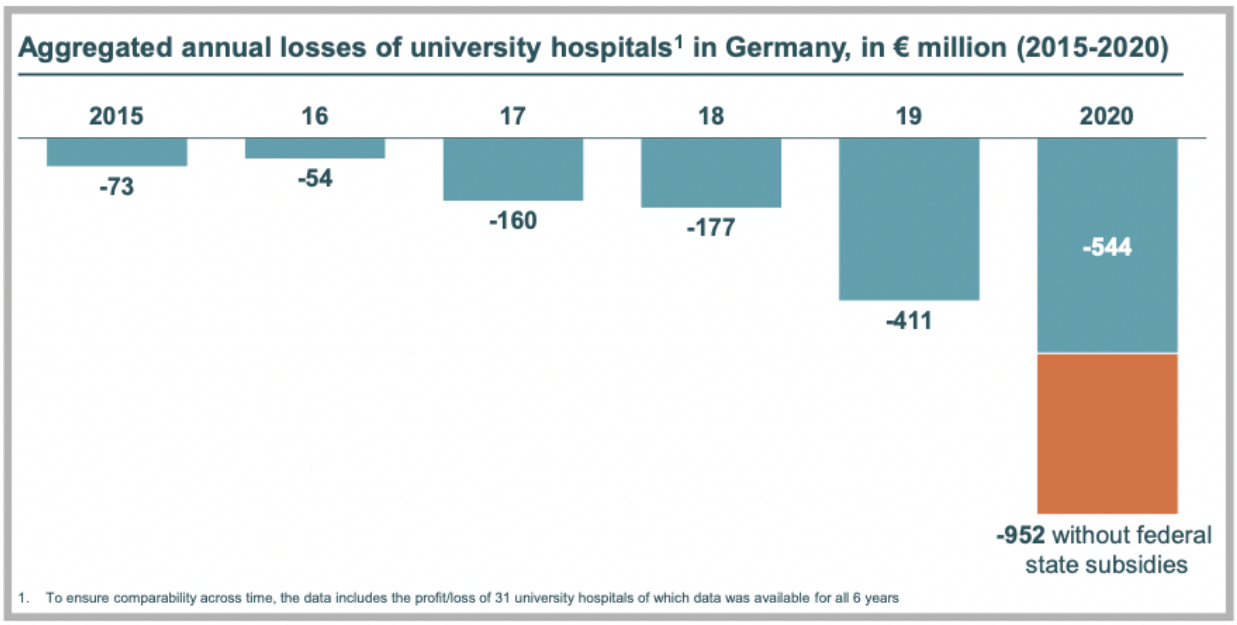

Figure 16 Aggregated annual losses of university hospitals 2015-2020

While losses were slightly reduced in 2016 compared to the previous year, aggregated annual losses of the 31 university hospitals included in this sample increased substantially from 2016 to 2020. Federal state subsidies offset approximately 57% of the total pre-subsidy loss in 2020 and amounted to around €408 million.

Source: Association of German university hospitals, 2020 [10]

University hospitals face several challenges with regard to DRG reimbursement. Figure 17 outlines some service areas that are disproportionately provided by university hospitals. These include extreme cost cases, emergency care, innovation, research, and education. These services are described in more detail below.

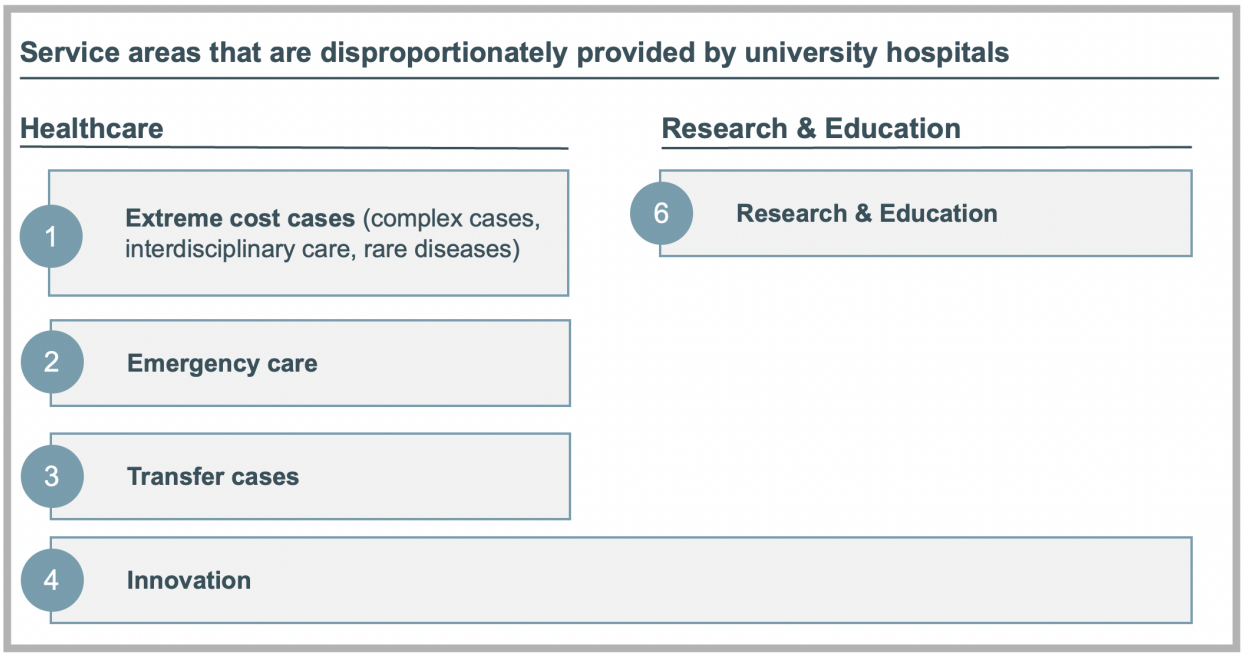

Figure 17 Overview of challenges faced by university hospitals

University hospitals face several challenges pertaining to the provision of certain services disproportionately to non-university hospitals. These services fall into the two categories of healthcare and research & education.

Source: German University Medicine, 2014 [50]

2.5.1 Extreme cost cases

While smaller hospitals may choose to specialize and reject certain patients, university hospitals are the ultimate providers and therefore cannot turn patients away, thereby needing to provide for all patients alike. University hospitals have a significantly larger share of extreme-cost cases, which include complex cases, interdisciplinary care, and rare diseases. Their care requires expensive, advanced infrastructure. The corresponding additional costs are not adequately covered by a normal DRG per-case flat rate, which is set as a mean value calculation [51].

Rathmayer et. al found that the costs for straightforward and standardized procedures such as gastroscopy, recto sigmoidoscopy, and several other procedures do not differ measurably between non-university and university hospitals. For certain examinations or procedures, university hospitals even perform more cost-effectively (e.g., balloon enteroscopy). It is notable that the more complex or high-risk the procedure is, or the more frequently it is performed as an emergency, the greater the financial loss (up to 25%) [43].

The reimbursement of inpatient gastroenterological cases was investigated within the framework of the DGVS's DRG project. Gundling et al. analyzed the reimbursement situation of cases with liver cirrhosis. They found that, in contrast to patients with cirrhosis in general, patients with hepatic encephalopathy are not treated in a cost-covering manner [8].

Every year, the InEK conducts an extreme costs report. In the extreme cost report 2021, the InEK found that extreme cost cases are disproportionally more common at university hospitals than non-university hospitals [52]. Overall university hospitals cover about 10% of all cases. For general care extreme-cost cases, university hospitals cover 21% of cases; while for specialized care extreme cost cases, they cover 43% (see left side of Figure 18).

It is important to note that extreme-cost cases can be either very low or very high in cost. As shown in Figure 18, university hospitals are significantly unprofitable with regards to extreme-cost cases, while non-university hospitals are generating profits on this classification of cases (see right side of Figure 18).

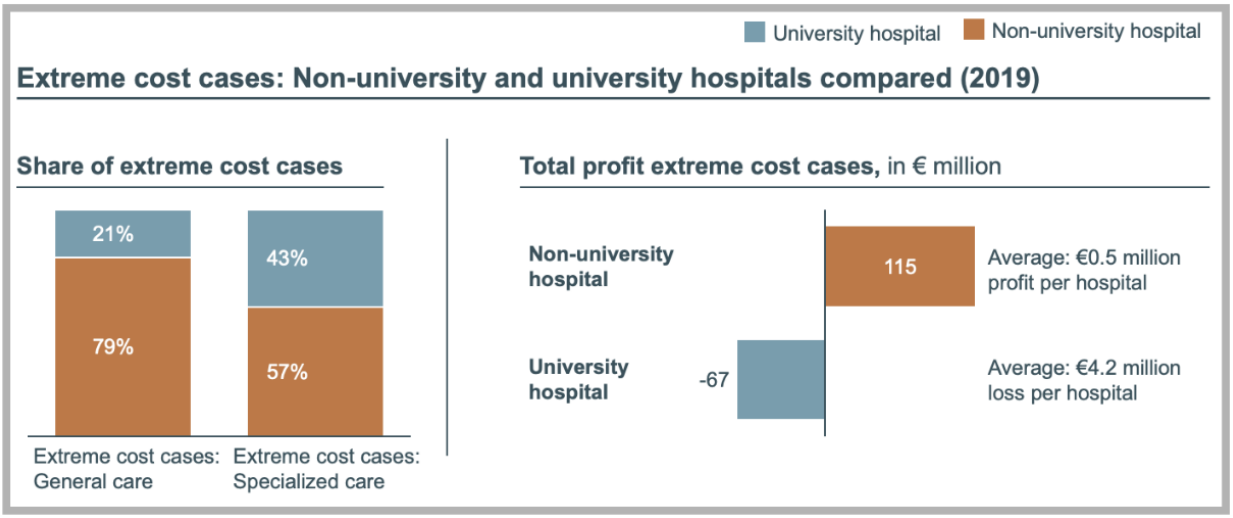

Figure 18 Extreme cost cases: non-university and university hospitals compared

For the extreme cost report, data from 279 hospitals were utilized. For analysis purposes, the 13 university hospitals were grouped with 3 large maximum-care hospitals into one group, the results of which were then compared with the remaining hospitals.

The left side of the figure illustrates the share of extreme cost cases (general care and specialized care) attributable to both university and non-university hospitals; university hospitals account for 21% of general care and 43% of specialized care extreme cost cases. The right side of the figure identifies the total profit generated by extreme cost cases in € millions. While the sampled non-university hospitals generated €115 millions (mn) profits in 2019, the sampled university hospitals incurred a €67mn loss in the same year.

Source: Extreme cost report 2021 [10,52]

Extreme-cost care patients are transferred to university hospitals for several reasons including specialized medical expertise, complex diagnosis and therapy, complex medical equipment, interdisciplinary knowledge, severe complications, innovative medical procedures, and other reasons. The most common reason, accounting for 54% of all cases was for the patient to receive specialized medical expertise [53].

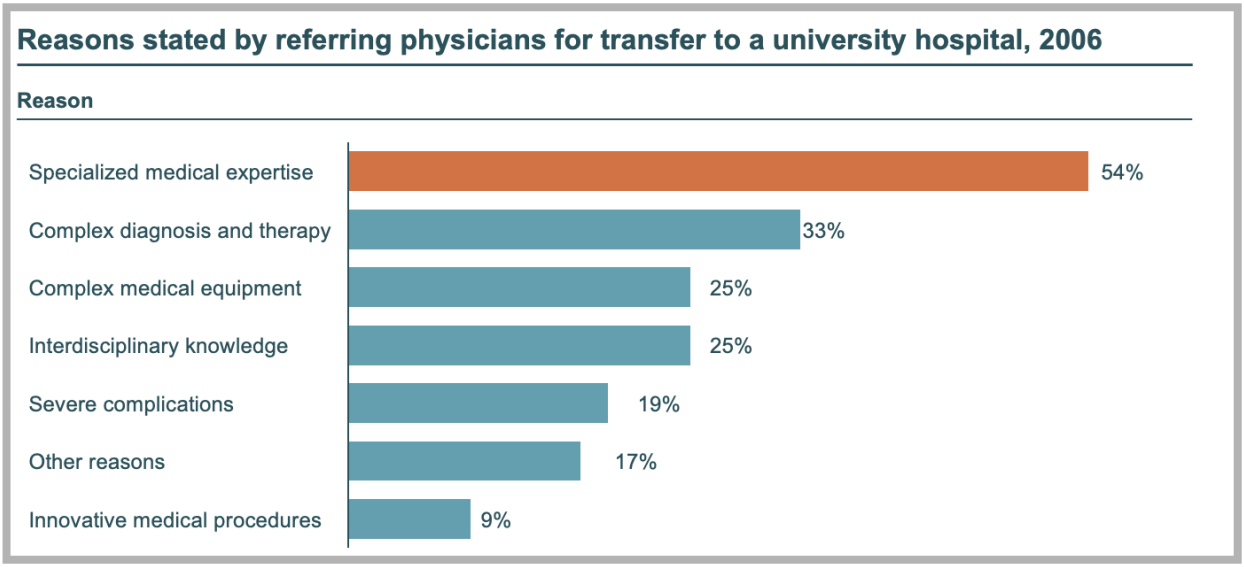

Figure 19 Reasons for transfer to university hospitals

The predominant reason physicians transfer patients to a university hospital is for specialized medical expertise, accounting for 54% of transfer cases. Other reasons include complex diagnosis and therapy, complex medical equipment, interdisciplinary knowledge, severe complications, innovative medical procedures, and other reasons. Transfers for the purpose of access to innovative medical procedures made up the smallest number of cases, accounting for only 9% of cases.

Source: Specialized outpatient care in hospitals, 2006 [53]

Interdisciplinary care

Interdisciplinary care is characterized by collaborative diagnosis. The development of a therapy plan by a team of specialists from different disciplines is another central component of interdisciplinary care. In addition, outreach by university centers, i.e., networking with physicians at private practices and other hospital providers, is provided as needed. Through this cooperation, new treatment methods spread quickly outside of university medicine. The range of tasks performed by these interdisciplinary healthcare centers is associated with a significant amount of additional work. However, although legal regulations for interdisciplinary healthcare centers provide for the negotiation of surcharges with the health insurance companies, the justified financial claims of the university hospitals are usually not met [10].

Outpatient

The outpatient clinics at the university hospitals are contact points for patients who have been unable to find a clear cause and therapy for their symptoms with their general practitioners or specialists. Many diagnostic steps, and specialized expertise, are often required for clarification. University outpatient clinics are predestined for cases that require methods beyond routine medical practice and interdisciplinary experience. Here, the entire medical service spectrum of the university hospitals can be called upon as needed. Patients find comprehensive diagnostics and therapy. If necessary, they are cared for jointly by an interdisciplinary team of specialists from a wide range of disciplines. In particular, for people with complex and rare diseases, such contact points are indispensable. In addition, disease patterns and therapies are researched, and future doctors are trained in university outpatient clinics [54].

2.5.1.1 Rare disease

The rarer a clinical presentation, the more likely it is that there will be no consensus classification and documentation, and therefore that it will not be appropriately represented in the DRG system. It is also more likely that it will be treated primarily in a university hospital [50]. The German hospital report from 2015 compared the special consultation hours of university hospitals and non-university hospitals for selected rare disease consultation hours and found that university hospitals cover the majority of special consultation hours (see Figure 20) [54].

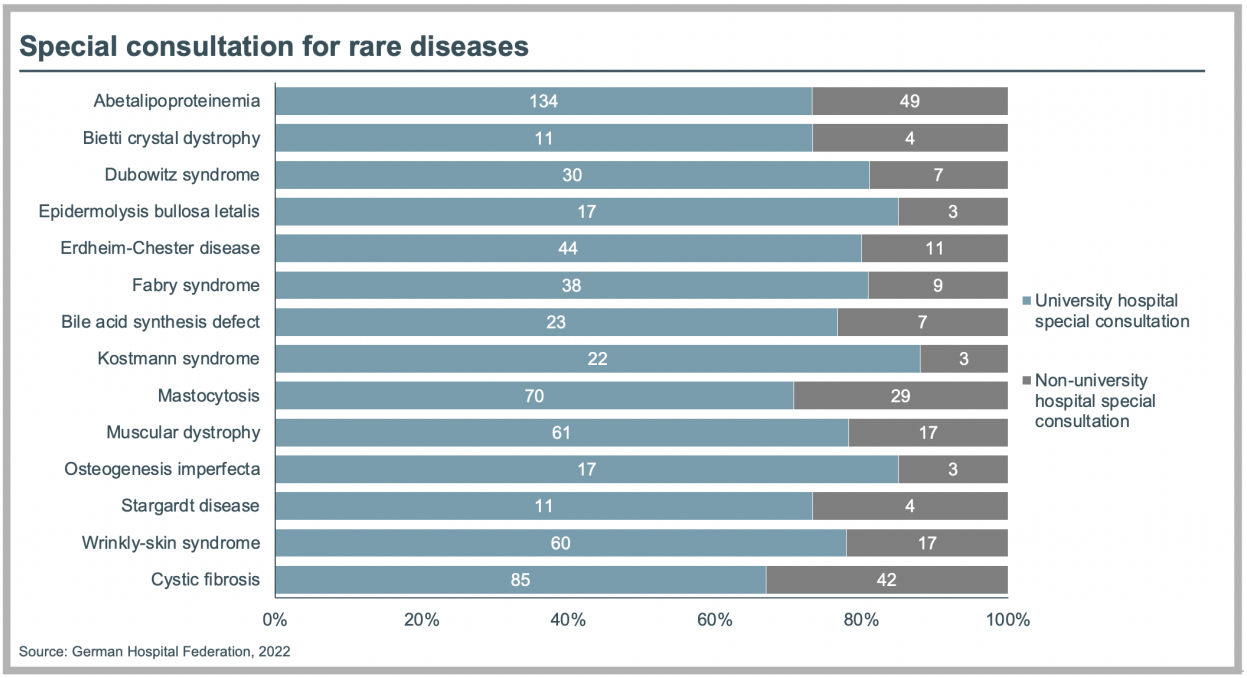

Figure 20 Special consultation for rare disease

This figure shows the number of special consultation hours for selected rare diseases. For example, university hospitals provide 134 of 183 specialty consultations for abetalipoproteinemia and 22 of 25 specialty consultations for Kostmann syndrome.
Source German hospital report 2015 [54]

Furthermore, for the extraordinarily small number of patients per disease, a great effort has to be provided in terms of medicine and organization. Whether it be information for physicians in private practice for the treatment of their patients, the transfer of medical know-how to other clinics, or further research into rare diseases, all of these services are not adequately financed [54].

In Germany, approximately four million patients suffer from a disease that affects no more than five out of every 10,000 people. Treating and caring for them requires enormous financial outlays. Financing these holding costs is generally extremely difficult [10].

2.5.2 Emergency care

The provision of emergency care is extremely unevenly distributed. Some hospitals do not participate at all, and others only participate selectively, and at certain times of the week. Still others participate only in certain disciplines or enforce case number limits to limit their supplies. Complete round-the-clock emergency care across all surgical, internal, and neurological disciplines is likely to be offered by only a few of the approximately 2,000 hospitals in Germany. Emergency care produces stand-by costs [55].

Currently, the base flat fee of around €3,700 is reduced by €50 only for those hospitals that demonstrably do not participate in emergency care at all [55]. This does not cover all the additional costs for emergency accident surgery, a stroke unit, or a heart attack center. According to calculations by the German Society for Interdisciplinary Emergency and Acute Medicine (DGINA), hospitals receive an average of €36 for each patient treated on an outpatient basis. The cost associated with their care is on average €136, resulting in a €100 deficit per patient (Figure 21) [55].

