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ORIGINAL ARTICLE

Inpatient treatment of acute diverticulitis between 2010 and 2021 – A German nationwide study about long-term trends and effects of the SARS-CoV-2 pandemic

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Abstract

Aim: The aims of this study were to analyse all hospitalizations for acute diverticulitis in Germany from 2010 to 2021 and to assess the effects of the first 2 years of the SARS-CoV-2 pandemic on hospitalizations for acute diverticulitis.

Method: Using data from the German Federal Statistical Office, we analysed fully anonymized healthcare data of hospitalizations and treatment regimens with acute diverticulitis as the main diagnosis between 2010 and 2021. Logistic regression analyses for in-hospital mortality were performed.

Results: A total of 608,162 hospitalizations were included. While the number of hospitalizations constantly increased until 2019 (+52.4%), a relative decrease of 10.1% was observed between 2019 and 2020, followed by stable numbers of hospitalizations in 2021 (+1.1% compared with 2020). In-hospital mortality showed a relative decrease of 33.2% until 2019 and thereafter a relative increase of 26.9% in 2020 and of 7.5% in 2021. A 21.6% and a 19.3% drop in hospitalizations was observed during the first and second waves of the SARS-CoV-2 pandemic, mostly affecting hospitalizations for uncomplicated diverticulitis, with a corresponding 11.6% and 16.8% increase in admissions for complicated diverticulitis. Multivariable logistic regression analyses showed significantly higher in-hospital mortality for hospitalizations in which surgery (OR = 2.76) and CT (OR = 1.32) were given, as well as lower mortality for women (OR = 0.88), whereas percutaneous drainage was not associated with higher in-hospital mortality compared with conservative treatment (OR = 0.71).

Conclusion: This study points out the long-term trends in inpatient treatment for acute diverticulitis and the in-hospital mortality risk factors of patients hospitalized for acute diverticulitis in a large nationwide cohort, as well as changes in these trends and factors resulting from the SARS-CoV-2 pandemic. These changes might be attributable to delayed diagnosis and thus more severe stages of disease as a result of containment measures.

KEYWORDS

diverticulitis, in-hospital mortality, nationwide analysis, SARS-CoV-2 Pandemic

INTRODUCTION

Acute diverticulitis is a very common gastrointestinal condition that has become more prevalent in recent decades [1, 2]. Common complications are abscesses and perforation [1]. Whereas uncomplicated diverticulitis can often be treated conservatively, complicated diverticulitis is often treated surgically [1]. According to German guidelines, percutaneous drainage is recommended for acute diverticulitis with an abscess of ≥1 cm; in daily clinical practice, percutaneous drainage is usually possible for an abscess of about 3 cm in size [3, 4]. Diagnosis can be made based on clinical examination, laboratory findings and diagnostic imaging such as ultrasound and CT. Imaging using CT is recommended in patients with suspected diverticulitis and diagnostic uncertainty or to visualize complications of acute diverticulitis [5].

In 2020, the SARS-CoV-2 pandemic started in Germany and resulted in a high number of infections, with four waves of SARS-CoV-2 infection occurring in 2020 and 2021 [6]. To flatten the curve of infections, the German Ministry of Health introduced lockdown measures and social distancing in March 2020. In previous studies, a decline was reported in hospitalization of patients with acute medical conditions (e.g., ischaemic stroke or vascular diseases) during the periods of lockdown and socual distancing in 2020 and 2021 [7–11].

Recent studies from other countries showed a decrease in hospital admissions for emergent general and gastrointestinal surgery during the SAR-SCoV-2 pandemic [12–14]. In addition, a review reported that the rate of complicated diverticulitis increased in the first year of the pandemic, whereas the overall number of hospitalizations for acute diverticulitis decreased during the same period of time [15–18].

To our knowledge, there are a lack of German nationwide data on trends in hospitalizations and treatments for acute complicated and uncomplicated diverticulitis, and on the impact of the SARS-CoV-2 pandemic.

The aims of this study were to analyse the evolution of treatment and diagnostic procedures for acute diverticulitis in Germany from 2010 to 2019 and to assess the effect of the first 2 years of the SARS-CoV-2 pandemic on these conditions.

What does this paper add to the literature?

This study adds long-term data about the inpatient treatment regimen as well as risk factors for in-hospital mortality in a large nationwide cohort and points out the impact of the lockdown measures during the SARS-CoV2-pandemic on these trends.

METHOD

Ethical approval and informed consent were not required by the Medical Research and Ethics Committee (MREC) because the data analysed in this study, kindly provided by the research data center (RDC) of the German Federal Statistical Office (Destatis), were fully anonymized. We have previously reported the procedure of data acquisition in detail [19]. In brief, syntaxes for remote data processing were written using Stata 17 (www.stata.com) and the results were sent to the authors after passing a secrecy check. According to German data regulations, all variables reported for fewer than three individuals were therefore censored.

The German healthcare system is mainly based on five principles: solidarity; mandatory insurance; finance by contributions; no direct payment by patients; and self-administration. Most (about 87%) German residents are covered by statutory health insurance, whereas about 10% are covered by private health insurance [20, 21]. Inpatient treatment is financed according to the diagnosis-related groups (DRG) system, in which hospitalization of patients is classified according to specific medical conditions [22, 23].

According to the German modification of the International Statistical Classification of Diseases and Related Health Problems-10 (ICD-10-GM), we obtained data from all hospitalizations between 2010 and 2021 with the diagnosis 'acute diverticulitis' and the following codes: K57.22 and K57.23 (acute complicated diverticulitis of the colon), K57.32 and K57.33 (acute uncomplicated diverticulitis of the colon), K57.82 and K57.83 (acute complicated diverticulitis of the bowel, not otherwise classified [NOS]), K57.92 and K57.93 (acute uncomplicated diverticulitis of the bowel, NOS). The codes K57.42, K57.43, K57.52 and K57.53 (acute complicated and uncomplicated diverticulitis of the colon and small bowel) were also included so that cases with acute diverticulitis of the colon and inflammatory reaction of the small bowel were not missed. These codes represented only a small number of hospitalizations (n<500/year). Only emergency admissions were included in the analysis.

According to recent German guidelines, conservative treatment is recommended for patients with uncomplicated diverticulitis, percutaneous drainage can be considered for patients with abscesses >3 cm in size and surgical treatment is recommended for patients with complicated diverticulitis (e.g., perforation, peritonitis) or chronic/recurrent diverticulitis. These guidelines have not changed significantly in the last decade; however, the level of evidence for percutaneous drainage has increased with time [24].

For all hospitalizations, as well as for subgroups, additional variables were recorded: male gender, duration of in-hospital stay, in-hospital mortality and acute diverticulitis as the main diagnosis. Comorbidity burden was assessed by analysing Elixhauser groups using all secondary diagnoses and calculating the Elixhauser score (the sum of positive Elixhauser comorbidity groups) [25, 26]. The Elixhauser score includes a total of 30 comorbidity groups and was established in 1998. The comorbidities included in the Elixhauser score (e.g., hypertension, congestive heart failure, depression) were associated with outcome and hospital stay [26]. Furthermore, we included data on the weighted linear van Walraven score (vWs) according to the established classification [27].

The subsequent treatment regimens and diagnostic procedures were recorded according to the following German 'Operationen- und Prozedurenschlüssel' (OPS) codes: 3–206, 3–207 (CT of the pelvis/abdomen without contrast) and 3–225, 3–226 (CT of the abdomen/pelvis with contrast), percutaneous drainage (8–153, 8–148), visceral surgery (5–45, 5–46) and conservative treatment (absence of OPS codes for percutaneous drainage and visceral surgery). Surgical treatment was defined as the presence of OPS codes for visceral surgery as well as the presence of OPS codes for both visceral surgery and percutaneous drainage to avoid bias as a result of postoperative drainage.

The time frame between hospital admission and specific procedures was assessed separately for all hospitalizations and for each subgroup.

We examined, semimonthly (from days 1 to 14 and from day 15 to the end of the month) hospitalizations in 2019, 2020 and 2021 and defined specific time frames according to the four waves of SARS-CoV-2 in 2020 and 2021 [6].

Statistical analyses

Descriptive statistical analyses were performed using SPSS Statistics 28.0 (IBM). The authors wrote syntaxes in Stata 17 (www.stata.com). Data are presented as absolute numbers (*n*) and percentages (%), as mean ± SD or as median (interquartile range [IQR]). Absolute and relative changes between 2010 and 2019 as well as between 2019 and 2020 and between 2020 and 2021 were calculated. Relative changes were calculated as the ratio between the difference of actual and former data and former data. Univariable and multivariable logistic regression analyses included the parameters age, sex, vWs, treatment regimen and CT as independent variables and in-hospital mortality as outcome. The McFadden's Pseudo R^2 was used to assess the explanatory power of the models. A McFadden's Pseudo R^2 value of between 0.2 and 0.4 indicates good model fit. Values of $p<0.05$ were considered to indicate statistically significant differences.