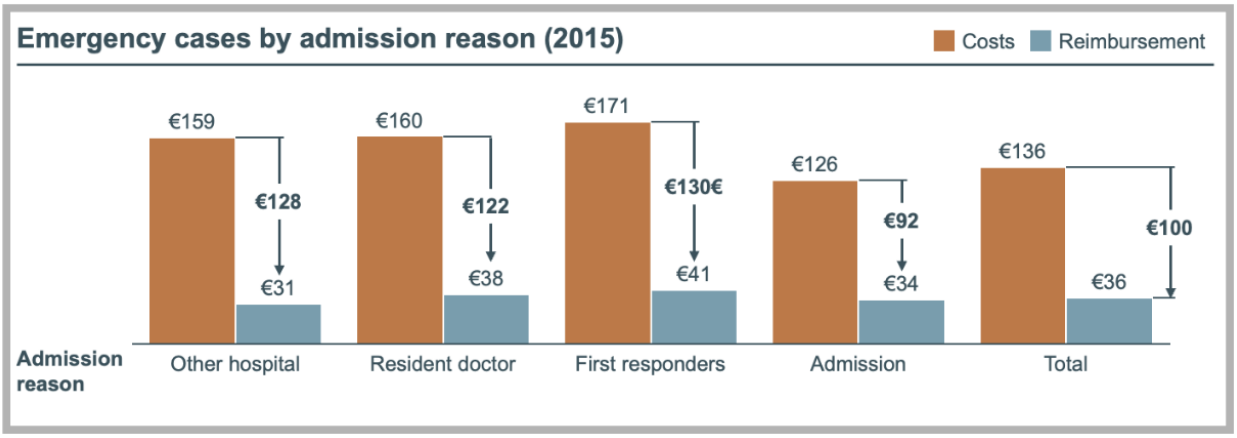

Figure 21 Emergency cases by admission reason 2015

Reasons for emergency cases being admitted included an admission by other hospitals, resident doctors, first responders, and regular admission. Overall, hospitals were reimbursed an average of €36 while incurring an associated cost of €136, resulting in a €100 loss per admission. The largest deficit was recorded for patients admitted by first responders, amounting to a €130 euro loss in 2015. The smallest deficit was seen in regular admissions, which was valued at €92 in the same year.

Source: German Society of Interdisciplinary Emergency and Acute Medicine (DGINA), 2015 [55]

2.5.3 Transfer cases

Lerch et al. found that the treatment cost of patients with endoscopic retrograde cholangiopancreatography (ERCP) differs depending on whether it was a planned admission or a transfer case. They found that for planned admission cases the contribution margin was -€183, while for transfer cases, the contribution margin of the university hospital was -€2,374 (difference of €2,191). Transfer cases that are transferred to non-university hospitals face a deficit of €1,003 and thus accounted for only half of that incurred at the university hospitals [9]. In Figure 22 transfer cases at university hospitals and non-university hospitals are compared; illustrating that cases with higher treatment costs are more prevalent at university hospitals [9].

Lerch et al explain this difference in cost by stating that patients are often transferred to a university hospital if an intervention is considered to be high-risk or is considered to be complex [9].

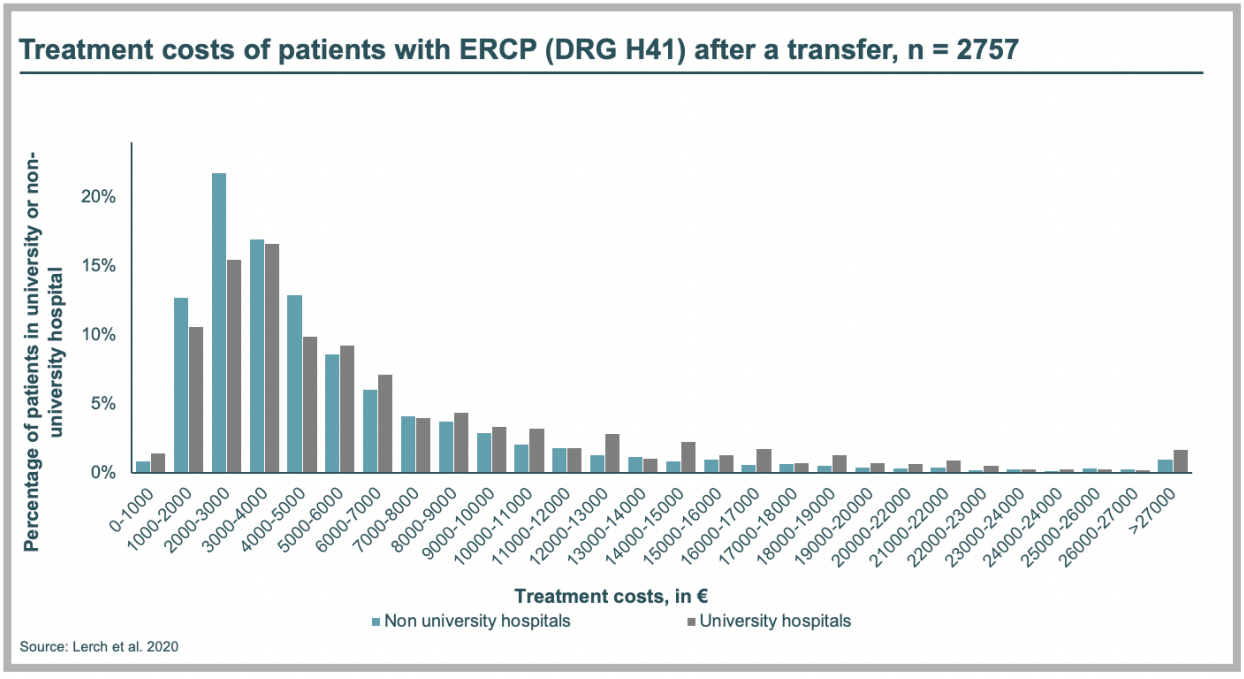

Figure 22 Treatment cost, patients with ERCP after referral to a second hospital

Representation of the treatment costs of all 2,757 cases treated by ERCP (basis DRG H41) in more than 70 calculating hospitals after transfer to a second hospital from 2011 to 2018. The X-axis shows cost groups in €1,000 increments, and the Y-axis shows the percentage of cases treated at either a university hospital (red bars) or a non-university

hospital (blue bars). In all cost groups below €5,000, the non-university hospitals led; in those above €5,000, the university hospitals always led..

Source: Lerch et al. 2020 [9]

2.5.4 Innovation

Modern medicine thrives on constant innovation to push the limits of diagnostic and therapeutic possibilities. The clinical testing and initial application of new treatment methods usually take place in university medicine. This is associated with a significant financial burden on several levels. First, new products and procedures are usually extremely expensive in their first years of market introduction. Second, these innovations must be introduced in a clinically controlled manner. Finally, the introduction of innovative services into the payment system faces several delays and may take a few years [56].

2.5.5 Research & Education

Due to the functional interaction between patient care, research and teaching, university hospitals belong to both the healthcare system and the university system. Therefore, university hospitals are financed from both systems. While separation is required for financing reasons, it may not be unity is required in view of of teaching, research, and patient care [56]. The state grants for research and teaching (*Landeszuschüsse für Forschung und Lehre*) increased by less than the inflation between 2006 and 2011 [50].

Medical education is also financially costly for university hospitals. Doctors in residency often do not have the same productivity as more experienced specialists. As a result, more physicians are often needed to provide the same services, resulting in additional direct personnel costs. Furthermore, experienced senior physicians and specialists must be reimbursed with an additional fee because they are responsible for instructing the newcomers [50]. Compared to other hospitals, university hospitals educate more than twice the number of physicians. In contrast to the U.S., the Netherlands, or Austria, the time required for the training of junior physicians is not financed separately in Germany. Instead, this is required to be covered by the revenues from patient care [51].

3 Research Design

This chapter introduces the research approach of this study. First, testable hypotheses are developed; second, the sampling frame is clarified; third, the measurement is explained; and finally, the modeling approach is outlined, and the handling of outliers is explained.

3.1 Hypotheses

Based on the literature review in Chapter 2, we developed three hypotheses to guide the analysis of the reimbursement situation of IBD in Germany.

- Hypothesis 1: The costs of complex cases are not recovered to the same extent as those of non-complex cases.
- Hypothesis 2: Complex cases occur more frequently in centers (university hospitals) than in other types of hospitals.
- Hypothesis 3: The G-DRG system does not reflect the complexity of centers, specifically university hospitals, appropriately.

3.2 Sampling Frame

3.2.1 Data: Sampling frame

Anonymized case data including cost data from the InEK calculation (§ 21-4 KHEntgG) of the DGVS's DRG project from 2019 were available for the retrospective study [57–59]. The case data includes only cases with at least one gastroenterological service. Due to the anonymization of the data, it is only available at the case level not at the patient level.

We pulled data from 6,659 cases with K50 or K51; 3,436 of these had IBD as their main diagnosis. Of those, we excluded one case due to missing cost data and 50 cases classified as partially stationary. We consequently analyzed 3,385 cases with IBD as the principal diagnosis from 49 hospitals.

For the identification of IBD cases, we identified 14 ICD codes that were categorized as IBD cases (see Table 2). Only cases with IBD as the main diagnosis were selected, since the DRG rate largely depends on the main diagnosis of a case.

Table 2 Overview of ICD-Codes

Crohn's disease (2019)			
ICD-Code	**Text: Crohn's disease of**	**Number of cases**	**Share of cases**
K50.0	Small intestine	689	20%
K50.1	Colon	466	14%
K50.80	Stomach	5	0%
K50.81	Esophagus	5	0%
K50.82	Esophagus and gastrointestinal tract	258	8%
K50.88	Other	234	7%
K50.9	Not specified	219	6%
Crohn's disease total		1876	55%
Ulcerative colitis (2019)			
ICD-Code	**Text: Ulcerative colitis**	**Number of cases**	**Share of cases**
K51.0	Pancolitis	504	15%
K51.2	Proctitis	83	2%
K51.3	Rectosigmoiditis	106	3%
K51.4	Inflammatory polyps of the colon	5	0%
K51.5	Left-sided colitis	174	5%
K51.8	Other	410	12%
K51.9	Not specified	227	7%
Ulcerative colitis total		1509	45%
689 cases, therefore 20% of the examined IBD cases, suffer from K50.0 (Crohn's disease of the small intestine)			

The 3,385 analyzed cases are distributed across 59 DRGs. G64B (inflammatory bowel disease) is the largest DRG, making up 37% of the cases. G47B (Esophago-Gastro-Duodenoscopy (EGD)) is the second largest DRG making up 33% of the cases. G48B (Colonoscopy) is the third largest DRG making up 8% of the cases. The remaining 22% of cases are spread across 56 different DRGs (see Table 3).

Table 3 Number of cases by DRG and ICD

Number of cases	DRG				
ICD-Code	G64B (Inflammatory bowel disease)	G47B (EGD)	G48B (Colonoscopy)	Other (56 DRGs)	Total
K50.0	180	285	33	191	689
K50.1	146	165	25	130	466
K50.80		3		2	5
K50.81		5			5
K50.82	54	91	34	79	258
K50.88	76	106	17	35	234
K50.9	67	92	24	36	219
K51.0	210	96	28	170	504
K51.2	49	23	3	8	83
K51.3	62	29	8	7	106
K51.4	3		2		5
K51.5	99	41	16	18	174
K51.8	200	111	41	58	410
K51.9	111	57	31	28	227
Total	1257	1104	262	762	3385
There are 180 cases with the diagnosis K50.0 and the DRG G64B					

To assess the completeness of IBD coding, we compared the published prevalence of 400,000 to 500,000 affected individuals from 2012 with the number of coded cases.

The cost data from the DRG project was compared with the cost data from the G-DRG Report Browser 2021 [60]. The G-DRG Report Browser 2021 is based on the cost data from 2019. The cost data in the G-DRG Report Browser 2021 represent the arithmetic mean of the costs of normal patients after excluding the nursing staff costs. Therefore, the cost data and the nursing staff costs were totaled.

3.2.2 Definition of types of care

To examine possible center effects, we grouped hospitals by the type of care they provide. Because grouping varied by state, we defined four care types. First, we distinguished between university hospitals and non-university hospitals. We then grouped the non-university hospitals by the number of beds as follows:

- I Primary care providers: ≤300 beds;
- II Focus providers: 301 to 700 beds;
- III Maximum care providers: ≥701 beds.

In this paper, university hospitals are classified as centers.

3.2.3 Definition of complex cases

To examine the impact of complexity on the payment situation, several variables were analyzed. The analyzed variables include the length of stay, gastroenterology complications, infections, specific procedures, admission occasions, and additional charges (see Table 4). The different factors for complexity are based on the disease severity in the IBD index developed by Siegel et al [61]. However, the analysis only includes factors that are encoded in the DRG system and is therefore incomplete with regards to the disease severity index as factors such as *frequency of loose stools* are not encoded. Furthermore, the Patient Clinical Complexity Level (PCCL) is included as an indicator for complexity, however, it should be interpreted with caution as the PCCL does not reflect the effort and complexity of the actual procedure, but only the patient-related documented

secondary diagnosis (e.g. hypertension, diabetes), which only allows very limited conclusions to be drawn about the complexity of the actual procedure [9].

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Table 4 Overview of the variables

Variable	**Average Interquartile range (IQR)**
Revenue (reimbursement)	€ 4901 (€2995)
Profit/loss	-10% (56%)
Length of stay	7.7 days (7 days)
	Share of cases
Gastroenterological complication	31%
Infection	6%
Additional charges	10%
Specific procedures	85%
Admission reason: Planned admission	55%
Admission reason: Emergency	43%
Admission reason: Transfer	2%
Partition: Surgical	16%
Partition: Medical	39%
Partition: Other	46%
Complications: toxic megacolon, hemorrhage, stoma, acute renal failure, primary sclerosing cholangitis (psc), colon carcinoma, rectal carcinoma, small bowel carcinoma, cholangiocarcinoma intrahepatic, cholangiocarcinoma extrahepatic, stenosis: intestinal adhesion, stenosis: other intestinal obstruction, stenosis: duodenal obstruction, stenosis: anal rectal stenosis, fistula: gastric duodenum, fistula: vaginal small intestine, fistula: vaginal large intestine, fistula: other genital intestine, fistula: vaginal pouch, fistula: enterovesical, fistula: intestinal, fistula: rectal, fistula: anal, fistula: anorectal, perforation: abscess anal, perforation: abscess peritonitis, perforation: abscess	
Infection: pneumonia, pneumonia nosocomial, sepsis, thrush esophagitis, thrush sepsis, tuberculosis, clostridioides difficile (cdiff), cytomegalovirus (cmv), herpes zoster, neutropenic fever, listeria, cholangitis	
Additional charges: infliximab, adalimumab, vedolizumab, ustekinumab, tofacitinib	
Specific procedures: EGD biopsy, EGD dilatation, enteroscopy biopsy, enteroscopy dilatation, colonoscopy biopsy, colonoscopy dilatation, colonoscopy polypectomy, ERCP biopsy, ERCP dilatation, ERCP stent, cholangioscopy, abscess drainage, Magnetic resonance imaging (MRI) small bowel, surgeries	

Gastroenterology complications

We coded 27 different gastroenterological complications as a complication across nine categories (see Figure 23).

As shown in Figure 23, regular gastroenterological complications were seen more regularly than severe complications. Stenosis was the most frequently occurring gastroenterological complication, with 444 cases recorded in 2019. This was followed by fistula complications which had 255 cases, and severe complications of hemorrhage which had 215 cases. The most uncommon complication was toxic megacolon, recording only 7 cases.

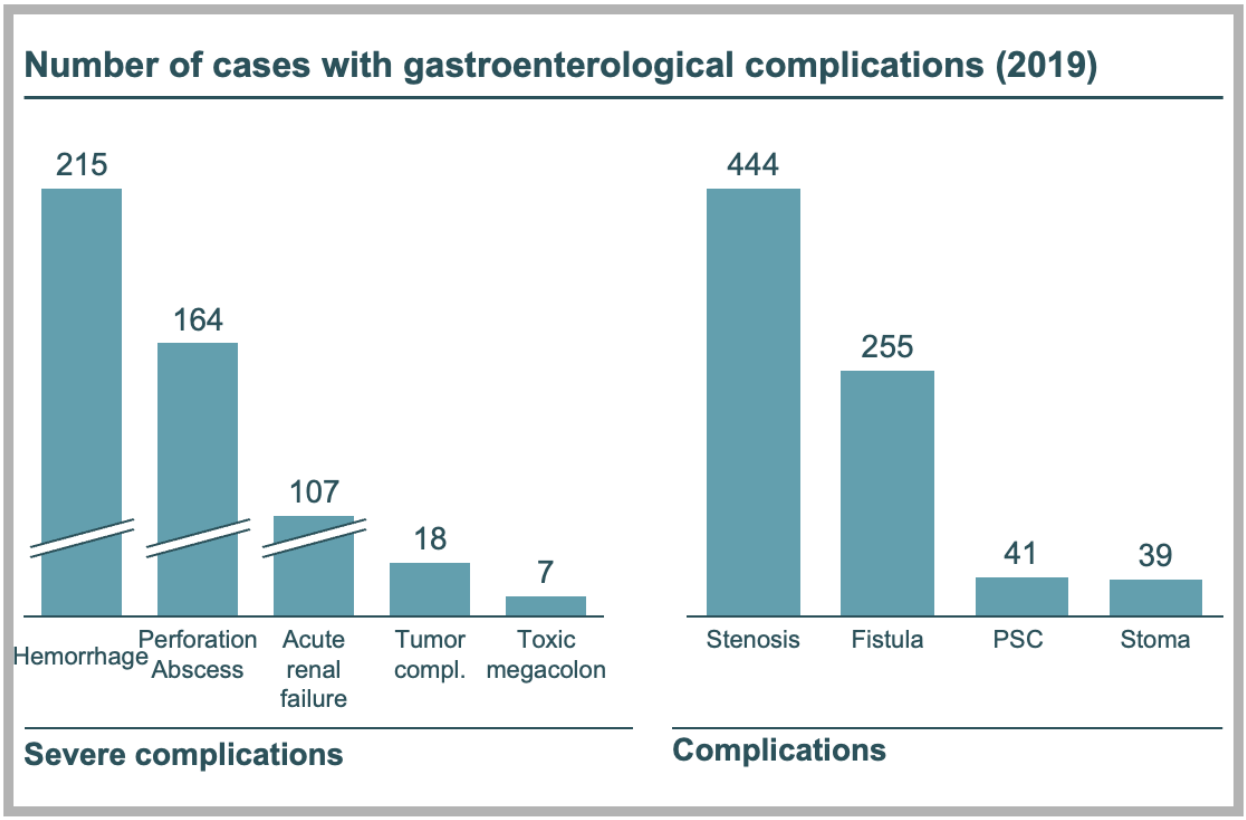

Figure 23 Overview of gastroenterological complications

Gastroenterological complications identified under severe complications include hemorrhage, perforation abscess, acute renal failure, tumor complication, and toxic megacolon. The most frequently occurring severe gastroenterological complications were hemorrhage and perforation abscess, for which 215 and 164 cases were recorded respectively. The least frequent was toxic megacolon, presenting only 7 cases.

Regular gastroenterological complications were classified under stenosis, fistula, Primary sclerosing cholangitis (PSC), and stoma. 444 cases with stenosis were recorded, making it the most common classification of regular gastroenterological complication.
Source: DRG project 2019

Infections

We coded 10 different infections (see Figure 24). Sepsis was the most commonly encoded infection with 42 cases.