RESULTS

A total of 608,162 hospitalizations (273,427 [45.0%] male, mean age 62.0 years) for acute diverticulitis between 2010 and 2021 were included. We found that 145,839 (24.0%) hospitalizations were for acute complicated diverticulitis and 462,323 (76.0%) hospitalizations were for uncomplicated diverticulitis. Between 2010 and 2021, sole percutaneous drainage, combined treatment (visceral surgery and percutaneous drainage), visceral surgeries and abdominopelvic CT were performed in 2,298 (0.4%), 2,495 (0.4%), 117,982 (19.4%) and 170,773 (28.1%) hospitalizations, respectively.

Trends between 2010 and 2019

Between 2010 and 2019, a total of 502,038 hospitalizations were recorded: 225,967 (45.0%) male; mean age 62.0 ± 14.7 years. The total number of hospitalizations increased by 52.4% from 2010 ($n=38{,}519$) to 2019 ($n=58{,}687$) (Table 1, Figure 1).

Between 2010 and 2019, a total of 116,840 hospitalizations were for complicated diverticulitis: 57,457 (49.2%) male; mean age 61.5 ± 14.7 years. Detailed descriptive statistics are presented in Table 1. Between 2010 and 2019, we observed an absolute (+6,025) and a relative (+12.2%) increase in hospitalizations, whereas in-hospital mortality decreased by 33.6% (from 6.0% in 2010 to 4.0% in 2019). The rate of percutaneous drainage (relative increase 134.0%; from 0.7% in 2010 to 1.7% in 2019) and the rate of conservative treatment (relative increase 43.7%; from 34.3% in 2010 to 49.2% in 2019) increased between 2010 and 2019, whereas the rate of surgical treatment decreased over the same period of time (relative decrease 25.8%; from 63.7% in 2010 to 47.3% in 2019). A relative increase of 5.5% (from 33.6% in 2010 to 35.4% in 2019) was observed for abdominopelvic CT in patients hospitalized for complicated diverticulitis (Figure 1, Table 2).

Hospitalizations for complicated diverticulitis showed a burden of comorbidities (mean vWs: 4.2 ± 6.7; mean Elixhauser score: 1.9 ± 1.9) that were largely constant between 2010 and 2019.

A total of 385,198 hospitalizations for uncomplicated diverticulitis were recorded between 2010 and 2019 (168,510 [43.7%] male; mean age 62.1 ± 14.6 years) (Table 1). Whereas the absolute number of hospitalizations increased (+14,143) between 2010 and 2019, we observed a relative decrease of 3.4%. In-hospital mortality decreased between 2010 and 2019 (relative decrease = 51.7%) (Table 2). The burden of comorbidities was lower compared with hospitalizations for complicated diverticulitis (mean vWs: 2.4 ± 5.1, mean Elixhauser score: 1.4 ± 1.5).

In the univariable model, all independent variables included showed a statistically significant association with the outcome 'in-hospital mortality' (all *p*-values <0.001) and were therefore included in the multivariable models.

In the multivariable models, female gender was independently associated with lower in-hospital mortality in both the whole cohort (OR = 0.88, 95% CI: 0.83–0.93, $p<0.001$) and for complicated diverticulitis (OR = 0.93, 95% CI: 0.87–0.99, $p<0.001$). While surgical treatment was associated with increased in-hospital mortality for complicated diverticulitis (OR = 2.39, 95% CI: 2.21–2.58, $p<0.001$), sole percutaneous drainage had no statistically significant effect (OR = 0.71, 95% CI: 0.50–1.03, $p=0.07$). In hospitalizations for complicated diverticulitis, where a CT of the abdomen/pelvis was performed, the in-hospital mortality was almost 30%

TABLE 1 Hospitalizations for complicated and uncomplicated diverticulitis in Germany between 2010 and 2019: patient characteristics.

Variable	Complicated diverticulitis	Uncomplicated diverticulitis
All hospitalizations	116,840	385,198
Age, y, mean (± SD)	61.5 (14.7)	62.1 (14.6)
Men, *n* (%)	57,457 (49.2)	168,510 (43.7)
In-hospital death, *n* (%)	5,621 (4.8)	1,723 (0.4)
In-hospital stay, d, median (IQR)	11 (7–17)	5 (4–7)
Elixhauser score, median (IQR)	0 (0–6)	0 (0–5)
Elixhauser score, mean (± SD)	4.2 (6.7)	2.4 (5.1)
vWs, median (IQR)	1 (0–3)	1 (0–2)
vWs, mean (± SD)	1.9 (1.9)	1.4 (1.5)
Conservative treatment, *n* (%)	50,561 (43.3)	348,978 (90.6)
Age, y, mean (± SD)	59.3 (14.4)	61.9 (14.7)
Men, *n* (%)	25,658 (50.7)	152,456 (43.7)
In-hospital death, *n* (%)	941 (1.9)	1,149 (0.3)
In-hospital stay, d, median (IQR)	7 (5–9)	5 (4–7)
Elixhauser score, median (IQR)	0 (0–5)	0 (0–5)
Elixhauser score, mean (± SD)	2.5 (5.3)	2.2 (5.0)
vWs, median (IQR)	1 (0–2)	1 (0–2)
vWs, mean (± SD)	1.3 (1.5)	1.3 (1.5)
Percutaneous drainage, *n* (%)	1,501 (1.3)	150 (0.04)
Age, y, mean (± SD)	62.7 (14.6)	62.0 (14.7)
Men, *n* (%)	732 (48.8)	69 (46.0)
In-hospital death, *n* (%)	35 (2.3)	6 (4.0)
In-hospital stay, d, median (IQR)	12 (9–17)	12 (8–18)
Elixhauser score, median (IQR)	1 (0–6)	2.5 (0–10)
Elixhauser score, mean (± SD)	4.4 (6.5)	5.7 (7.7)
vWs, median (IQR)	2 (0–3)	2 (1–3)
vWs, mean (± SD)	1.9 (1.9)	2.1 (2.1)
Surgical treatment, *n* (%)	64,778 (55.4)	36,070 (9.4)
Age, y, mean (± SD)	63.2 (14.7)	65.0 (13.7)
Men, *n* (%)	31,067 (48.0)	15,985 (44.3)
In-hospital death, *n* (%)	4,645 (7.2)	568 (1.6)
In-hospital stay, d, median (IQR)	15 (11–23)	11 (7–17)
Elixhauser score, median (IQR)	5 (0–9)	0 (0–5)
Elixhauser score, mean (± SD)	5.5 (7.4)	3.6 (6.1)
vWs, median (IQR)	2 (1–3)	1 (0–3)
vWs, mean (± SD)	2.3 (2.0)	1.8 (1.8)
CT, *n* (%)	40,872 (35.0)	99,248 (25.8)
Age, y, mean (± SD)	63.1 (14.8)	62.3 (14.3)
Men, *n* (%)	19,558 (47.9)	42,896 (43.2)
In-hospital death, *n* (%)	2,709 (6.6)	594 (0.6)
In-hospital stay, d, median (IQR)	12 (7–20)	6 (4–8)
Elixhauser score, median (IQR)	3 (0–8)	0 (0–5)
Elixhauser score, mean (± SD)	5.2 (7.4)	2.5 (5.3)
vWs, median (IQR)	2 (1–3)	1 (0–2)
vWs, mean (± SD)	2.1 (2.0)	1.4 (1.6)

Abbreviations: d, days; IQR, interquartile range; vWs, van Walraven score; y, years.

higher (OR = 1.29, 95% CI: 1.21–1.37, $p < 0.001$) (Table 3). The model fit was good, with a McFadden's Pseudo R^2 of 0.31 for complicated diverticulitis admissions and a McFadden's Pseudo R^2 of 0.38 for all hospitalizations.

Effect of the SARS-CoV-2 pandemic

In 2020, a total of 52,762 hospitalizations for acute diverticulitis was reported - a relative decrease of 10.1% compared with such hospitalizations in 2019 ($n = 58,687$). While there was a relative decrease of hospitalizations for complicated diverticulitis in 2020 (−4.2%), the rate of uncomplicated diverticulitis decreased even more (by 13.8%). In 2020 an increase was reported in the rate of in-hospital deaths; this increase – of 26.9% compared with 2019 – was the first since 2010. In addition, increases from 2019 to 2020 were reported for hospitalizations for complicated diverticulitis (relative increase 17.4%) as well as for hospitalizations for uncomplicated diverticulitis (relative increase 36.2%).

For hospitalizations required for complicated diverticulitis, an increase in the rate of surgical treatment, of 1.2%, was observed, whereas the rate of conservative treatment decreased by 1.9% (Figure 1, Table 2). A higher rate of comorbidities was recorded in 2020 compared with 2019 (Table 4).

In 2021, a total of 53,362 hospitalizations for acute diverticulitis was reported, reflecting almost stable trends compared with 2020 (relative increase 1.1%). The number of hospitalizations for complicated diverticulitis further increased in 2021 (relative increase 7.5%), while the number of hospitalizations for uncomplicated diverticulitis slightly decreased (−1.4%) compared with 2020. In-hospital mortality also slightly increased in 2021 compared with 2020 (+7.5%).