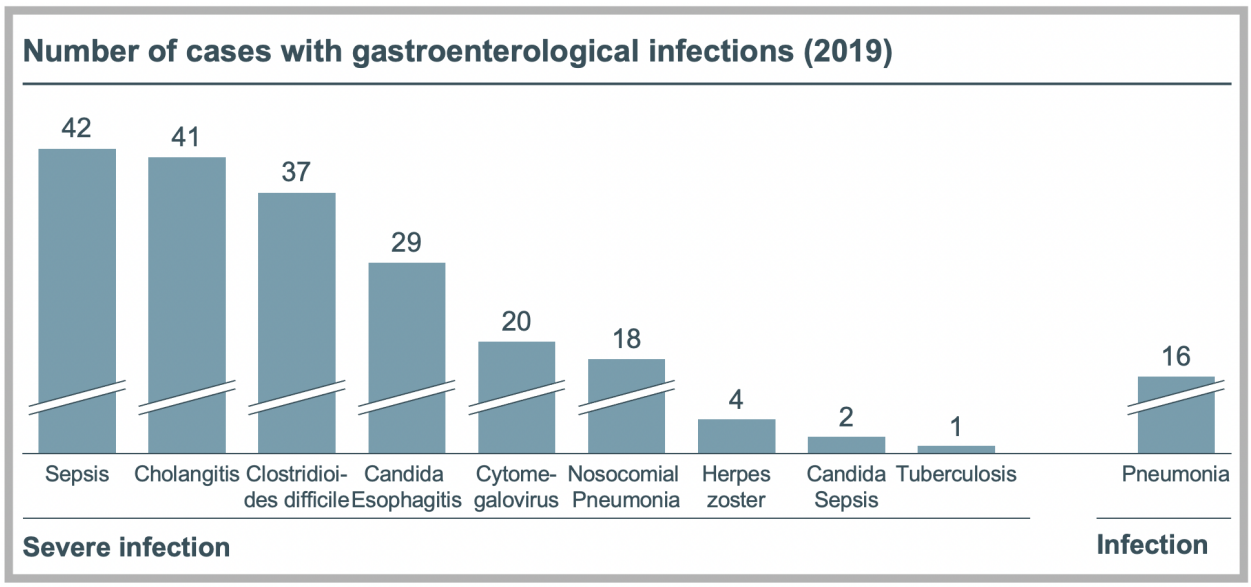

Figure 24 Overview of infections

Figure 24 provides a breakdown of the number of cases that presented gastroenterological infections in the sample year, classified under 'severe infection' and 'infection'. Sepsis and Cholangitis arose in the largest number of cases (42 and 41 cases out of the total 210 shown above, respectively). Both of these fall under the severe infection category. Pneumonia was the only regular gastroenterological infection included, presenting 16 cases.
Source: DRG project 2019

Reason for admission

Planned admission cases are considered to be less complex than emergency- or transfer-related cases. The transfer of cases to a hospital is often the result of the admitting hospital not being sufficiently equipped to treat them, as outlined in Chapter 2.5.3 Transfer cases.

Planned admission was the most commonly occurring reason for admission, as shown in Figure 25. This was closely followed by emergency admissions. Only about 2% of the 3,384 cases were admitted following a transfer.

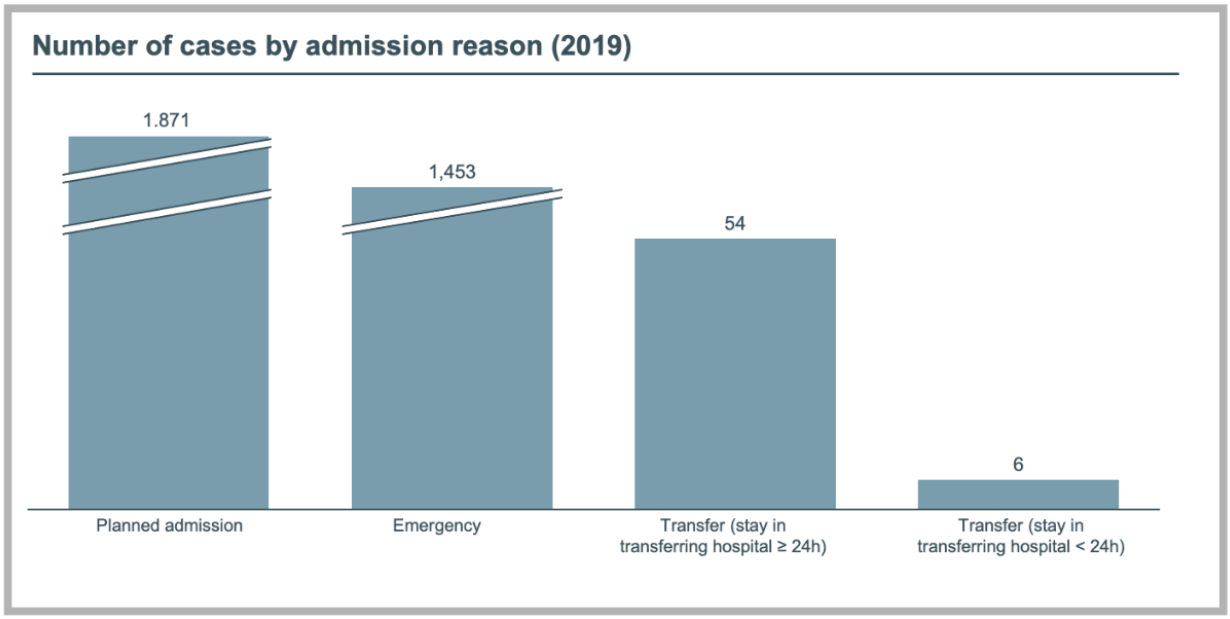

Figure 25 Overview of admission reasons

55% of the 3,384 cases recorded stated planned admission as the reason for admission. 43% were emergency admissions. Transfers accounted for 60 of the cases (2%), within which only 6 transfer cases were admitted following a stay in the transferring hospital of under 24 hours. One case with the admission reason “dentist” was excluded.

Source: DRG project 2019

Special procedures

We coded 7 different categories of specific procedures (see Figure 24). Special procedures are based on the OPS (operation and procedure code). They include colonoscopy biopsy, EGD biopsy and MRI of the small intestine, colonoscopy dilation, colonoscopy polypectomy, EGD dilation, and operation. Figure 26 describes the number of

cases with specific procedures. Colonoscopy biopsy was performed for 2,004 cases and is the most common special procedure. This is followed by EGD biopsy which saw 1,161 cases.

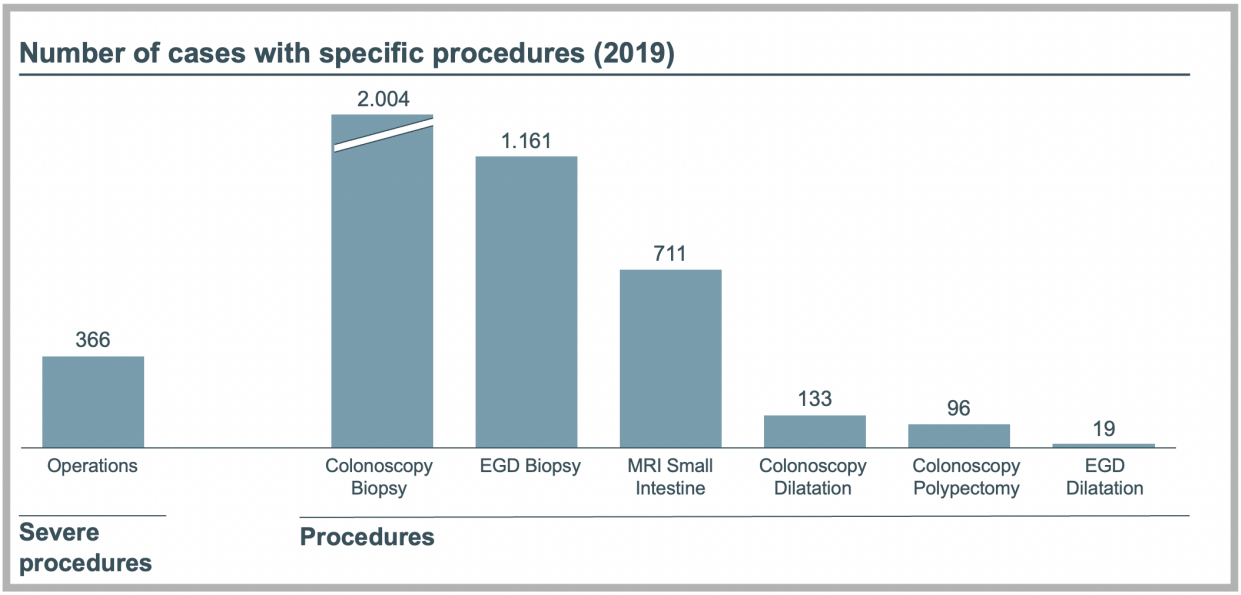

Figure 26 Overview of special procedures

45% of the 4,490 special procedure cases analyzed required a colonoscopy biopsy, and 26% required an EGD biopsy. The least common special procedure was EGD dilation which was recorded in only 0.4% of the above cases. 366 cases of severe procedures were recorded, in which surgery was required.

Source: DRG project 2019

3.3 Measurement

Profitability, defined as the difference between reimbursement and cost, is the critical variable of interest and, consequently, the dependent variable of the analysis. As mentioned in Chapter *2.3.2 DRG System*, we use the term deficits when we refer to cost under-recovery (costs higher than revenues), and profits when we refer to cost over-recovery (revenues higher than costs).

The hospital remuneration system in Germany is set up with the aim of recovering costs. To analyze the reimbursement situation of IBD cases in German hospitals, we compared the cost of a specific case with its effective revenue (revenue received by a hospital after accounting for applicable surcharges or discounts).

For the comparative cost analysis between the actual cost of the DRG cases and InEK costs, we compared the total actual costs of the inlier cases (*Normallieger)* excluding the nursing-personnel costs to the InEK costs. The difference between the actual costs and InEK costs was then compared with the InEK standard deviation, as the InEK requirement for submitting a request to change the DRG reimbursement includes the difference between the actual costs and the InEK costs exceeding the InEK standard deviation.

3.4 Methods

First, we analyzed the reimbursement situation in relation to the main diagnosis. Following this, we assessed the possible drivers of the financial loss. This analysis consisted of (1) a multiple linear least square regression analysis including all complexity variables to analyze the impact of different complexity factors on the profitability of a case and (2) a comparative analysis of each complexity driver grouped by type of care. The statistical analyses were performed using SPSS for Windows Version 28.0.1.1 (14) and Excel 16.56.

We conducted the analysis on two levels: first on an aggregate level, taking all IBD-DRG codes into account, and then on an individual DRG-code level. Although we initially completed the analysis for Crohn's disease and Ulcerative colitis separately, we discovered that the findings were consistent between both diagnoses, and consequently an aggregate analysis is presented.

For the individual DRG code analysis, we focused on three DRG codes that together represent 78% of the 3385 analyzed cases:

- G64B: *Inflammatory bowel disease or other severe diseases of the digestive organs, without extremely severe Complication or Comorbidity (CC), age > 15 years or without severe CC* — **1,257 cases**
- G47B: *Other gastroscopy or certain colonoscopic procedures, age > 15 years, without endoscopic submucosal dissection of the colon, or more than one day of hospitalization* — **1,104 cases**

- G48B: *Colonoscopy with extremely severe or severe CC, complicating procedure or age < 15 years, or multiple endoscopic hemostasis, without severe intestinal infection, except for malignant neoplasm or without extremely severe CC* — **262 cases**

When completing the analysis on the aggregate level, we first calculated the relative profitability per case as a percentage, and then averaged it per comparison group, to ensure comparability of profitability across diagnosis groups and DRG codes. Each case was weighted equally. This relative approach ensures that individual outliers do not have a disproportionate influence on the results.

When completing the analysis on the DRG-code level, we analyzed the absolute profitability. Finally, we compare the actual incurred costs to the InEK costs. For this, we examined the costs of the inlier (normal length of stay, excluding nursing personnel costs) cases and compared them at DRG level with the costs of the InEK (excluding nursing personnel costs) from the DRG Report Browser 2021. For this purpose, the cost data were regrouped according to DRG 2021. The difference between actual costs and InEK costs was compared with the InEK standard deviation.

The data is not normally distributed, however, due to the large number of cases, parametric methods such as t-tests are considered accurate [62].

3.5 Handling of Outliers

To understand the distribution of profitability across the different types of care, we graphed both the absolute and relative profitability as a bee plot (Figure 27, Figure 28, Table 2, and Table 6). Cases at university hospitals had a higher standard deviation of 0.61 compared with 0.43 at maximum care providers and 0.44 at both primary care providers and focus care providers.

As Hypothesis 1 assumes that the costs of complex cases are not recovered to the same extent as those of non-complex cases, we considered outliers to be a critical component of the dataset, and thus did not exclude them.

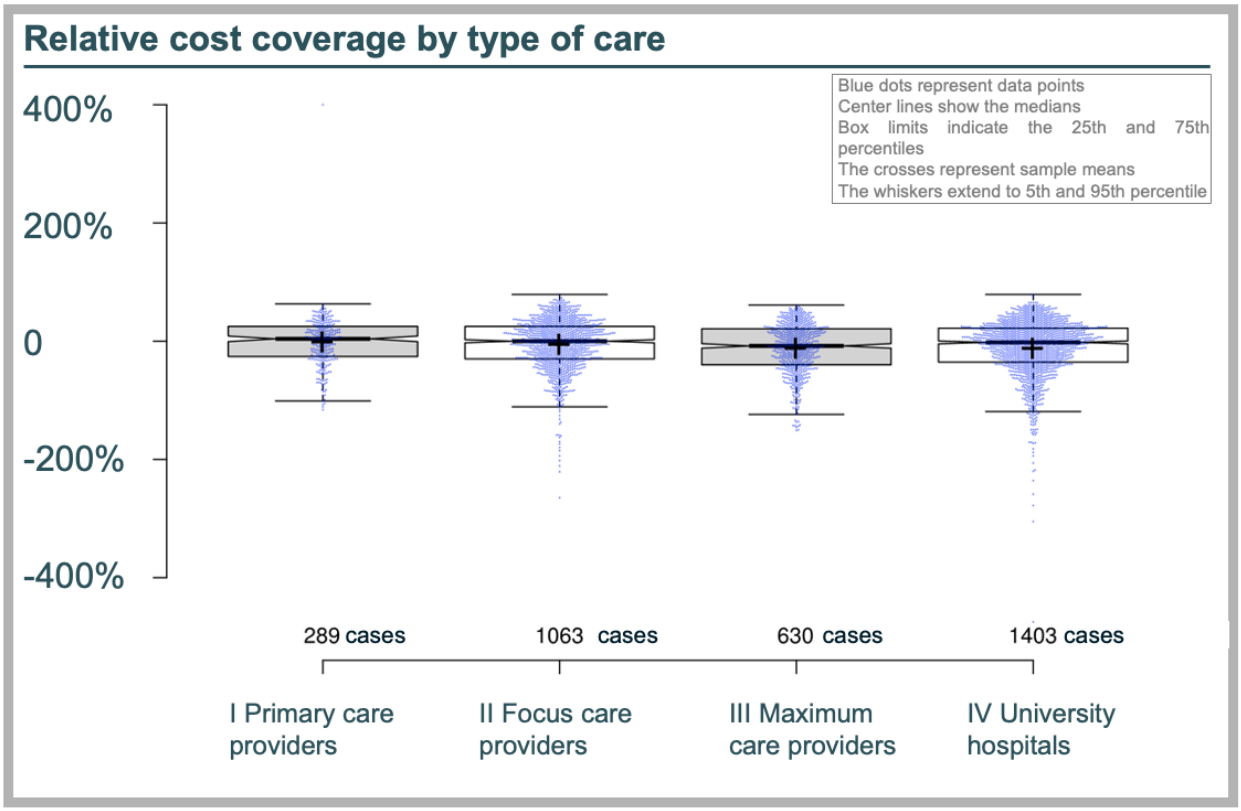

Figure 27 Relative profitability by care type

All four care types demonstrate financial losses when referring to the mean data. The largest losses measured by the mean are seen in maximum care providers and university hospitals, which have on average 13% relative losses. Maximum care providers have the largest median losses (8%), and primary care providers are the most profitable according to the median (4%). The standard deviation is the highest for university hospitals (61%), indicating higher volatility in the data. The other three care types have similar standard deviations of 43-44%.

Source: DRG project 2019

Table 5 Relative profitability by types of care

	I Primary care providers	II Focus care providers	III Maximum care providers	University hospitals
Standard deviation	44%	44%	43%	61%
Mean	-2%	-6%	-13%	-13%
Median	4%	0%	-8%	-2%

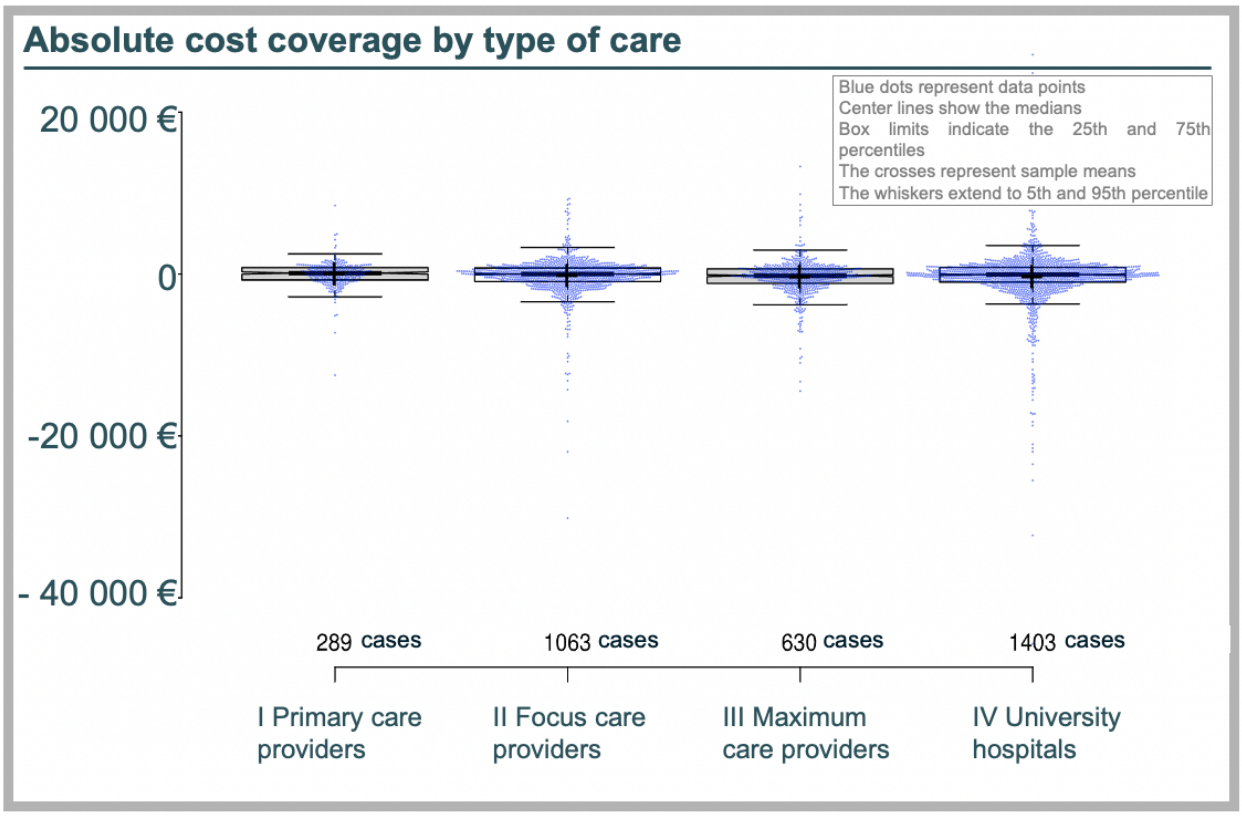

Figure 28 Absolute profitability by care type

Absolute profitability data confirms that maximum care providers and university hospitals display the highest mean financial losses (€384 and €365 respectively). University hospitals also display the highest variability in data, as demonstrated by the €3,784 standard deviation.

Source: DRG project 2019

Table 6 Absolute profitability by types of care

	I Primary care providers	II Focus care providers	III Maximum care providers	University hospitals
Standard deviation	€1590	€2409	€2203	€3754
Mean	-€19	-€229	-€384	-€365
Median	€116	-€1	-€205	-€72

4 Results

This chapter presents the results of the statistical analysis and evaluates the data with respect to the three hypotheses listed in Chapter 3:

Hypothesis 1: The costs of complex cases are not recovered to the same extent as those of non-complex cases.

Hypothesis 2: Complex cases occur more frequently in centers (maximum care providers and university hospitals) than in other types of hospitals.

Hypothesis 3: The G-DRG system does not reflect the complexity of centers, specifically university hospitals, appropriately.

4.1 IBD patients are not treated in a cost-covering manner in the DRG system

To investigate the reimbursement situation of IBD cases and possible drivers for financial losses, the first step was to analyze the reimbursement situation depending on the principal diagnosis.

Twelve of the 14 IBD diagnoses examined have an average relative financial loss. On average, IBD cases are treated incurring a financial loss of 10%, as shown in Figure 29. Crohn's disease and ulcerative colitis have an average financial loss of 10% and 9%, respectively. The average total costs (personnel, material, and infrastructure costs) vary between €870 per case for K50.81 and €6,732 per case for K50.1. The costs also vary significantly within a DRG code (e.g., G64B: minimum: €458, maximum: €22,859) (Table 7).

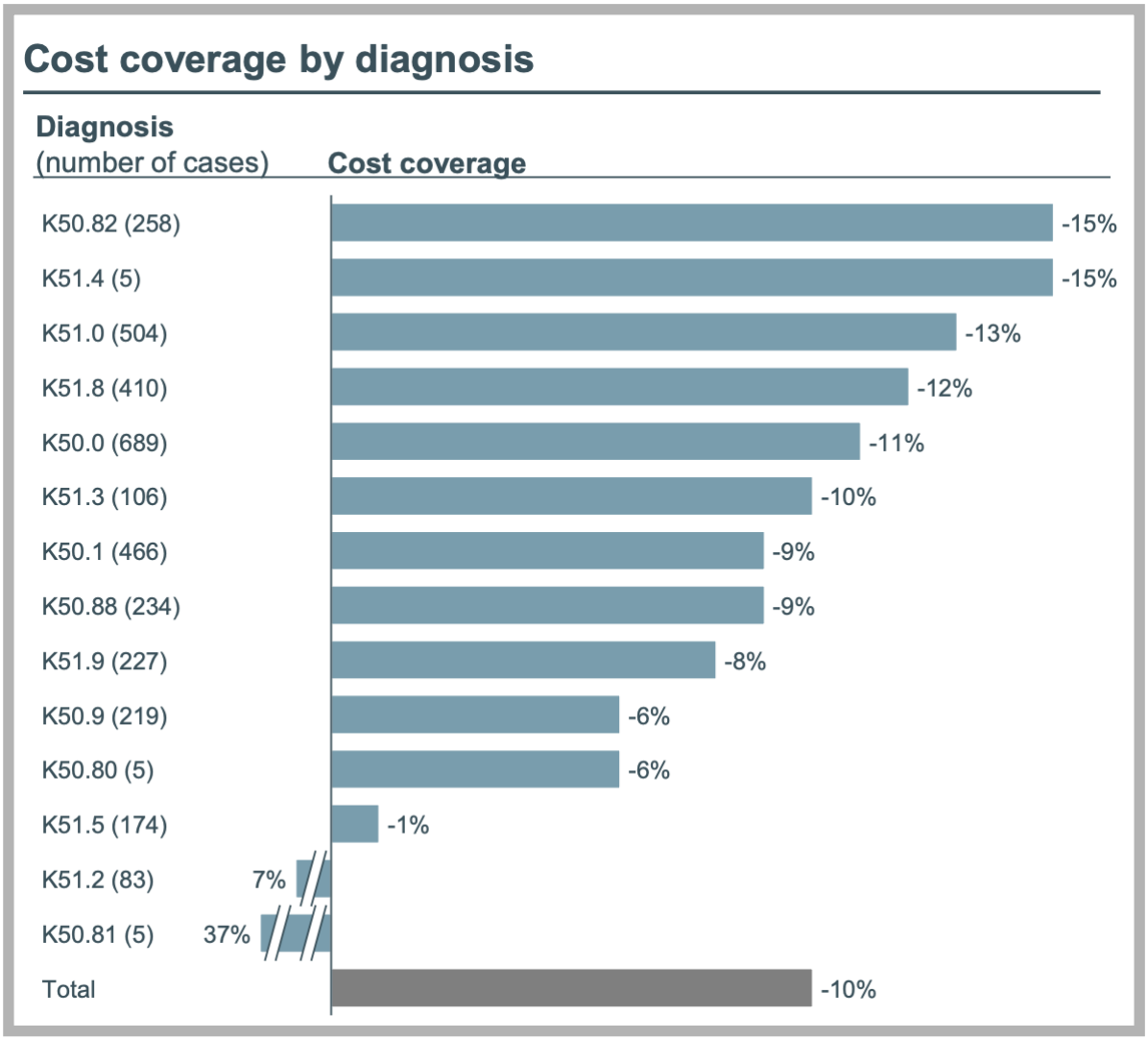

Figure 29 Average relative profitability (cost coverage) by diagnosis

The blue bars represent a specific diagnosis; the x-axis represents the profitability. For example, K50.81 was diagnosed for 5 cases and incurred a cost under-coverage of 37%. The average financial losses for treating IBD are 10%

Source: DRG project 2019

Table 7 Overview of reimbursement parameters by DRG

DRG-Code	Number of cases	Ø Relative profit/loss (IQR)	Ø Reimbursement (IQR)	Ø Total costs (IQR)	Ø Absolute profit/loss (IQR)	Ø Length of stay (IQR)
G64B (IBD)	1,257 (37%)	-18% (61%)	€2,603 (€59)	€2,876 (€1,869)	-€273 (€1,304)	5 days (5 days)
G47B (Other gastroscopy)	1,104 (33%)	-6% (53%)	€3,309 (€9)	€3,441 (€2,042)	-€132 (€1,530)	6 days (5 days)
G48B (Colonoscopy)	262 (8%)	10% (40%)	€4,521 (€1,403)	€4,195 (€2,938)	€326 (€1,770)	7 days (8 days)
G16B (Complex rectal resection)	121 (4%)	-2% (45%)	€16,820 (€30)	€17,677 (€8,277)	-€857 (€7,155)	21 days (11 days)
G18C (Certain procedures on small and large intestine)	91 (3%)	-7% (40%)	€8492 (€15)	€9,149 (€3697)	-€657 (€3,487)	13 days (8 days)
G46C (Various complex and other gastroscopy)	74 (2%)	-7% (71%)	€3557 (€1376)	€3,811 € (€2,886)	-€254 (€2,146)	5 days (6 days)
Other (53 DRG-Codes)	476 (14%)	-10% (53%)	€11362 (€8566)	€12,239 (€9,762)	-€877 (€3,735)	16 days (14 days)
Total	**3,385 (100%)**	**-10% (56%)**	**€4901 € (€2,603)**	**€5,197 € (€3,342)**	**-€296 (€1,735)**	**8 days (7 days)**

In the second step, we examined the reimbursement situation in relation to the defined types of care. On average, all types of care bear a financial loss, which varies by type (primary care providers: 3%, focus care providers: 10%, maximum care providers: 13%, university hospitals: 13% financial loss). However, there are also some hospitals that treat IBD cases profitably among the primary and focus care providers as well as among the maximum providers. Specifically, these are eight of the 12 care providers and seven of the 21 focus care providers. Maximum care providers and university hospitals all generate a financial loss, as illustrated in Figure 30.

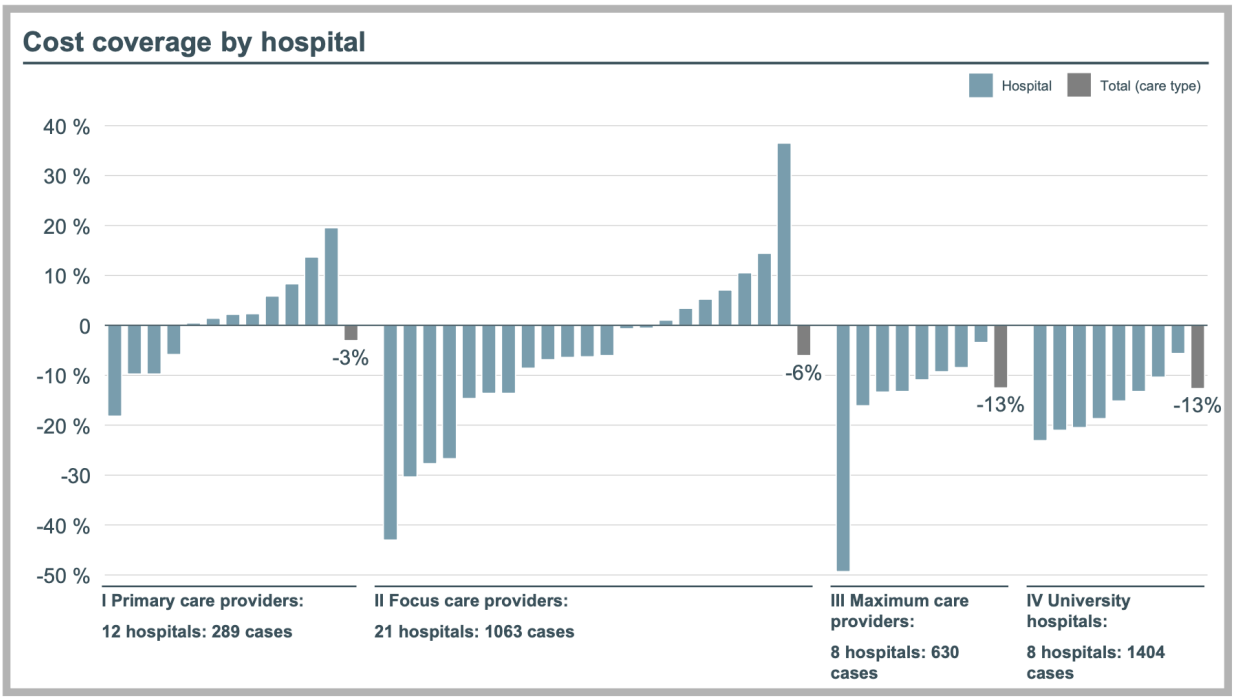

Figure 30 Average relative profitability by hospital

Each of the blue bars represents a single hospital, and the gray bars represent the average cost coverage per care type. The y-axis represents the average profitability per hospital/provision type. All cases are equally weighted.

Source: DRG project 2019

4.2 Complex cases are less profitable than non-complex cases

To examine the possible drivers of profitability, we examined gastroenterological complications, infections, specific procedures, the reason for admission, additional charges (*Zusatzentgelte*), length of stay (VWD), the severity of sickness (PCCL), and type of procedure (medical, surgical, or other).

First, we conducted a multiple linear least square regression analysis with the relative profitability per case as the dependent variables and different complexity factors as the independent variables (see Table 8). We found that the Variance Inflation Factor (VIF) is less than three for all variables, indicating that there is no linear relationship, and therefore no multicollinearity, between the variables. Therefore, all variables may be included in the analysis [63]. The regression analysis shows that cases with a university hospital or maximum care provider as the type of care have significantly lower profitability than

cases with focus care providers. As the multiple linear regression includes several variables, the significance is relatively low. If we were to only include the admission reason, the results would be statistically significant.

Table 8 Multiple linear regression

Variable	Estimate	Standard error	95% Confidence Interval (asymptotic)	VIF
Intercept	0.1722	0.0225	0.1280 to 0.2164	
IV University hospital	-0.1208	0.0202	-0.1604 to -0.08121	1.5
I Primary care provider	0.0343	0.0319	-0.02824 to 0.09685	1.2
III Maximum care provider	-0.0607	0.0243	-0.1083 to -0.01307	1.3
Relative length of stay	-0.1890	0.0102	-0.2090 to -0.1690	1.2
PCCL	0.0159	0.0080	0.0002368 to 0.03148	1.7
Number of gastroenterological complications	-0.0036	0.0142	-0.03133 to 0.02421	1.5
Number of infections	-0.0328	0.0331	-0.09771 to 0.03221	1.2
Additional charges	0.1702	0.0288	0.1138 to 0.2266	1.1
Number of special procedures	-0.0276	0.0098	-0.04673 to -0.008486	1.0
Admission reason: emergency	-0.0190	0.0175	-0.05331 to 0.01525	1.1
Admission reason: transfer (≥24h)	-0.0661	0.0675	-0.1984 to 0.06626	1.1
Admission reason: transfer (<24h)	-0.1898	0.1964	-0.5748 to 0.1953	1.0

To assess the correlation between the variables, we generated a correlation matrix of the continuous variables and found that the number of gastroenterological complications and patient clinical complexity level (PCCL) have the highest correlation of 0.57 (see Table 9).

Table 9 Correlation of matrix complexity variables

	Relative length of stay	PCCL	Number of gastroenterological complications	Number of infections	Number of special procedures
Relative length of stay	1.000	0.283	0.161	0.165	0.096
PCCL	0.283	1.000	0.574	0.358	0.057
Number of gastroenterological complications	0.161	0.574	1.000	0.196	0.029
Number of infections	0.165	0.358	0.196	1.000	0.019
Number of special procedures	0.096	0.057	0.029	0.019	1.000

Additionally, we evaluated the individual factors for complexity with regard to the type of care and its effect on profitability.

4.2.1 Gastroenterological complications

The analysis indicates that cases with a high number of gastroenterological complications are especially non-cost covering. Figure 31 illustrates both the distribution of cases (left side) and the cost coverage (right side) by the number of gastroenterological complications. Cases across all care types with at least three complications showed a total financial loss of 24%, whereas cases without any complications showed a total financial loss of 9% (Table 10, Figure 31: right side). University hospitals demonstrated larger financial losses in the presence of at least three complications than all other care types, amounting to 33%. In the presence of only one complication, maximum care providers faced the largest losses. We found no significant differences in the distribution of cases by the number of complications among care types (Figure 31: left side). Therefore, it cannot be inferred from this data that cases at university hospitals have more complications on average than cases at other types of care providers (see Table 10).

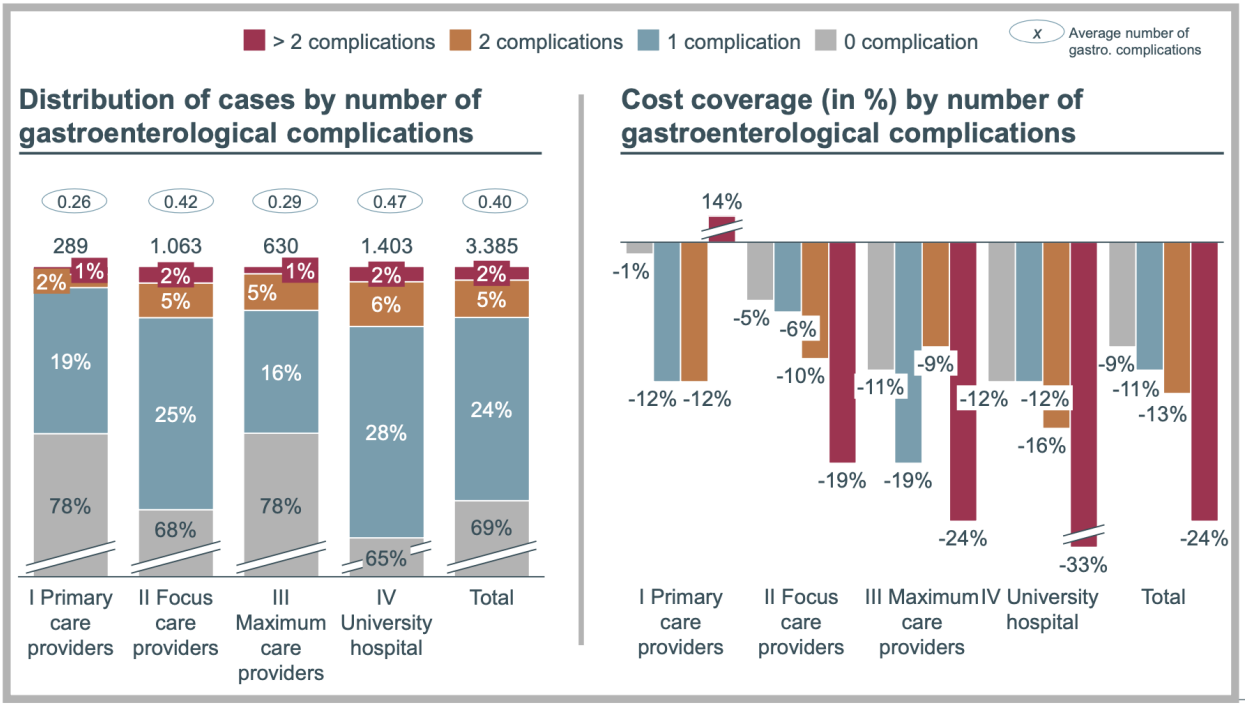

Figure 31 Distribution and profitability of cases by the number of gastroenterological complications

Left: Each represents the distribution of cases by the number of complications per type of care. In total the largest number of cases (69%) had no gastroenterological complications, as shown by the grey area on the bar.

Right: The profitability by reason for the number of complications and type of care. Cases with more than two complications incurred financial losses of 24%, as shown by the maroon bar. Within this category, university hospitals incurred higher losses than all other care providers, amounting to 33%.

Source: DRG project 2019

Table 10 Overview of cost recovery by type of care and number of complications

Type of care		Number of gastroenterological complications				
		0 complications	1 complication	2 complications	>2 complications	Total
I Primary care provider	**Average profit/loss**	**-1%**	**-12%**	**-12%**	**14%**	**-3%**
	Significance unequal 0	0.34	0.02	0.31	0.29	0.08
	Standard deviation	35%	42%	55%	44%	37%
	Number of cases	226	55	5	3	289
II Focus provider	**Average profit/loss**	**-5%**	**-6%**	**-10%**	**-19%**	**-6%**
	Significance unequal 0	<0.001	0.01	0.03	0.01	<0.001
	Standard deviation	45%	44%	37%	40%	44%
	Number of cases	726	266	48	23	1063
III Maximum care provider	**Average profit/loss**	**-11%**	**-19%**	**-9%**	**-24%**	**-13%**
	Significance unequal 0	<0.001	<0.001	0.09	0.001	<0.001
	Standard deviation	43%	46%	34%	20%	43%
	Number of cases	493	101	30	6	630
IV University hospital	**Average profit/loss**	**-12%**	**-12%**	**-16%**	**-33%**	**-13%**
	Significance unequal 0	<0.001	<0.001	<0.001	<0.001	<0.001
	Standard deviation	67%	47%	46%	46%	60%
	Number of cases	907	386	82	28	1403
Total	**Average profit/loss**	**-9%**	**-11%**	**-13%**	**-24%**	**-10%**
	Significance unequal 0	<0.001	<0.001	<0.001	<0.001	<0.001
	Standard deviation	53%	46%	42%	42%	51%
	Number of cases	2352	808	165	60	3385

There are 386 cases with one gastroenterological complication at university hospitals; on average, these present with a 12% deficit with a standard deviation of 47%.

Additionally, we analyzed the gastroenterological complication categories. Here we found that differences exist in profitability among different types of complications and that no complication was treated, on average, in a cost-covering manner. These findings are summarized in Figure 32. When analyzing the distribution of complications, we can see that although toxic megacolon presented the least frequently (7 cases), it incurred the largest loss compared to all other categories, averaging 62%. The smallest losses were seen in hemorrhage cases, which occurred the most frequently within the severe complication subcategory, averaging just 7%.