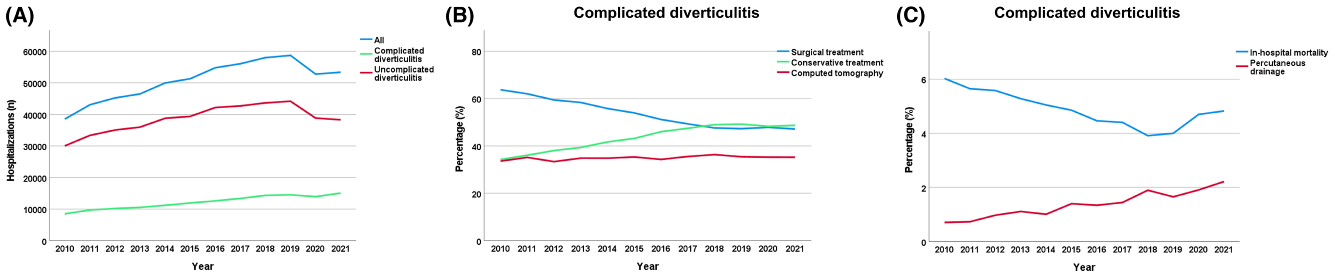

FIGURE 1 Trends in total number of hospitalizations and number of hospitalizations for complicated and uncomplicated diverticulitis (A), and rates of treatment (surgical, conservative and percutaneous drainage), diagnostic procedures (CT imaging) and in-hospital mortality for complicated diverticulitis (B, C) from 2010 to 2021.

The largest decrease in hospitalizations was observed during the first wave of the SARS-CoV-2 pandemic in spring 2020 with 21.6% less admissions compared with the same time frame in 2019. Also during the second wave of SARS-CoV-2 in winter of 2020/2021, a decrease in hospitalizations was observed (−19.3%) followed by a slightly smaller decrease during the third (−10.2%) and fourth (−7.7%) waves of SARS-CoV-2. The decrease in hospitalizations was mainly observed for uncomplicated diverticulitis, which is also reflected by a relative increase in hospitalizations for complicated diverticulitis during the whole pandemic (the largest increase was 16.8%, reported during the second wave of infection) (Figure 2, Table S1).

Whereas the time frame between hospital admission and surgery as well as CT did not differ among 2019, 2020 and 2021 for both complicated and uncomplicated diverticulitis, we observed a slight delay for percutaneous drainage in 2020 and 2021 (Figure S1).

DISCUSSION AND CONCLUSION

This study provided German nationwide data on trends in emergency hospitalizations and treatments for acute complicated and uncomplicated diverticulitis, and the impact of the SARS-CoV-2 pandemic. The main findings are as follows:

- The number of emergency hospitalizations for diverticulitis has increased from 2010 to 2019, with a relative increase in complicated diverticulitis and a decrease in in-hospital mortality
- While the rates of conservative treatment, percutaneous drainage and CT increased, the rate of surgical approaches decreased over time
- Besides age and increased comorbidity, multivariable logistic regression analyses showed male gender, surgical treatment and the need for CT imaging to be independently associated with increased in-hospital mortality
- During the first 2 years of the pandemic, the number of hospitalizations decreased, with a relative increase in hospitalizations for complicated diverticulitis and in-hospital mortality suggesting selection of hospitalizations with advanced disease stages.

Our data showed an increasing number of hospitalizations for acute diverticulitis from 2010 to 2019, with a relative increase of 52.4% for this time period. These findings are consistent with previous studies reporting an increasing incidence of acute diverticulitis [1, 28–31]. While the rate of complicated diverticulitis increased over time, the rate of uncomplicated diverticulitis decreased between 2010 and 2019. These findings might be explained by the fact that no difference has been found between inpatient and outpatient care for patients with uncomplicated diverticulitis, potentially resulting in a shift towards ambulatory care of this subgroup [32]. In this study, however, we only included inpatient data; therefore, no assumptions can be made about the recent increase in numbers of patients with acute diverticulitis in outpatient care.

A previous nationwide study from the United States pointed out a decrease in age of patients with diverticulosis from 1997 to 2018. In the present study, we observed a similar trend, of a relative decrease in patient age of 2.2%. The cited study suggested changes in eating habits and increasing rates of obesity as potential explanations for this fact [31].