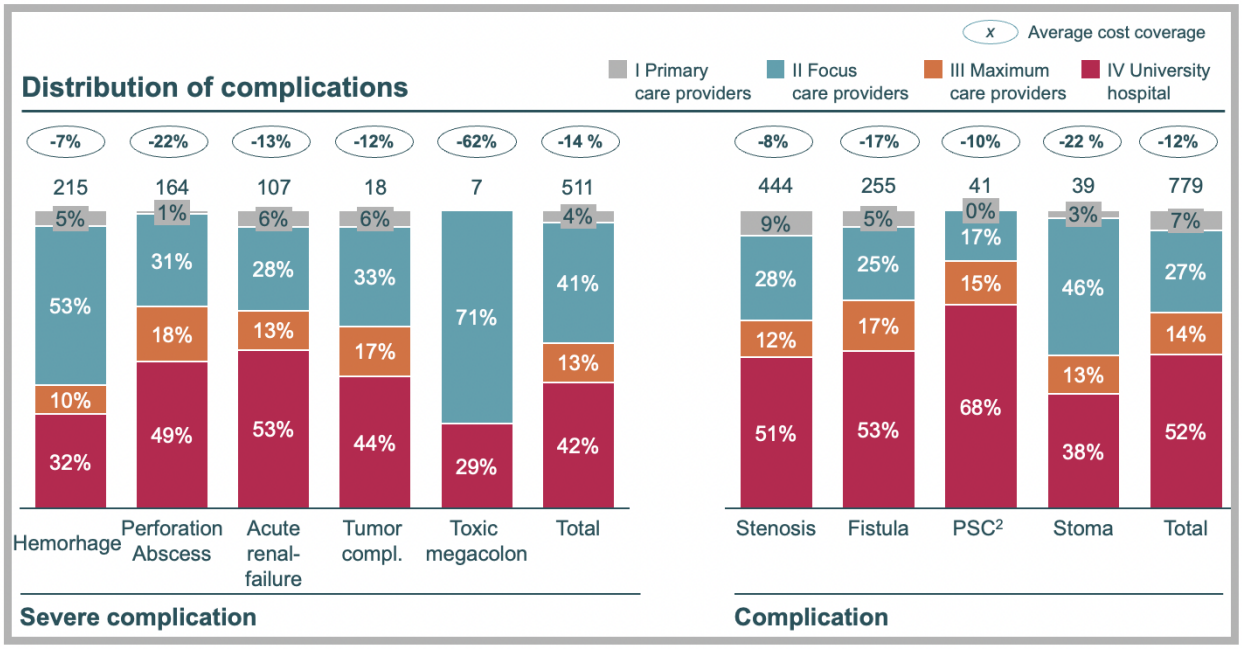

Figure 32 Profitability of different complications and distribution among the types of care

Each represents one complication category. The distribution of cases among the type of care is visualized through the different colors. The average profitability of each complication category is shown in the bubbles above each bar.

Source: DRG project 2019

4.2.2 Infections

Cases with at least one infection incur a higher financial loss than cases without infections. The average financial loss of cases with at least one infection was approximately twice as high compared with cases without infection (21% compared with 9%). 94% of the cases recorded experienced 0 infections, with only 5% recording 1 infection. The distribution of these cases across care types did not display any significant variation (see Figure 33: left side and Table 11). In the cases that were recorded, those with more infections generated higher financial losses, as shwon in Figure 33. Cases with more than two infections incurred the highest losses in university hospitals (155%), while they generated profits of 22% in maximum care facilities and 1% at focus case facilities.

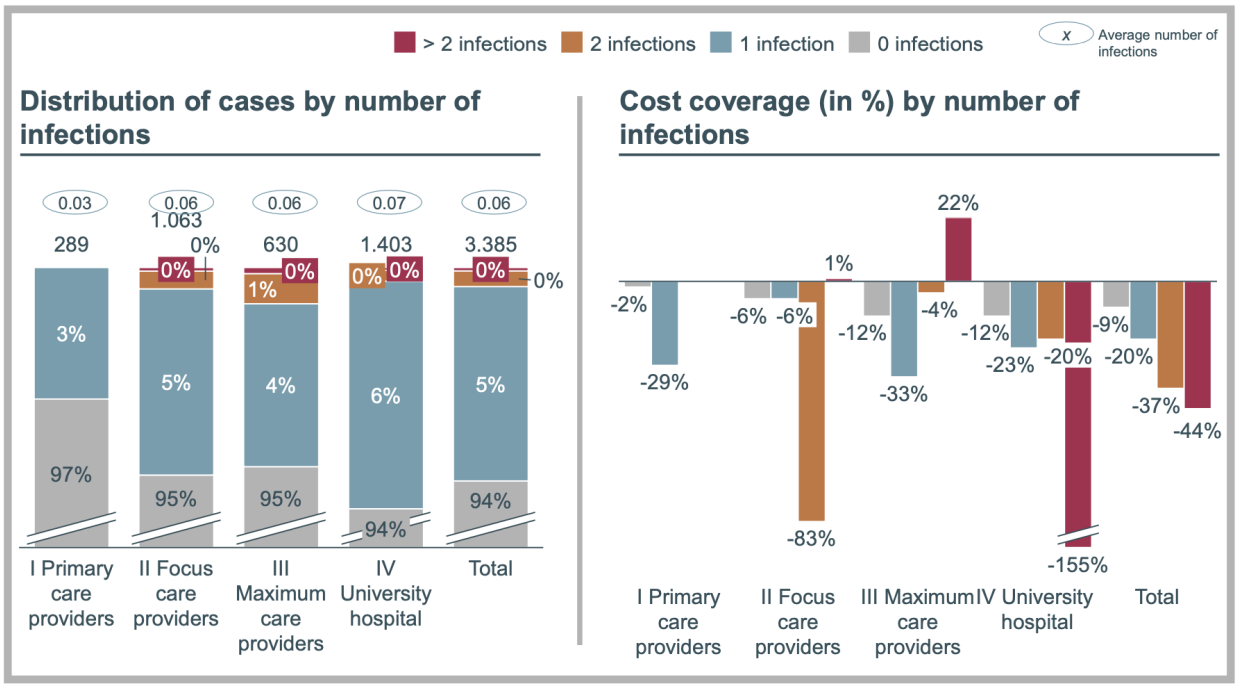

Figure 33 Distribution and profitability of cases by the number of infections

Left: One bar represents the distribution of cases by the number of infections by type of care. Right: The profitability by reason for the number of infections and type of care.

Source: DRG project 2019

Table 11 Overview of cost recovery by type of care and number of infections

Type of care		Number of infections				
		0 infections	1 infection	2 infections	> 2 infections	Total
I Primary care provider	**Average profit/loss**	**-2%**	**-29%**			**-3%**
	Significance unequal 0	0.170	0.002			0.08
	Standard deviation	37%	32%			37%
	Number of cases	279	10			289
II Focus provider	**Average profit/loss**	**-6%**	**-6%**	**-83%**	**1%**	**-6%**
	Significance unequal 0	<0.001	0.123	<0.001		<0.001
	Standard deviation	44%	40%	50%		44%
	Number of cases	1005	52	5	1	1063
III Maximum care provider	**Average profit/loss**	**-12%**	**-33%**	**-4%**	**22%**	**-13%**
	Significance unequal 0	<0.001	<0.001	32%		<0.001
	Standard deviation	42%	48%	19%		43%
	Number of cases	597	27	5	1	630
IV University hospital	**Average profit/loss**	**-12%**	**-23%**	**-20%**	**-155%**	**-13%**
	Significance unequal 0	<0.001	<0.001	0.002		<0.001
	Standard deviation	60%	60%	13%		60%
	Number of cases	1314	84	4	1	1403
Total	**Average profit/loss**	**-9%**	**-20%**	**-37%**	**-44%**	**-10%**
	Significance unequal 0	<0.001	<0.001	0.002	0.22	<0.001
	Standard deviation	51%	52%	47%	97%	51%
	Number of cases	3195	173	14	3	3385

There are 84 cases with one infection at university hospitals; on average, these present with a 23% deficit with a standard deviation of 60%.

When analyzing the infection categories, we found that the profitability of specified infections varies between 18% and -66%, and only pneumonia was treated in a cost-covering manner (see Figure 34). While it may not be indicative of a trend for the specific infection category given that only 1 case was reported, the largest loss of 66% was encountered when treating a case of tuberculosis at a university hospital. Candida esophagitis, which was treated at all four hospital types, was the least costly infection, with losses of 8%. In total, considering all infection categories, university hospitals treated almost half of the infections, with primary care providers treating only 4%. The total average cost coverage of all infections was -21%.

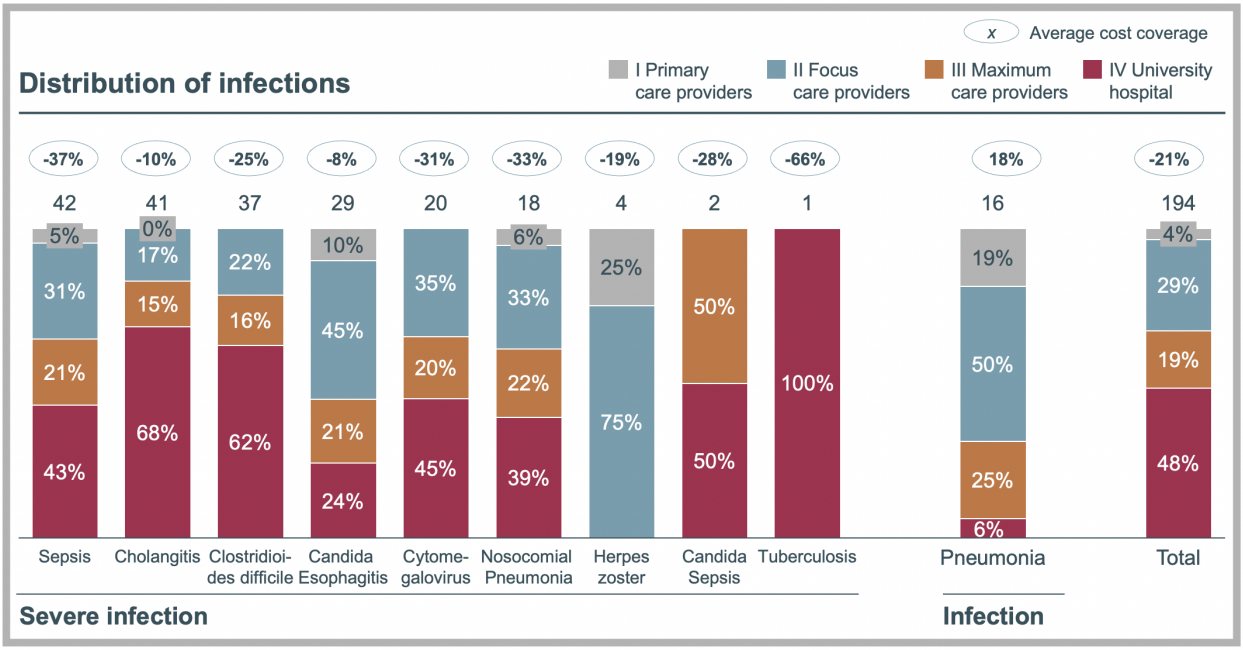

Figure 34 Profitability of different infections and distribution by type of care

Each represents one infection. The distribution of cases by type of care is highlighted in different colors within each bar. The profitability of each infection category is shown in the bubbles above each bar. In total, university hospitals treated 48% of all infection cases. The total average cost coverage was -21%.

Source: DRG project 2019

4.2.3 Reason for admission

Profitability varies significantly by admission reason. Cases that were admitted due to an *emergency* or were *transfers* incur much higher financial losses than cases recorded as *planned admissions* (see Table 26). The largest losses were incurred by cases admitted as transfers (under 24 hours). The financial losses caused by cases with the admission reason *transfer* (over 24 hours) were approximately five times higher compared with cases with the admission reason *planned admission* (loss of 28% vs. 6%).

The distribution by admission reason varies among care types. Out of the 289-case sample at primary care providers, no *transfers* were registered, with the majority of cases being *emergency* admissions. Similar trends were seen in focus care and maximum care facilities, where *transfers* made up only around 1% of the cases registered, based on sample sizes of 1,062 and 630 respectively. University hospitals have a higher proportion of cases with the admission reason *transfer* than other types of care (see Figure 35).

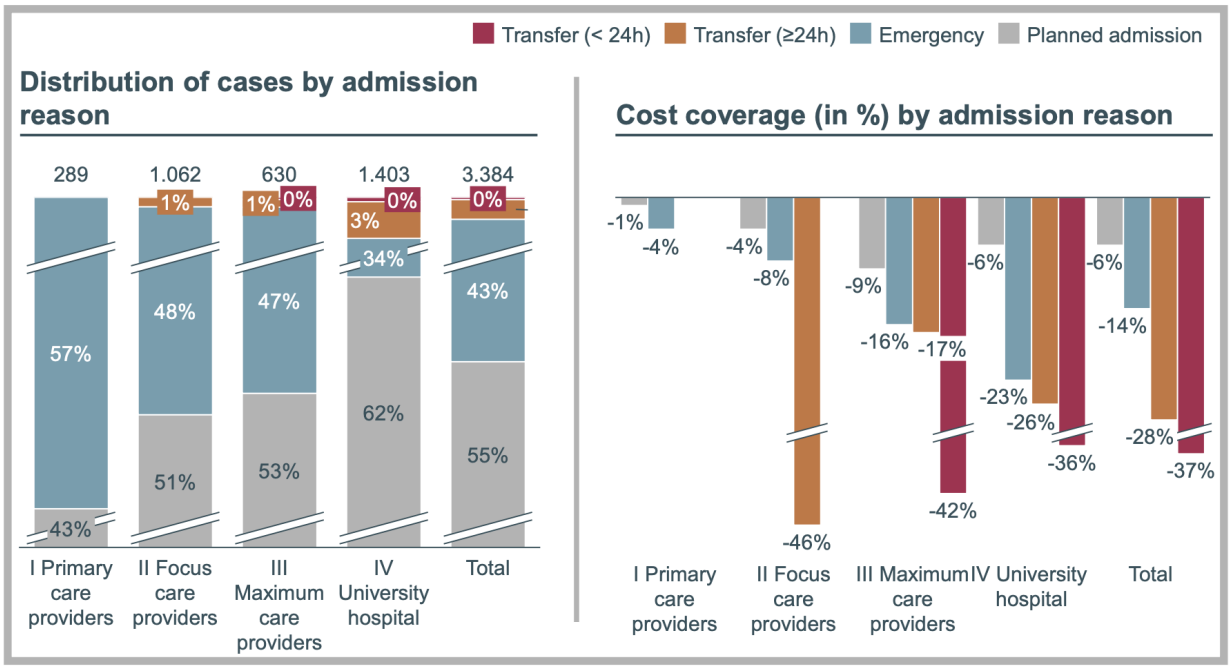

Figure 35 Distribution and profitability (cost coverage) of cases by admission reason and type of care

Left: One bar represents the distribution of cases by reason for admission for each type of care. Sample sizes ranged from 289 for primary care providers, to 1,403 for university hospitals, with the total sample amounting to 3,384 cases. Of this, the largest proportions of cases at all care facilities were emergency and regular admissions, with transfers accounting for 1% of cases in focus and maximum care facilities, and 3% of university hospital cases. Primary care providers encountered no transfer cases.

Right: The profitability by reason for admission and type of care. Cases which are transferred from another hospital with less than 24h stay at the referring hospital are highlighted in red. The transfer cases with a greater or equal to 24h length of stay are highlighted in orange. The largest losses were seen in transfer admissions, with regular admissions causing the least financial damage across all care types.

Source: DRG project 2019

4.2.4 Patient clinical complexity level

The profitability varied by PCCL. The PCCL represents the severity of comorbidities and complications. However, as IBD patients are relatively young, the PCCL should be interpreted with caution. As seen on the left side of Figure 36, 48% of the 3,385 cases had a PCCL of zero, and the average PCCL number across them was 1.1. The proportion of cases by PCCL across care types was relatively similar, with no notable variations between them.

All cases in the sample experienced financial losses, except the PCCL of 3 at focus care providers, which broke even (Figure 36: right). Across all cases, the PCCL of 2 had the highest financial loss, amounting to 23%. The smallest losses were incurred by PCCL 0 and 3, both reaching a 6% loss)

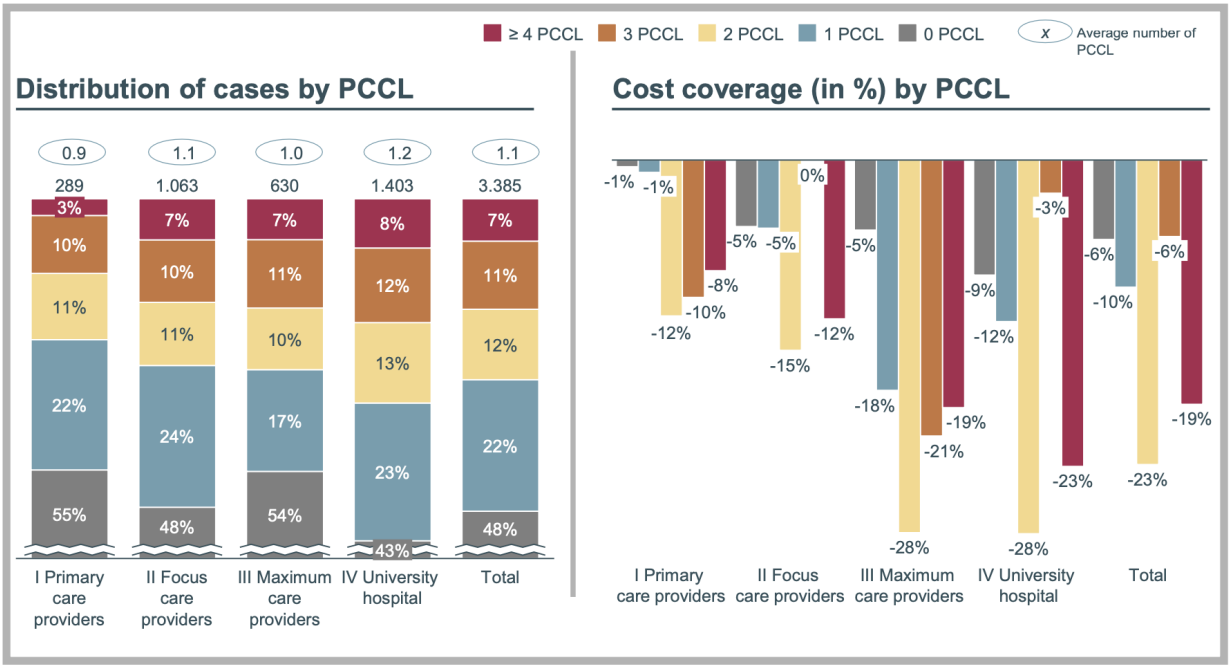

Figure 36 Distribution and profitability (cost coverage) of cases by PCCL and type of care

Left: One bar represents the distribution of cases by PCCL number for each type of care. The largest proportion of cases at all care facilities had a PCCL of zero, with the proportion reducing as the PCCL number increased.

Right: The profitability by PCCL number and type of care. PCCL 2 cases incurred the largest financial losses, amounting to 28% in total. The smallest losses were incurred by PCCL 0 and 3, both reaching a 6% loss.

Source: DRG project 2019

4.2.5 Length of stay

We then examined the length of stay and financial loss. As expected, cases with a length of stay above the average length of stay (ALOS) are more loss-making than cases below the ALOS. Figure 37 (right) shows that cases with a length of stay over 1.8x ALOS incurred a 53% financial loss. Cases with a length of stay equal to 1.6x ALOS saw losses of 33% and those with 1.2x ALOS saw a 15% financial loss. Meanwhile, cases admitted for a duration of 0.8x and 0.4x ALOS saw profits of 8% and 28% respectively. The distribution of cases by the relative length of stay showed no significant variation by care type (Figure 37: left), with the largest proportion of total cases staying for a duration of 0.4x ALOS, and representing 23% of all cases. The least frequent length of was 1.6x ALOS, making up 9% of all cases.

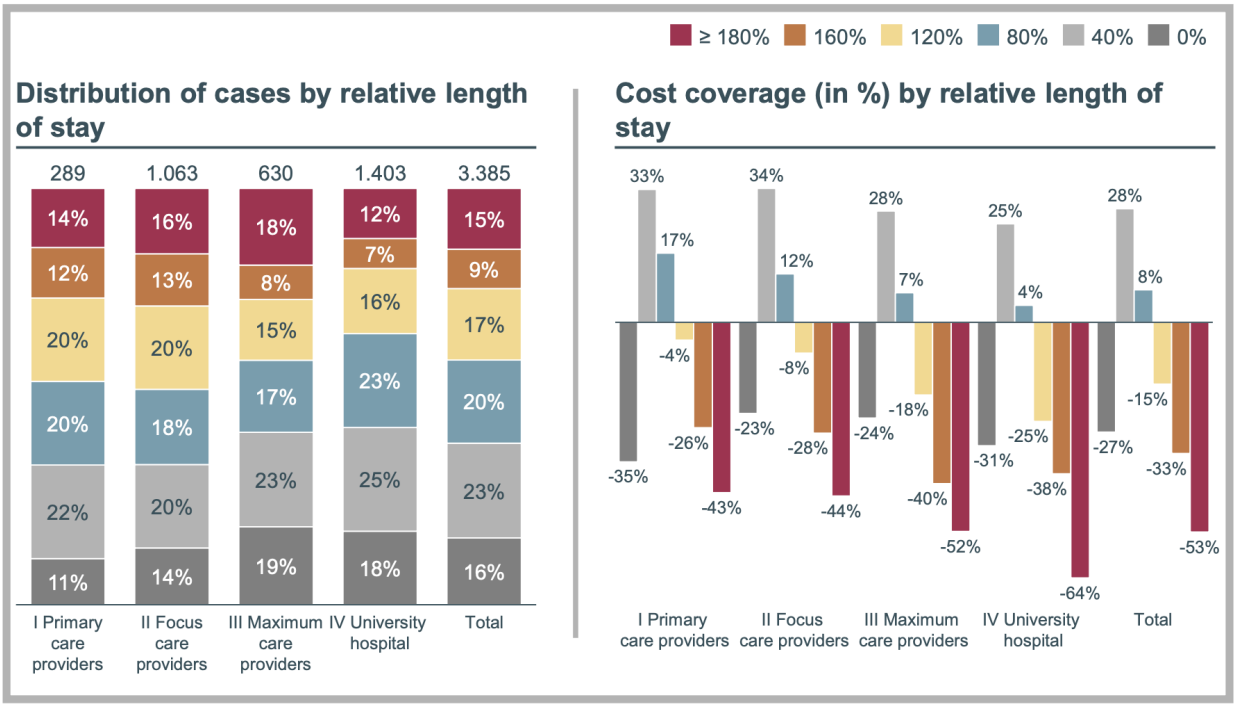

Figure 37 Distribution and profitability (cost coverage) of cases by the relative length of stay and type of care

Cases were grouped into 6 categories by relative lengths of stay, rounding the relative lengths of stay to the nearest 40%.

Left: One bar represents the distribution of cases by the length of stay relative to ALOS by type of care. The proportions of relative lengths of stay are similar across all care types, with 0.4x ALOS representing the largest proportion, equal to 23% of the total.

Right: The profitability by the length of stay and type of care. Stays for longer than the ALOS (≥180%, 160%, and 120%) are all loss-making, with losses ranging from 15% to 53%. Stays for less than the ALOS (80% and 40%) generate profits equal to 8% and 28% respectively.

Source: DRG project 2019

4.3 Cases with a high number of specific procedures, surgical DRG partitions, and additional charges are also not treated in a cost-covering manner

4.3.1 Specific procedures

Cases with a high number of specific procedures had a high financial loss. The financial loss incurred by cases with four specific procedures was approximately 15 times higher compared to cases without any specific procedures (33% compared with 2%) (see Table *12*). With reference to the right side of Figure 38, cases with specific procedures experienced cost under-coverage in all types of care centers, except at primary care providers where cases with 0 and 2 procedures booked profits of 3%. As mentioned before, the largest financial losses were seen in cases with over 2 specific procedures, and the lowest were seen in cases with none. In the presence of at least 1 specific procedure, university hospitals booked the largest financial losses of all the subcategories, while for cases with than 2 specific procedures, primary care provides had the largest financial losses of 23%, compared to the 21% at university hospitals. The left side of Figure 38, shows us that most of the sampled patients undertook only 1 specific procedure (46% of the total), with the average number of specific procedures amounting to 1.33. Cases with more than 2 specific procedures were significantly less common within the sample, with only about 304 patients out of the 3,385 (9%) encountering this.

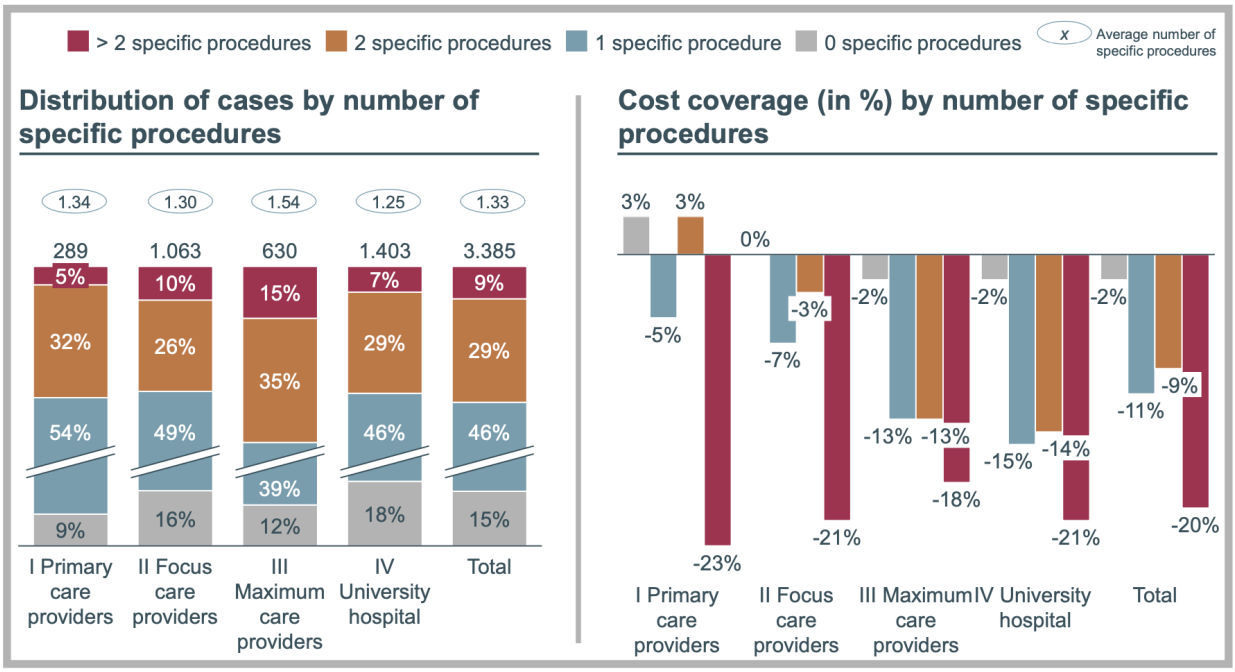

Figure 38 Distribution and profitability (cost coverage) of cases by the number of specific procedures and type of care

Left: Each represents the distribution of cases by the number of specific procedures per type of care. The bubble above each bar indicates the average number of specific procedures at each of the care facilities. The largest proportion of cases at all care facilities are those with 1 specific procedure, and the smallest are those with over 2 specific procedures. The average number of specific procedures across all facilities is 1.33.

Right: The profitability by the number of specific procedures and type of care. The most loss-making cases are those with over 2 specific procedures, with 20% losses on average. Cases with 1-2 specific procedures incurred relatively similar losses at all care facilities, except at primary care providers. Primary care providers generated small profits when treating cases with 0 and 2 specific procedures.

Source: DRG project 2019

Table 12 Overview of cost recovery by type of care and specific procedures

Type of care		Number of specific procedures					
		0 specific procedures	1 specific procedure	2 specific procedures	3 specific procedures	4 specific procedures	Total
I Primary care provider	**Average profit/loss**	**3%**	**-5%**	**3%**	**-18%**	**-92%**	**-3%**
	Significance unequal 0	0.31	0.04	0.23	0.02		0.08
	Standard deviation	31%	40%	33%	34%	-	37%
	Number of cases	26	156	92	14	1	289
II Focus provider	**Average profit/loss**	**0%**	**-7%**	**-3%**	**-19%**	**-51%**	**-6%**
	Significance unequal 0	0.45	<0.001	0.11	<0.001	<0.001	<0.001
	Standard deviation	43%	46%	40%	45%	36%	44%
	Number of cases	166	522	274	95	6	1063
III Maximum care provider	**Average profit/loss**	**-2%**	**-13%**	**-13%**	**-19%**	**-4%**	**-13%**
	Significance unequal 0	0.34	<0.001	<0.001	<0.001	0.39	<0.001
	Standard deviation	45%	44%	42%	37%	34%	43%
	Number of cases	73	244	221	86	6	630
IV University hospital	**Average profit/loss**	**-2%**	**-15%**	**-14%**	**-20%**	**-35%**	**-13%**
	Significance unequal 0	0.21	<0.001	<0.001	<0.001	0.003	<0.001
	Standard deviation	50%	69%	50%	62%	31%	60%
	Number of cases	256	645	400	96	6	1403
Total	**Average profit/loss**	**-2%**	**-11%**	**-9%**	**-19%**	**-33%**	**-10%**
	Significance unequal 0	0.23	<0.001	<0.001	<0.001	<0.001	<0.001
	Standard deviation	46%	56%	45%	49%	39%	51%
	Number of cases	521	1567	987	291	19	3385

There are 645 cases with one specific procedure at university hospitals; on average, these present with a 15% deficit with a standard deviation of 69%.

4.3.2 DRG partition

The DRG partition, determined by the second and third digits of the DRG code, identifies the type of treatment, which may be *surgical*, *medical*, or *other*. Profitability varies significantly by DRG partition. The financial loss of cases with medical DRG partition was about twice as high compared with cases with surgical DRG partition (17% versus 9% financial loss). The database only includes cases with IBD as the principal diagnosis and therefore cases admitted primarily through gastroenterology. The left side of Figure 39 shows that *surgical* partitions make up a relatively small proportion of cases at all care centers, representing only 16% of the total. *Medical* and *other* partitions make up the largest proportion of all cases across all facilities. In terms of cost coverage, *medical* partitions incur the highest losses at all facilities, except at primary care providers, where they come a close second. Excluding focus care providers which generated a 1% profit on their 467 *other* cases, all other care facilities incurred losses, regardless of the DRG partition (see Figure 39: right side).

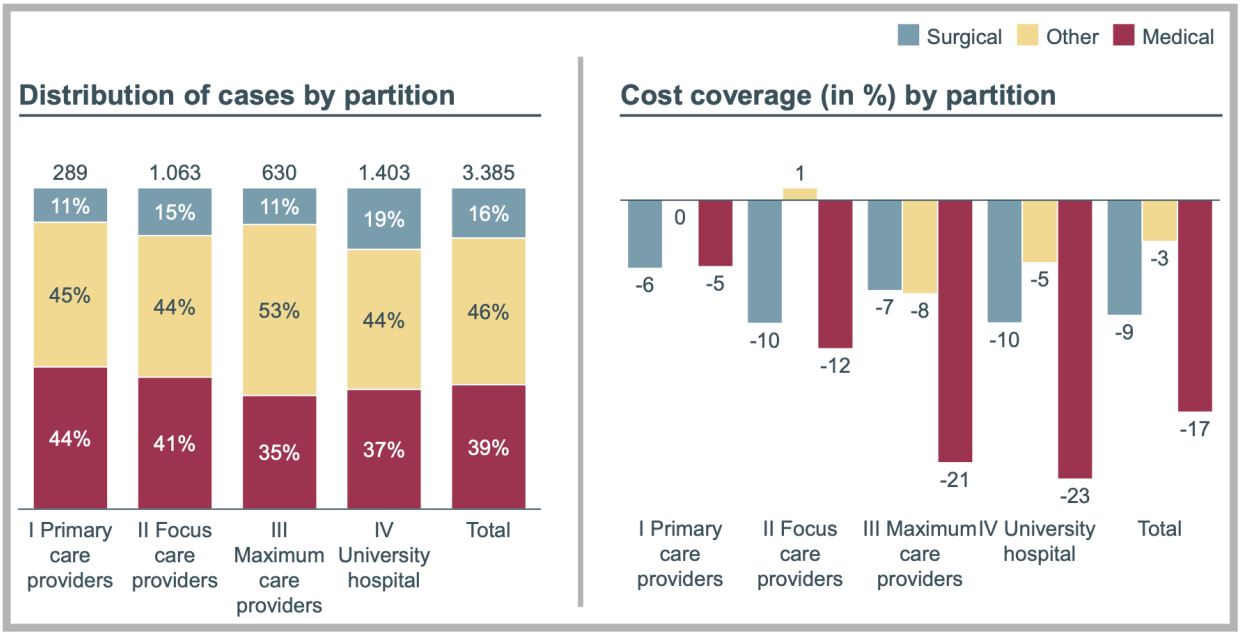

Figure 39 Distribution and profitability (cost coverage) of cases by partition (surgical, medical, and other) and type of care

Left: Each represents the distribution of cases by partition (surgical, medical and other) per type of care. 39% of the 3,385 cases were medical*, 16% were* surgical*, and 46% were classified in the* other *DRG partition.*

Right: The profitability by partition and type of care. Medical *partitions generated the largest losses at most care centers and represented a 17% cost under-coverage out of the total.* Surgical *partitions generated losses of 9% out of the total, with* other *partitions accounting for 3% losses.* Other *partitions generated profits of 1% at focus care providers and broke even at primary care providers.*

Source: DRG project 2019

4.3.3 Additional charges (*Zusatzentgelte*)

University hospitals encounter a significantly higher proportion of cases with additional charges, nameley 17.6% (Figure 40: left side), while primary care providers encountered the fewest cases with additional charges. Cases with additional charges treated at university hospitals tend to be less deficient, in terms of financial viability, than at other types of care. Overall, the financial loss incurred by cases without additional charges was approximately twice as high as that of cases with additional charges (a 10% compared to 6% financial loss) (see Table 13 and Figure 40: right side). At both primary and focus care providers, cases with additional charges faced higher losses than cases without additional charges. This loss was particularly significant at primary care providers, where the cost under-coverage amounted to 26%. At maximum care providers and university hospitals, which treated the larger proportions of patients with additional charges (17.6% and 5.7% respectively), cases with additional charges proved to trigger losses amounting to 10% and 3% respectively.

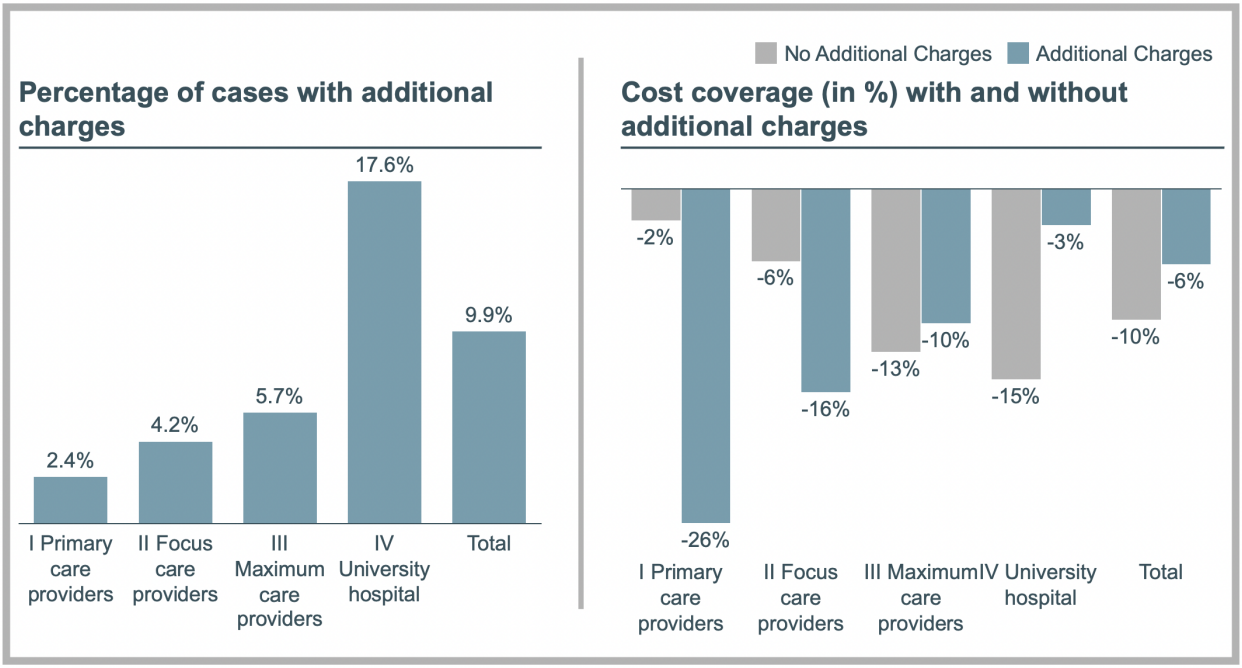

Figure 40 Distribution and profitability (cost coverage) of cases with additional charges by type of care

Left: Each represents the percentage of total cases with at least one additional charge by type of care. University hospitals treated the highest proportion of cases with additional charges, while primary care providers treated the lowest proportion. Overall, 9.9% of all cases sampled had additional charges.

Right: The profitability of cases with (blue bar) and without (grey bar) additional charges. The largest recorded loss was associated with cases at primary care providers that had additional charges, and the smallest financial loss was also recorded at primary care providers for cases without additional charges, amounting to 2%. Overall, cases with additional charges incurred approximately half the losses incurred by those without additional charges. However, this varies by care type, in that primary and focus care providers incurred larger losses for cases with additional charges, while maximum care providers and university hospitals incurred larger losses for cases with additional charges.

Source: DRG project 2019

Table 13 Overview of cost recovery by type of care and additional charges

Type of care		Without additional charges	With additional charges	Total
I Primary care provider	**Average profit/loss**	**-2%**	**-26%**	**-3%**
	Significance unequal 0	0.13	<0.001	0.08
	Standard deviation	37%	19%	37%
	Number of cases	282	7	289
II Focus provider	**Average profit/loss**	**-6%**	**-16%**	**-6%**
	Significance unequal 0	<0.001	<0.001	<0.001
	Standard deviation	45%	31%	44%
	Number of cases	1018	45	1063
III Maximum care provider	**Average profit/loss**	**-13%**	**-10%**	**-13%**
	Significance unequal 0	<0.001	0.07	<0.001
	Standard deviation	43%	42%	43%
	Number of cases	594	36	630
IV University hospital	**Average profit/loss**	**-15%**	**-3%**	**-13%**
	Significance unequal 0	<0.001	0.13	<0.001
	Standard deviation	64%	40%	60%
	Number of cases	1156	247	1403
Total	**Average profit/loss**	**-10%**	**-6%**	**-10%**
	Significance unequal 0	<0.001	0.003	<0.001
	Standard deviation	52%	39%	51%
	Number of cases	3050	335	3385

There are 247 cases with additional charges at university hospitals; on average, these present with a 3% deficit with a standard deviation of 40%.

4.4 At the DRG code level, we observe largely the same trends as at the aggregate level

Of the 59 DRG codes analyzed, 44 incurred an average financial loss, while 15 generated an average profit (Figure 41). The reported cost coverage varied between approximately -€13,000 and +€10,000. Two DRG codes, G64B and G47B (see grey shaded area in Figure 41), incurred losses equivalent to €273 and €132 respectively, yet they accounted for 70% of cases. Hence, we performed the analyses from sections 4.211 and 4.2.3 specifically for these two codes, the results of which may be found in Table 14, Table 15, Table 16, and Table 17.