In-hospital mortality was 1.8% in 2010 and 1.2% in 2019. These data are consistent with previously reported rates of in-hospital mortality [30, 33]. The rates reported of in-hospital mortality differed between patients who received surgery and patients who received conservative treatment and depended on several other factors (including age, comorbidities, stage of disease); therefore, comparisons with groups of patients in other studies are challenging. In our study cohort, mortality differed between hospitalizations for uncomplicated diverticulitis and hospitalizations for complicated diverticulitis, with considerably lower mortality rates found for hospitalizations for uncomplicated diverticulitis. In particular, a significant decrease of in-hospital mortality was observed regarding hospitalizations for complicated diverticulitis between 2010 (6.0%) and 2019 (4.0%). These findings might be explained by further improvement in management and treatment of acute diverticulitis during the past decade [1]. In-hospital mortality of all patients with acute diverticulitus showed a considerable (26.9%) increase between 2019 and 2020, followed by a further 7.5% increase in 2021. A relative increase of in-hospital mortality was observed for both complicated and uncomplicated diverticulitis. One explanation could be hospitalization of patients with more advanced stages of diverticulitis

TABLE 2 Hospitalizations for diverticulitis in 2010, 2015 and 2019.

Variable	Year 2010	2015	2019	Absolute change 2010–2019	Rel. Change 2010–2019
All hospitalizations, *n*	38,519	51,300	58,687	+20,168	**+52.4%**
Age, y, mean (± SD)	62.9 (14.9)	61.9 (14.7)	61.6 (14.5)	−1.3	**−2.2%**
Men, *n* (%)	17,335 (45.0)	23,134 (45.1)	26,239 (44.7)	+8,904 (−0.3)	**−0.7%**
In-hospital death, *n* (%)	705 (1.8)	728 (1.4)	718 (1.2)	+13 (−0.6)	**−33.2%**
In-hospital stay, d, median (IQR)	7 (5–11)	6 (4–9)	5 (4–8)	−2	**−28.6%**
vWs, median (IQR)	0 (0–5)	0 (0–5)	0 (0–5)	0	**0.0%**
vWs, mean (± SD)	2.7 (5.5)	2.9 (5.7)	2.8 (5.6)	+0.1	**+3.7%**
Elixhauser score, median (IQR)	1 (0–2)	1 (0–2)	1 (0–2)	0	**0.0%**
Elixhauser score, mean (±SD)	1.5 (1.6)	1.5 (1.6)	1.5 (1.6)	0.0	**0.0%**
Complicated diverticulitis, *n*	8,493	11,928	14,518	+6,025	**+28.8%**
Age, y, mean (± SD)	62.0 (15.0)	61.4 (14.7)	61.4 (14.6)	−0.6	**−2.4%**
Men, *n* (%)	4,166 (49.1)	5,839 (49.0)	7,202 (49.6)	+3,036 (+0.6)	**+1.1%**
In-hospital death, *n* (%)	512 (6.0)	579 (4.9)	581 (4.0)	+69 (−2.0)	**−33.6%**
In-hospital stay, d, median (IQR)	13 (9–20)	11 (7–17)	9 (6–16)	−4	**−30.8%**
Percutaneous drainage, *n* (%)	60 (0.7)	167 (1.4)	240 (1.7)	+180 (+0.9)	**+134.0%**
Surgical treatment, *n* (%)	5,414 (63.7)	6,436 (54.0)	6,867 (47.3)	+1.453 (−16.4%)	**−25.8%**
Conservative treatment, *n* (%)	2,910 (34.3)	5,151 (43.2)	7,147 (49.2)	+4,237 (+15.0)	**+43.7%**
CT, *n* (%)	2,852 (33.6)	4,215 (35.3)	5,145 (35.4)	+2,293 (+1.9)	**+5.5%**
vWs, median (IQR)	0 (0–6)	0 (0–7)	0 (0–5)	0	**0.0%**
vWs, mean (±SD)	4.1 (6.6)	4.4 (6.9)	4.1 (6.7)	0.0	**0.0%**
Elixhauser score, median (IQR)	1 (0–3)	1 (0–3)	1 (0–3)	0	**0.0%**
Elixhauser score, mean (± SD)	1.8 (1.8)	1.9 (1.9)	1.8 (1.9)	0.0	**0.0%**
Uncomplicated diverticulitis, *n*	30,026	39,372	44,169	+14,143	**+23.7%**
Age, y, mean (± SD)	63.2 (14.8)	62.0 (14.7)	61.7 (14.5)	−1.5	**−2.1%**
Men, *n* (%)	13,169 (43.9)	17,295 (43.9)	19,037 (43.1)	+5,868 (−0.8)	**−1.7%**
In-hospital death, *n* (%)	193 (0.6)	149 (0.4)	137 (0.3)	−56 (−0.3)	**−51.7%**
In-hospital stay, d, median (IQR)	6 (5–9)	5 (4–7)	5 (3–6)	−1	**−16.7%**
Percutaneous drainage, *n* (%)	6 (0.02)	19 (0.05)	16 (0.04)	+10 (0.0)	**+81.3%**
Surgical treatment, *n* (%)	4,269 (14.2)	3,385 (8.6)	2,995 (6.8)	−1,274 (−7.4)	**−52.3%**
Conservative treatment, *n* (%)	25,741 (85.7)	35,957 (91.3)	41,143 (93.1)	+15,402 (+7.4)	**+8.7%**
CT, *n* (%)	7,761 (25.8)	9,828 (25.0)	11,412 (25.8)	+3,651 (0.0)	**0.0%**
vWs, median (IQR)	0 (0–5)	0 (0–5)	0 (0–5)	0	**0.0%**
vWs, mean (± SD)	2.4 (5.1)	2.5 (5.2)	2.4 (5.1)	0.0	**0.0%**