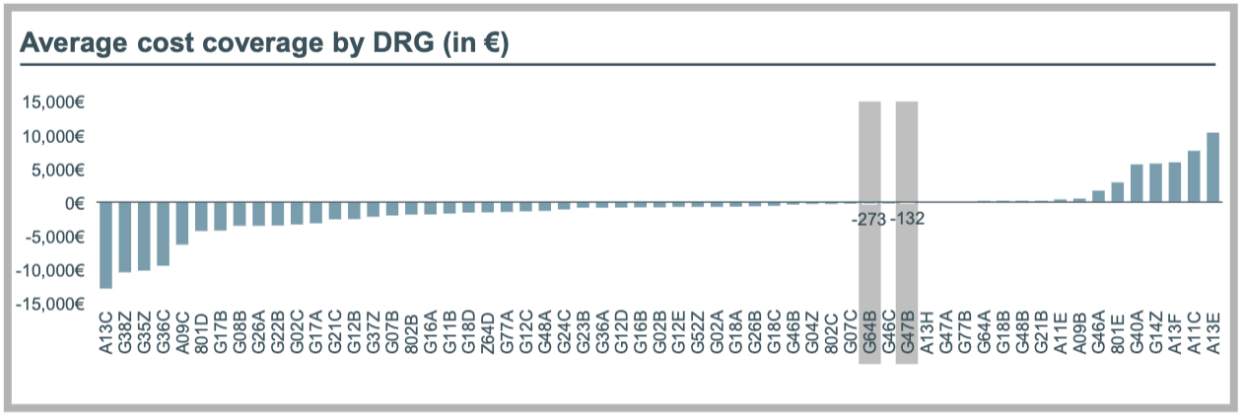

Figure 41 Average profitability (cost coverage) by DRG code (in €)

The figure shows 59 bars, representing the 59 unique DRG codes that are classified within the sample. Each represents the average absolute profitability for a single DRG code. While 15 codes generated profits, the remaining 44 incurred losses. DRG codes G64B and G47B represented 70% of the sampled cases.

Source: DRG project 2019

Table 14 G64B: Overview of cost recovery by type of care and number of complications

G64B		Number of gastroenterological complications				
Type of care		0 complications	1 complication	2 complications	>2 complications	Total
I Primary care provider	**Average profit/loss**	**-2%**	**-26%**			**-6%**
	Significance unequal 0	30%	0%			4%
	Standard deviation	35%	46%			38%
	Number of cases	105	20			125
II Focus provider	**Average profit/loss**	**-12%**	**-11%**	**-58%**	**-68%**	**-13%**
	Significance unequal 0	<0.001	0.9%	<0.001	<0.001	<0.001
	Standard deviation	46%	45%	15%	22%	45%
	Number of cases	323	88	4	2	417
III Maximum care provider	**Average profit/loss**	**-21%**	**-29%**	**23%**		**-22%**
	Significance unequal 0	<0.001	0.2%			<0.001
	Standard deviation	46%	49%			46%
	Number of cases	188	23	1		212
IV University hospital	**Average profit/loss**	**-24%**	**-23%**	**-39%**		**-24%**
	Significance unequal 0	<0.001	<0.001	0.9%		<0.001
	Standard deviation	85%	52%	46%		77%
	Number of cases	367	128	8		503
Total	**Average profit/loss**	**-17%**	**-20%**	**-40%**	**-68%**	**-18%**
	Significance unequal 0	<0.001	<0.001	<0.001	<0.001	<0.001
	Standard deviation	63%	49%	42%	22%	60%
	Number of cases	983	259	13	2	1257

G64B: There are 128 cases with one gastroenterological complication at university hospitals; on average, these present with a 23% deficit with a standard deviation of 52%.

Table 15 G47B: Overview of cost recovery by type of care and number of complications

G47B		Number of gastroenterological complications				
Type of care		0 compli-cations	1 compli-cation	2 compli-cations	>2 com-plica-tions	Total
I Primary care provider	**Average profit/loss**	**1%**	**-23%**		**55%**	**-2%**
	Significance unequal 0	0.43	0.03			32%
	Standard deviation	35%	46%			38%
	Number of cases	91	13		1	105
II Focus provider	**Average profit/loss**	**0%**	**1%**	**-19%**		**0%**
	Significance unequal 0	0.43	0.39	0.07		46%
	Standard deviation	44%	40%	36%		43%
	Number of cases	293	83	8		384
III Maximum care provider	**Average profit/loss**	**-11%**	**-18%**	**-54%**		**-13%**
	Significance unequal 0					
	Standard deviation	38%	45%	19%		39%
	Number of cases	193	33	3		229
IV University hospital	**Average profit/loss**	**-12%**	**-6%**	**-14%**		**-11%**
	Significance unequal 0	<0.001	0.06	0.20		<0.001
	Standard deviation	57%	41%	44%		53%
	Number of cases	284	95	7		386
Total	**Average profit/loss**	**-6%**	**-6%**	**-23%**	**55%**	**-6%**
	Significance unequal 0	<0.001	0.01	0.01		<0.001
	Standard deviation	47%	42%	38%		46%
	Number of cases	861	224	18	1	1104

G47B: There are 95 cases with one gastroenterological complication at university hospitals; on average, these present with a 6% deficit with a standard deviation of 41%. "

Table 16 G64B: Overview of cost recovery by type of care and admission reason

G64B		Admission reason				
Type of care		Planned admis-sion	Emer-gency	Transfer (≥24h)	Trans-fer (<24h)	Total
I Primary care provider	**Average profit/loss**	**0%**	**-9%**			**-6%**
	Significance unequal 0	49%	0.01			4%
	Standard deviation	43%	34%			38%
	Number of cases	47	78			125
II Focus pro-vider	**Average profit/loss**	**-16%**	**-10%**	**-1%**		**-13%**
	Significance unequal 0	<0.001	<0.001			<0.001
	Standard deviation	50%	41%	23%		46%
	Number of cases	198	215	3		416
III Maximum care provider	**Average profit/loss**	**-23%**	**-21%**	**-25%**	**-42%**	**-22%**
	Significance unequal 0	<0.001	<0.001			<0.001
	Standard deviation	48%	45%	4%		46%
	Number of cases	107	102	2	1	212
IV University hospital	**Average profit/loss**	**-18%**	**-31%**	**-40%**	**-61%**	**-24%**
	Significance unequal 0	<0.001	<0.001	0.15		<0.001
	Standard deviation	91%	52%	41%	85%	77%
	Number of cases	291	199	11	2	503
Total	**Average profit/loss**	**-17%**	**-19%**	**-31%**	**-55%**	**-18%**
	Significance unequal 0	<0.001	<0.001	0.06		<0.001
	Standard deviation	71%	46%	38%	61%	60%
	Number of cases	643	594	16	3	1256

G64B: There are 199 cases with the admission reason "emergency" at university hospitals; on average, these present with a 31% deficit with a standard deviation of 52%. 1 case with the admission reason "dentist" has been excluded from this analysis.

Table 17 G47B: Overview of cost recovery by type of care and admission reason

G47B		Admission reason			
Type of care		Planned admission	Emergency	Transfer (≥24h)	Total
I Primary care provider	**Average profit/loss**	**-4%**	**0%**		**-2%**
	Significance unequal 0	25%	49%		
	Standard deviation	40%	36%		38%
	Number of cases	45	60		105
II Focus provider	**Average profit/loss**	**5%**	**-4%**	**-16%**	**0%**
	Significance unequal 0	7%	8%		
	Standard deviation	44%	41%		43%
	Number of cases	190	193	1	384
III Maximum care provider	**Average profit/loss**	**-8%**	**-17%**		**-13%**
	Significance unequal 0	1%	<0.001		
	Standard deviation	36%	41%		39%
	Number of cases	118	111		229
IV University hospital	**Average profit/loss**	**-2%**	**-25%**	**-18%**	**-11%**
	Significance unequal 0	23%	<0.001		
	Standard deviation	49%	59%	32%	53%
	Number of cases	242	137	7	386
Total	**Average profit/loss**	**-1%**	**-12%**	**-18%**	**-6%**
	Significance unequal 0	22%	<0.001		
	Standard deviation	45%	47%	30%	46%
	Number of cases	595	501	8	1104

G47B: There are 137 cases with the admission reason "emergency" at university hospitals; on average, these present with a 25% deficit with a standard deviation of 59%.

A positive relationship may be observed between a high number of gastroenterological complications and high financial losses. Similarly, cases with fewer gastroenterological complications displayed lower financial losses. For example, cases with DRG code G64B experiencing at least three complications have a financial loss of 24%, whereas cases with no complications have a financial loss of 9% (see Table 14). Additionally, cases with DRG code G47B with two complications incur a financial loss of 23%, whereas cases without complications incur a financial loss of only 6% (see Table 15).

Cases with the admission reason *emergency* or *transfer* have a higher financial loss than cases with the admission reason *planned admission* (Table 16 and Table 17). The financial loss of cases with the admission reason *transfer* (over 24 hours) was significantly higher for cases with DRG code G64B compared with cases with the admission reason *planned admission* (31% compared with 17%). There are no sampled transfer cases for cases with DRG code G47B, however, cases with the admission reason *emergency* faced a significantly higher financial loss than cases with the admission reason *planned admission* (12% compared with 1%) (see Table 16 and Table 17).

For the other variables examined (infections and number of specific procedures), we observed similar trends as were identified in the aggregate analysis, i.e., high complexity correlates with high financial loss.

Furthermore, we analyzed the extreme cost cases looking at cases with the highest 2% and lowest 2% of costs. We found that for G64B, university hospitals treat more high-cost cast cases than non-university hospitals (4% vs. 1% for maximum care providers and 0% for focus and primary care providers) (see Table 18).

Table 18 Extreme cost case analysis of G64B, G47B and G48B

G64B	Total number of cases	Number of cases: 2% highest costs	Number of cases: 2% lowest cost
I Primary care provider	125	0 (0%)	1 (1%)
II Focus provider	417	2 (0%)	13 (3%)
III Maximum care provider	212	2 (1%)	5 (2%)
IV University hospital	503	21 (4%)	6 (1%)
Total	1257	25 (2%)	25 (2%)
G47B			
I Primary care provider	105	0 (0%)	0 (0%)
II Focus provider	384	0 (0%)	15 (4%)
III Maximum care provider	229	1 (0%)	2 (1%)
IV University hospital	386	20 (5%)	6 (2%)
Total	1104	21 (2%)	23 (2%)
G48B			
I Primary care provider	18	1 (6%)	0 (0%)
II Focus provider	48	0 (0%)	1 (2%)
III Maximum care provider	66	3 (5%)	0 (0%)
IV University hospital	130	1 (1%)	4 (3%)
Total	262	5 (2%)	5 (2%)

4.5 Cases with DRG G64B and G47B and the admission reason *transfer* show significantly higher costs than the InEK costs

For the InEK cost comparison, i.e., the comparison at the DRG level, the analyzed case costs of the three most frequent IBD-DRGs are higher than the InEK costs for inlier patients. However, the difference between the actual costs and the InEK costs is lower than the InEK standard deviation for all three DRGs (see Table 19).

Table 19 Actual costs (inliers of the dataset) and InEK costs compared

DRG-Code	Number inlier (regrouped 2021)	Ø Actual costs: inlier excl. nursing personnel (regrouped 2021)	Costs InEK	Costs InEK standard deviation	Difference between actual costs and InEK costs
G64B	977	€2,350	€1,771	€789	€579
G47B	938	€2,821	€2,344	€1,066	€477
G48B	121	€4,128	€3,954	€1,741	€174
Grouped according to DRG 2021, for G64B 1 case with €0 costs excluded, for all three DRGs the difference between actual and InEK costs is less than the InEK standard deviation.					

A closer look at the three most frequent IBD-DRGs (G64B, G47B, and G48B) shows that for G64B and G47B the cases with the admission reason *transfer* have significantly higher costs than the InEK costs; therefore the difference between the actual costs and the InEK costs is higher than the InEK standard deviation (see Table 20 and Table 21). With respect to G48B, higher costs were identified in cases with the admission reason *transfer*, but the difference is lower than the InEK standard deviation (see Table 22). Furthermore, significantly higher costs were found for G64B for cases at university hospitals (see Table 20). For G47B for cases with 2 complications (see Table 21) and for G48B for cases with two infections (see Table 22) higher costs were found, but the number of cases is too low to interpret the data (n=7 and n=1 respectively).

Table 20 G64B: Comparison of costs of inlier cases with the InEK costs

Number of gastro-enterological complications	Number inlier (regrouped 2021)	Ø Actual costs: inlier excl. nursing personnel (regrouped 2021)	Costs InEK	Costs InEK standard deviation	Difference between actual costs and InEK costs
0 complications	767	€2,353	€1,771	€789	€582
1 complication	202	€2,351	€1,771	€789	€580
2 complications	8	€2,065	€1,771	€789	€294
Admission reason					
Planned admission	466	€2,264	€1,771	€789	€493
Emergency	496	€2,426	€1,771	€789	€655
Transfer (≥24h)	12	€2,432	€1,771	€789	€661
Transfer (<24h)	2	€3,854	€1,771	€789	€2,083
Transfer (total)	14	€2,635	€1,771	€789	€864
Infections					
0 infections	964	€2,344	€1,771	€789	€573
1 infection	13	€2,766	€1,771	€789	€995
Type of care					
I Primary care provider	99	€1,839	€1,771	€789	€68
II Focus provider	329	€2,000	€1,771	€789	€229
III Maximum care provider	145	€2,127	€1,771	€789	€356
IV University hospital	404	€2,840	€1,771	€789	€1,069
Total	977	€2,350	€1,771	€789	€579

G64B: Average inlier costs of €2350 and InEK costs of €1771; the difference between actual costs and InEK costs is higher than the standard deviation in transfer cases and in cases at university hospitals (highlighted in yellow).
Cost data from 2019, regrouped according to DRG 2021, one case with €0 costs excluded, in the breakdown by admission reason, one case with the admission reason "dentist" was excluded from the analysis.

Table 21 G47B: Comparison of costs of inlier cases with the InEK costs

Number of gastro-enterological complications	Number inlier (regrouped 2021)	Ø Actual costs: inlier excl. nursing personnel (regrouped 2021)	Costs InEK	Costs InEK standard deviation	Difference between actual costs and InEK costs
0 complications	737	€2,776	€2,344	€1,066	€432
1 complication	186	€2,880	€2,344	€1,066	€536
2 complications	15	€4,289	€2,344	€1,066	€1,945
Admission reason					
Planned admission	489	€2,609	€2,344	€1,066	€265
Emergency	442	€3,006	€2,344	€1,066	€662
Transfer (≥24h)	7	€5,947	€2,344	€1,066	€3,603
Infections					
0 infections	903	€2,824	€2,344	€1,066	€480
1 infection	35	€2,745	€2,344	€1,066	€401
Type of care					
I Primary care provider	93	€2,360	€2,344	€1,066	€16
II Focus provider	320	€2,484	€2,344	€1,066	€140
III Maximum care provider	193	€2,748	€2,344	€1,066	€404
IV University hospital	332	€3,317	€2,344	€1,066	€973
Total	938	€2,821	€2,344	€1,066	€477

G47B: Average inlier costs of €2821 and InEK costs of €2344; the difference between the actual costs and the InEK costs is higher than the standard deviation for transfer cases and for cases with 2 complications (highlighted in yellow).
Cost data from 2019, regrouped according to DRG 2021

Table 22 G48B: Comparison of costs of inlier cases with the InEK costs

Number of gastroenterological complications	Number inlier (regrouped 2021)	Ø Actual costs: inlier excl. nursing personnel (regrouped 2021)	Costs InEK	Costs InEK standard deviation	Difference between actual costs and InEK costs
0 complications	68	€4,135	€3,954	€1,746	€181
1 complication	42	€4,173	€3,954	€1,746	€219
2 complications	8	€4,059	€3,954	€1,746	€105
>2 complications	3	€3,514	€3,954	€1,746	-€440
Admission reason					
Planned admission	55	€4,151	€3,954	€1,746	€197
Emergency	63	€4,118	€3,954	€1,746	€164
Transfer (≥24h)	3	€3,917	€3,954	€1,746	-€37
Infections					
0 infections	107	€4,105	€3,954	€1,746	€151
1 infection	13	€3,903	€3,954	€1,746	-€51
2 infections	1	€9,477	€3,954	€1,746	€5,523
Type of care					
I Primary care provider	9 €	€3,428	€3,954	€1,746	-€526
II Focus provider	33 €	€4,055	€3,954	€1,746	€101
III Maximum care provider	18 €	€4,418	€3,954	€1,746	€464
IV University hospital	61 €	€4,185	€3,954	€1,746	€231
Total	121	€4,128	€3,954	€1,746	€174

G48B: Average inlier costs of €4128 and InEK costs of €3954; the difference between the actual cost and the InEK cost for a case with 2 infections is higher than the standard deviation (marked in yellow).
Cost data from 2019, grouped according to DRG 2021

4.6 Summary of the Results

Hypothesis 1: The costs of complex cases are not recovered to the same extent as those of non-complex cases.

This hypothesis holds true. Across different indicators for complexity including the number of complications, infections, admission reason, and others, the deficit is higher for complex cases than for less complex cases. Furthermore, non-complex cases are on average also not treated in a cost-covering manner.

At the DRG level, the costs are higher than the reimbursements for the six most prominent DRGs, however, the difference between the actual costs and the InEK costs is lower than the InEK standard deviation at the DRG level. Nevertheless, for selected complexities such as the admission reason *transfer*, the difference between the actual costs and the InEK costs is higher than the InEK standard deviation.

Hypothesis 2: Complex cases occur more frequently in centers than in other types of hospitals.

This hypothesis could not be validated by the given data. Table 9 summarizes the frequency of the different complexity factors. We only observed a significant difference in the distribution of complex vs. non-complex cases with regard to admission reasons. Here, we found that cases with the admission reason *transfer* are significantly overrepresented at university hospitals, when compared to all other care types.

Table 23 Frequency of different complexity factors

	I Primary care provider	II Focus provider	III Maximum care provider	IV University hospital	Total
Average number of gastroenterological complications	0.26	0.42	0.29	0.47	0.40
Average number of infections	0.03	0.06	0.06	0.07	0.06
Average of special procedures	1.34	1.30	1.54	1.25	1.33
Average of PCCL	0.84	1.05	1.02	1.23	1.10
Share of cases with additional charges	2%	4%	6%	18%	10%
Share of cases with admission reason transfer	0%	1%	1%	3%	2%
Number of cases	289	1,063	630	1,403	3,385

Hypothesis 3: The G-DRG system does not reflect the complexity of centers appropriately.

While all types of care do not treat IBD in a cost covering manner, university hospitals had a consistently higher cost under-coverage than all other types of hospitals. As Figure 30 illustrates, on average, no maximum care provider or university hospital treated IBD in a cost-covering manner, while some primary care and focus care providers were able to.

5 Discussion

Based on the case and cost data of hospitals in the DGVS-DRG project, the present retrospective analysis investigated the reimbursement status of IBD. In summary, the analysis revealed that inpatient treatment of IBD in hospitals is not reimbursed in a cost-covering manner. To further understand the factors that contribute to the financial loss, we analyzed the reimbursement situation with regard to complications, infections, admission reasons, special procedures, PCCL, and length of stay.

5.1 Proposition 1: Higher remuneration for complex cases

A substantial subgroup of inpatients comprises patients with complications, as the majority of non-complicated cases may also be treated on an outpatient basis [3–5]. For the purpose of this analysis, we define complex cases as those with gastroenterological complications, infections, and specific surgeries and procedures. These cases displayed higher financial losses than cases of a less complex nature. It is notable that for gastroenterological complications, infections, and specific operations and procedures, the average financial loss increases with the number of complications (see Table 24).

Table 24 Overview of cost recovery by number of different complications

	Number of complications			
	0	**1**	**2**	**>2**
Gastroenterological complications	-9%	-11%	-13%	-24%
Infections	-9%	-20%	-37%	-44%
Specific procedures	-2%	-11%	-9%	-20%
	Planned admission	**Emer-gency**	**Transfer (≥24h)**	**Transfer (<24h)**
Admission reason	-6%	-14%	-28%	-37%

While the average revenue per case also increases with the number of complications, this increase is less than proportional to the increase in the average cost, resulting in cost under-coverage (see Table 25).

Table 25 Overview of costs and gastroenterological complications

Number of gastroenterological complications	Average costs	Average reimbursement
0 complications	€3,967	€3,863
1 complication	€5,803	€5,348
2 complications	€11,765	€11,089
>2 complications	€27,193	€22,547

The financial loss may be lowered by adjusting the reimbursement for complications and infections, as well as by adapting the reimbursement for specific operations and procedures.

Emergency admissions are associated with higher costs than cases with regular admissions. The substantial loss incurred by cases with emergency admission amounts to 14%, compared with a 6% loss for cases with planned admission (see Table 26). Surcharges and discounts for participation in emergency care are agreed upon at a flat rate per hospital and billed per full inpatient case [64]. Cases that are transferred are billed by each treating hospital according to the respective DRG rate. However, if the average length of stay is exceeded, a deduction is applied at the admitting hospital.

The present analysis demonstrates that cases with *transfer* as the admission reason face particularly high financial losses (see Table 26). This can be explained by the

fact that most often particularly complex cases are transferred. Cases with *transfer* as the admission reason face on average 0.9 gastroenterological complications, while cases with *emergency* or *transfer* as the admission reason have on average 0.4 gastroenterological complications. University hospitals are particularly affected by the complexity of transfer cases; they have significantly more cases with the admission reason transfer than other types of care centers (university hospitals: 3.3% transfer cases, maximum and priority care providers: 0.8% transfer cases, significance: < 0.001). Instead of the existing transfer deduction, a surcharge for admitting hospitals should be considered, in order to better reflect the complexity associated with most transfer patients.

Table 26 Overview of cost recovery by type of care and admission reason

Type of care		Admission reason				
		Planned admission	Emergency	Transfer (≥24h)	Transfer (<24h)	Total
I Primary care provider	**Average profit/loss**	**-1%**	**-4%**			**-3%**
	Significance unequal 0	0.37	0.05			0.08
	Standard deviation	39%	35%			37%
	Number of cases	125	164			289
II Focus provider	**Average profit/loss**	**-4%**	**-8%**	**-46%**		**-6%**
	Significance unequal 0	0.02	<0.001	0.00		<0.001
	Standard deviation	46%	42%	49%		44%
	Number of cases	541	513	8		1062
III Maximum care provider	**Average profit/loss**	**-9%**	**-16%**	**-17%**	**-42%**	**-13%**
	Significance unequal 0	<0.001	<0.001	<0.001		<0.001
	Standard deviation	42%	43%	10%		43%
	Number of cases	332	293	4	1	630
IV University hospital	**Average profit/loss**	**-6%**	**-23%**	**-26%**	**-36%**	**-13%**
	Significance unequal 0	0.00	<0.001	<0.001	0.06	<0.001
	Standard deviation	64%	54%	40%	52%	60%
	Number of cases	873	483	42	5	1403
Total	**Average profit/loss**	**-6%**	**-14%**	**-28%**	**-37%**	**-10%**
	Significance unequal 0	<0.001	<0.001	<0.001	0.02	<0.001
	Standard deviation	54%	46%	40%	46%	51%
	Number of cases	1871	1453	54	6	3384

There are 483 cases with the admission reason "emergency" at university hospitals; on average, these present with a 23% deficit with a standard deviation of 54%.

5.2 Proposition 2: Surcharge for university hospitals

The higher costs of university hospital cases in comparison to those at non-university hospitals can be attributed to higher holding costs (*Vorhaltekosten*). Hospitals are required to constantly maintain infrastructure, materials, and staff to be able to provide high-quality healthcare at all times. The average cost per case at university hospitals is €6,019, of which €2,854 is attributed to personnel costs, €1,708 to infrastructure costs, and €1,458 to material costs (Figure 42). The average cost per case incurred by primary care providers remains the lowest, standing at €3,723. Of this, €1,951 is attributed to personnel costs, €1,187 to infrastructure costs, and €584 to material costs. The personnel cost per case incurred by university hospitals is approximately 46% higher than that of primary care providers.

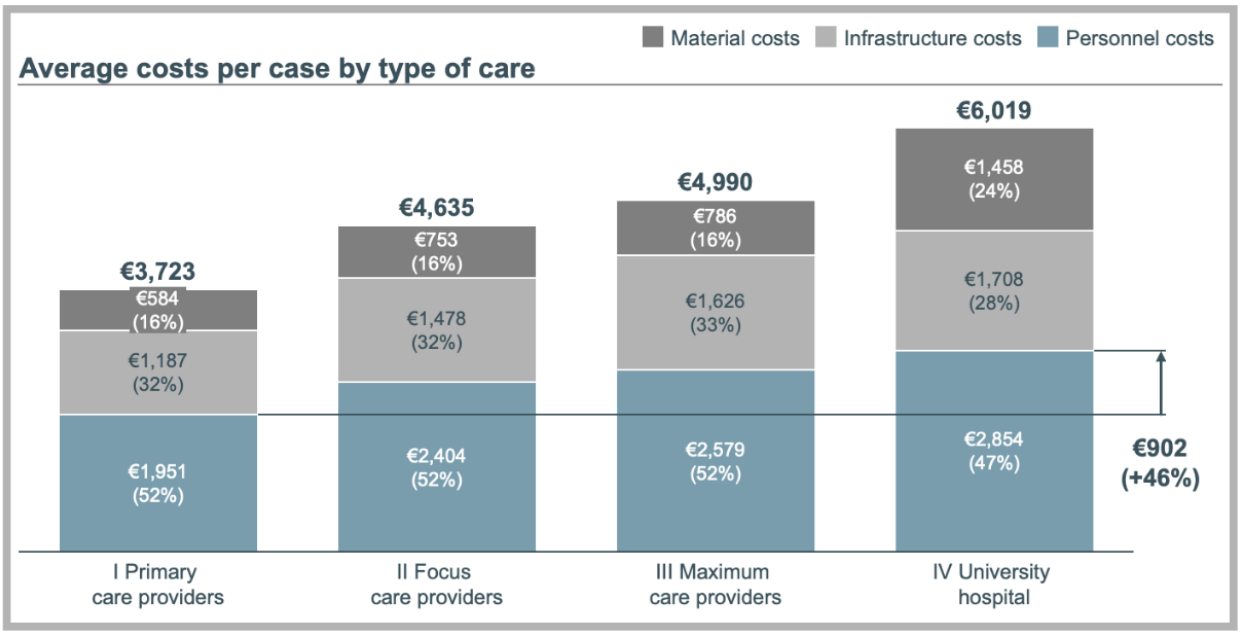

Figure 42 Average cost by type of care

One bar represents the average total costs per case by type of care. These are further subdivided into personnel, infrastructure, and material costs. University hospitals face the highest cost per case of €6,019. Of this, 47% is personnel cost, 28% is infrastructure costs, and 24% is material costs. The average cost per case declines as you move from right to left, with primary care providers facing the lowest average cost per case. At all care centers, personnel cost account for the largest proportion of total costs per case, and material costs account for the smallest.

A 2017 study published by Rathmayer et al. showed that university hospitals are just as cost-effective as non-university hospitals. However, the more complex or high-risk a procedure is, or the more frequently the procedure is performed as an emergency, the higher the associated financial burden [43].

According to Lerch et al., an economically accurate cost representation of the more complex and more severely ill patients at university hospitals is not possible in the current G-DRG system by means of corrections or further differentiation within the existing system. The claim that a further increase in the operating deficit of university hospitals in the provision of health care may only be remedied by either a case-related system surcharge or the separation of a university medical U-DRG system from the general G-DRG system [9]. Maximum care hospitals and university hospitals provide 24/7 complete care for all patients, including those with rare or very special diseases, to be able to treat above-average complexity diseases that cannot be treated in any other hospital due to a lack of equipment and expertise [9]. University hospitals have particularly high costs per case. This can be explained by the higher case severity at university hospitals than at maximum-care hospitals of the same size [43,65,66].

The financing of hospital operating costs is currently primarily based on per-case flat rates. At present, remuneration is linked almost exclusively to the treatment of cases. This creates an incentive to increase the number of cases in order to cover the costs involved with maintaining the hospital [67]. A case-independent reimbursement of holding costs would decouple holding from the economic incentive to expand case numbers [37]. Austria is a case in point: here, the federal states can adjust the relative weights to four types of care, and the per-case flat rates are weighted by a factor. Thus, a university hospital in a city with a high wage level would receive a higher factor than a primary care provider in the countryside with a lower wage level [37].

Furthermore, it is important to note that there is a substantial investment backlog as the states have not covered the required investments (see Chapter 2.3.1) [15].

Germany has taken steps to finance the costs of care through the introduction of a surcharge for the provision of care (*Sicherstellungszuschlag*), center surcharges for medical care centers, and emergency-level surcharges and discounts as part of the Hospital Structure Act. However, surcharges comprise a relatively small volume in comparison with the flat-rate payment per case [59].

6 Implications

6.1 Consider a request to the InEK to adjust reimbursement for selected sub-groups of G64B and G47B cases

Significantly higher costs, and hence a higher difference than the InEK standard deviation, were found for G64B and G47B for cases with the admission reasons and *transfer*, however, the number of cases is relatively small (G64B: 14 transfer cases, G47B: 7 transfer cases) (see Table 20 and Table 21). Here, an adjustment of the flat rate per case has to be considered, and a corresponding application submitted.

6.2 Higher reimbursement for different complexity factors

Alternatively, a reduction of the deficit may be achieved by adjusting the reimbursement of complications and infections, as well as by adjusting the reimbursement of specific operations and procedures.

6.3 Surcharge for “emergency” and “transfer” cases

Given the higher costs associated with *emergency* and *transfer* cases, the abolishment of the transfer-deduction mechanism and a surcharge for cases with the admission reasons *emergency* and *transfer* should be considered.

6.4 Surcharge or factor for university hospitals

University hospitals, face several challenges as outlined in Chapter 2.5. This translates to higher costs incurred. Hence, a surcharge for university hospitals should be considered.

7 Limitations and Directions for Further Research

7.1 Limitations

7.1.1 Reporting issues

DRGs may not always be coded correctly

Significant effort is required in the coding and verification of the DRG. Furthermore, there is no uniform system aimed at proposing the relevant code immediately after the admission diagnosis. On the basis of clinical pathways, operational procedures, and medically oriented classifications, an unambiguous assignment may occur at any time. If the coding quality is poor, all the relevant case information may not be used for the coding. Consequently, the optimal and accurate relative weights for a case may not be achieved.

Cost data may not be reported correctly

Reporting issues may arise with respect to data on costs incurred at the hospitals, and the correct attribution of these costs to a particular case.

Large ranges and standard deviations

Due to the nature of the data, large ranges may be observed. As a result of this, whenever sample sizes are small, results may not be statistically significant.

7.1.2 Disease severity

The analysis took only different complexity factors that are encoded and embedded in the cost data set into consideration. Hence, several factors that impact disease severity, such as abdominal pain and impact on daily activities, were not analyzed.

7.1.3 Quality of treatment

This study does not account for the quality of treatment provided. When considering reforms to the reimbursement system, this is of utmost importance. Therefore, whenever a change to the reimbursement system is made, the impact on the quality of treatment

should be considered. In their 2020 paper, Schreyögg et al. outlined possible reimbursements of stationary cases in Germany by including three components: 1) budgets based on demographic factors and holding costs, 2) flat rates per case, and 3) surcharges upon meeting specified quality criteria (Figure 43) [37].

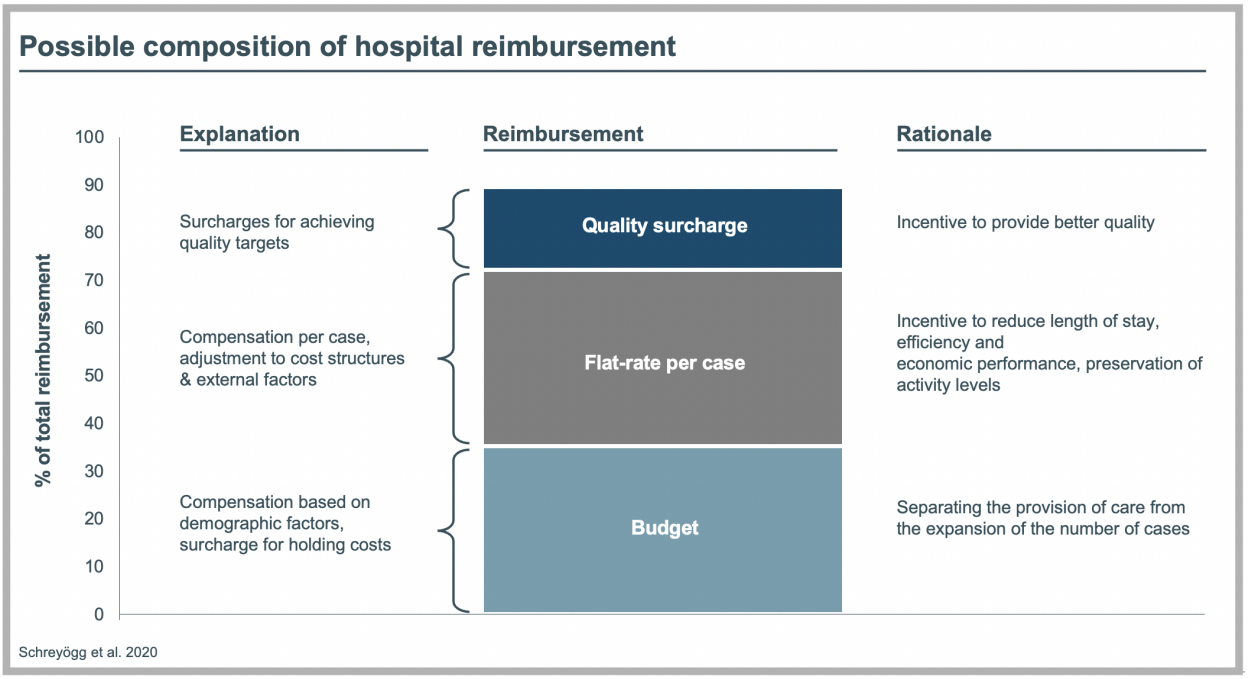

Figure 43 Possible components of a revised hospital reimbursement system

Schreyögg et al. propose the incorporation of 3 components in the determination of the reimbursement of cases at German hospitals. The largest component is made up of the budget allocation based on demographic factors and holding costs. This makes up 35% of the reimbursement and is aimed at separating the provision of care from the expansion of the number of cases. The second component, which accounts for around 35% of the reimbursement amount, is a flat-rate fee per case which adjusts for cost structures and external factors. This incentivizes lower lengths of stays, higher efficiency and economic performance, and the preservation of activity levels. The final and smallest component, making up approximately 20% of the reimbursement amount, is the quality surcharge received upon achieving specified quality targets. This incentivizes improved quality of service.

Source: Schreyögg et al. 2020 [37]

7.1.4 Outpatient care

This paper exclusively evaluates inpatient cases and does not analyze the proportion of cases that may also be treated in an outpatient care setting. Existing literature outlined in chapter 2.4 indicates that not all cases currently treated as inpatient cases are required to be treated in an inpatient setting; a shift to outpatient care may also reduce financial loss without reducing the quality of treatment. To achieve this, a structural shift towards a more integrated outpatient and inpatient care is necessary [45].

7.2 Further research

Further research may investigate the reimbursement situation of other diagnoses, to draw a comparison as to whether the findings with respect to complexity and admission reason occur across diagnoses. Furthermore, the relation between disease severity and the reimbursement situation could be analyzed. Finally, factors for the quality of treatment in relation to the reimbursement of complex cases at different types of care may be analyzed and the possibility to shift some procedures to outpatient care may be evaluated.

8 Conclusion

Existing literature focuses on the reimbursement of selected DRGs and on potential reasons as to why university hospitals are facing higher costs. Leveraging existing literature on these topics, this paper contributes to the discussion with a quantitative analysis of the reimbursement situation of IBD in Germany.

This study finds that IBD is, in general, not treated in a cost-covering manner. Furthermore, this work reveals that complex cases incur greater financial losses than non-complex cases. However, due to large ranges in the data and high InEK standard deviations, the results do not meet the required criteria to submit a request for the amendment of the reimbursement mechanism at the DRG level. Nevertheless, it can be shown that for selected DRGs and the admission reason *transfer*, the actual costs are higher than the InEK costs. Here, an adjustment of the reimbursement rate could be considered, and a corresponding application may be submitted.

In addition, this paper finds that for most complexities (e.g., gastroenterological complications or infections), there is no significant difference in the distribution between the different types of care. However, maximum care providers, and especially university hospitals, face higher costs and higher losses than other types of care.

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Statutory Declaration

"I, Maria Moll-von der Wettern, by personally signing this document in lieu of an oath, hereby affirm that I prepared the submitted dissertation on the topic *Analysis of complex IBD cases with regards to complications, interventions, additional charges as well as costs with distinct evaluation of center effects (Analyse der komplexen CED-Fälle in Bezug auf Komplikationen, Intervention, Zusatzentgelte sowie Kosten mit gesonderter Evaluation von Zentrumseffekten*) independently and without the support of third parties, and that I used no other sources and aids than those stated.

All parts which are based on the publications or presentations of other authors, either in letter or in spirit, are specified as such in accordance with the citing guidelines. The sections on methodology (in particular regarding practical work, laboratory regulations, statistical processing) and results (in particular regarding figures, charts and tables) are exclusively my responsibility.

Furthermore, I declare that I have correctly marked all of the data, the analyses, and the conclusions generated from data obtained in collaboration with other persons, and that I have correctly marked my own contribution and the contributions of other persons (cf. declaration of contribution). I have correctly marked all texts or parts of texts that were generated in collaboration with other persons.

My contributions to any publications to this dissertation correspond to those stated in the below joint declaration made together with the supervisor. All publications created within the scope of the dissertation comply with the guidelines of the ICMJE (International Committee of Medical Journal Editors; www.icmje.org) on authorship. In addition, I declare that I shall comply with the regulations of Charité – Universitätsmedizin Berlin on ensuring good scientific practice.

I declare that I have not yet submitted this dissertation in identical or similar form to another Faculty.

The significance of this statutory declaration and the consequences of a false statutory declaration under criminal law (Sections 156, 161 of the German Criminal Code) are known to me."

_____ _____

Date Signature

Declaration of contribution to any publications

Publication 1: Maria Moll-von der Wettern, Wolfgang Heinlein, Markus Rathmayer, Lisa Koller, Britta Siegmund, Ein kritischer DRG-Blick auf Fälle mit chronisch entzündlichen Darmerkrankungen, E641, Zeitschrift für Gastroenterologie, 2022

The publication is an abstract. I contributed to the abstract as well as the introduction, methods and results as well as tables 1 to 7 and figures 1 to 4 of the corresponding paper which has been submitted for publication.

_____

Signature of doctoral candidate

Curriculum Vitae

Mein Lebenslauf wird aus datenschutzrechtlichen Gründen in der elektronischen Version meiner Arbeit nicht veröffentlicht.

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Certification of the accredited statistician

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Bescheinigung

Hiermit bescheinige ich, dass *Frau Maria von der Wettern* innerhalb der Service Unit Biometrie des Instituts für Biometrie und klinische Epidemiologie (iBikE) bei mir eine statistische Beratung zu einem Promotionsvorhaben wahrgenommen hat. Folgende Beratungstermine wurden wahrgenommen:

- *Termin 1: 09.11.2022*

Folgende wesentliche Ratschläge hinsichtlich einer sinnvollen Auswertung und Interpretation der Daten wurden während der Beratung erteilt:

- Deskription: Erstellung einer tabelone.
- Gemischtes Modell – Random Intercept um die Krankenhauseffekte zu berücksichtigen, Interpretation des Outputs. Überprüfung auf Multikollinearität via VIF.
- Unabhängiger t-Test für kontinuierliche Variablen zwischen Center und anderen Krankenhaustypen. Chi-Quadrat Test + Häufigkeitstabellen für kategoriale Variablen zwischen Center und anderen Krankenhaustypen.
- Umgang mit fehlenden Werten: Complete Case Analyse nach Absprache sonst Imputation.

Diese Bescheinigung garantiert nicht die richtige Umsetzung der in der Beratung gemachten Vorschläge, die korrekte Durchführung der empfohlenen statistischen Verfahren und die richtige Darstellung und Interpretation der Ergebnisse. Die Verantwortung hierfür obliegt allein dem Promovierenden. Das Institut für Biometrie und klinische Epidemiologie übernimmt hierfür keine Haftung.

Datum: 09.11.2022 Name des Beraters/ der Beraterin: Simrit Rattan

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