TABLE 2 (Continued)

Variable	Year 2010	2015	2019	Absolute change 2010–2019	Rel. Change 2010–2019
Elixhauser score, median (IQR)	1 (0–2	1 (0–2)	1 (0–2)	0	**0.0%**
Elixhauser score, mean (± SD)	1.4 (1.5)	1.4 (1.5)	1.4 (1.5)	0.0	**0.0%**

Abbreviations: d, days; IQR, interquartile range; vWs, van Walraven score; y, years.

TABLE 3 Uni- and multivariate logistic regression analyses for in-hospital mortality.

Complicated diverticulitis	**Univariable analysis**		**Multivariable analysis McFadden's pseudo R^2: 0.3057**	
	OR (95% CI)	***p*-value**	**OR (95% CI)**	***p*-value**
Age	1.12 (1.11–1.12)	<0.001	1.09 (1.09–1.09)	<0.001
Gender				
Male (ref)	1.00	<0.001	1.00	0.019
Female	1.86 (1.76–1.96)		0.93 (0.87–0.99)	
vWs	1.16 (1.15–1.16)	<0.001	1.11 (1.10–1.11)	<0.001
Type of treatment				
Conservative treatment (ref)	1.00	0.186	1.00	0.069
Percutaneous drainage	1.26 (0.90–1.77)	<0.001	0.71 (0.50–1.03)	<0.001
Surgical treatment	4.07 (3.79–4.37)		2.39 (2.21–2.58)	
CT				
No (ref)	1.00	<0.001	1.00	<0.001
Yes	1.78 (1.69–1.88)		1.29 (1.21–1.37)	

All hospitalizations	**Univariable analysis**		**Multivariable analysis McFadden's Pseudo R^2: 0.3837**	
	OR	***p*-value**	**OR**	***p*-value**
Age	1.11 (1.11–1.12)	<0.001	1.10 (1.09–1.19)	<0.001
Gender				
Male (ref)	1.00	<0.001	1.00	<0.001
Female	1.47 (1.40–1.55)		0.88 (0.83–0.93)	
vWs	1.18 (1.18–1.19)	<0.001	1.11 (1.11–1.11)	<0.001
Type of diverticulitis				
Complicated disease (ref)	1.00	<0.001	1.00	<0.001
Uncomplicated disease	0.09 (0.08–0.09)		0.18 (0.17–0.19)	
Type of treatment				
Conservative treatment (ref)	1.00	<0.001	1.00	0.657
Percutaneous drainage	4.84 (3.54–6.62)	<0.001	0.93 (0.66–1.30)	<0.001
Surgical treatment	10.37 (9.85–10.91)		2.76 (2.59–2.95)	
CT				
No (ref)	1.00	<0.001	1.00	<0.001
Yes	2.14 (2.04–2.24)		1.32 (1.25–1.40)	

Abbreviations: ref, Reference; vWs, van Walraven score.

TABLE 4 Hospitalizations for diverticulitis in 2019, 2020 and 2021.

Variable	Year						
	2019	2020	2021	Absolute change 2019–2020	Rel. change 2019–2020	Absolute change 2020–2021	Rel. change 2020–2021
All hospitalizations, *n*	58,687	52,762	53,362	−5,925	**−10.1%**	+600	**+1.1%**
Age, y, mean (± SD)	61.6 (14.5)	61.8 (14.5)	62.1 (14.7)	0.2	**0.0%**	+0.2	**+0.4%**
Men, *n* (%)	26,239 (44.7)	23,474 (44.5)	23,986 (44.9)	−2,765 (−0.2)	**−0.5%**	+512 (+0.5)	**+1.0%**
In-hospital death, *n* (%)	718 (1.2)	819 (1.6)	895 (1.7)	+101 (+0.3)	**+26.9%**	+76 (+0.1)	**+7.5%**
In-hospital stay, d, median (IQR)	5 (4–8)	5 (4–8)	5 (3–8)	0	**0.0%**	0	**0.0%**
vWs, median (IQR)	0 (0–5)	0 (0–5)	0 (0–5)	0	**0.0%**	0	**0.0%**
vWs, mean (± SD)	2.8 (5.6)	3.0 (5.8)	3.1 (5.8)	+0.2	**+7.1%**	+0.1	**+4.0%**
Elixhauser score, median (IQR)	1 (0–2)	1 (0–2)	1 (0–2)	0	**0.0%**	0	**0.0%**
Elixhauser score, mean (± SD)	1.5 (1.6)	1.6 (1.7)	1.6 (1.7)	+0.1	**+6.7%**	0	**+0.1%**
Complicated diverticulitis, *n*	14,518	13,936	15,063	−582	**−4.2%**	+1,127	**+7.5%**
Age, y, mean (± SD)	61.4 (14.6)	61.6 (14.6)	61.8 (14.8)	+0.3	**−0.2%**	+0.2	**+0.3%**
Men, *n* (%)	7,202 (49.6)	6,776 (48.6)	7,384 (49.0)	−426 (−1.0)	**−2.0%**	+608 (+0.4)	**+0.8%**
In-hospital death, *n* (%)	581 (4.0)	655 (4.7)	727 (4.8)	+74 (+0.7)	**+17.4%**	+72 (+0.1)	**+2.6%**
In-hospital stay, d, median (IQR)	9 (6–16)	9 (6–15)	9 (5–15)	0	**0.0%**	0	**0.0%**
Percutaneous drainage, *n* (%)	240 (1.7)	266 (1.9)	334 (2.2)	+26 (+0.3)	**+15.5%**	+68 (+0.3)	**+13.9%**
Surgical treatment, *n* (%)	6,867 (47.3)	6,669 (47.9)	7,104 (47.2)	−198 (+0.6)	**+1.2%**	+435 (−0.7)	**−1.5%**
Conservative treatment, *n* (%)	7,147 (49.2)	6,730 (48.3)	7,335 (48.7)	−417 (−0.9)	**−1.9%**	+605 (+0.4)	**+0.8%**
CT, *n* (%)	5,145 (35.4)	4,914 (35.3)	5,305 (35.2)	−231 (−0.2)	**−0.5%**	+391 (0.0)	**−0.1%**
vWs, median (IQR)	0 (0–5)	0 (0–7)	0 (0–7)	0	**0.0%**	0	**0.0%**
vWs, mean (± SD)	4.1 (6.7)	4.4 (6.9)	4.4 (6.9)	+0.3	**+7.3%**	0	**+0.1%**
Elixhauser score, median (IQR)	1 (0–3)	1 (0–3)	1 (0–3)	0	**0.0%**	0	**0.0%**
Elixhauser score, mean (± SD)	1.8 (1.9)	1.9 (1.9)	1.9 (1.9)	+0.1	**+5.6%**	0	**+1.1%**

TABLE 4 (Continued)

Variable	Year						
	2019	2020	2021	Absolute change 2019–2020	Rel. change 2019–2020	Absolute change 2020–2021	Rel. change 2020–2021
Uncomplicated diverticulitis, *n*	44,169	38,826	38,299	−5,343	**−13.8%**	−527	**−1.4%**
Age, y, mean (± SD)	61.7 (14.5)	61.9 (14.5)	62.2 (14.7)	+0.2	**+0.1%**	+0.2	**+0.4%**
Men, *n* (%)	19,037 (43.1)	16,698 (43.0)	16,602 (43.3)	−2,339 (−0.1)	**−0.2%**	−96 (+0.3)	**+0.8%**
In-hospital death, *n* (%)	137 (0.3)	164 (0.4)	168 (0.4)	+27 (+0.1)	**+36.2%**	+4 (0.0)	**+3.7%**
In-hospital stay, d, median (IQR)	5 (3–6)	5 (3–6)	4 (3–6)	0	**0.0%**	−1	**−25.0%**
Percutaneous drainage, *n* (%)	16 (0.04)	20 (0.1)	27 (0.1)	+4 (0.0)	**+42.2%**	+7 (0.0)	**+26.9%**
Surgical treatment, *n* (%)	2,995 (6.8)	2,603 (6.7)	2,640 (6.9)	−392 (−0.1)	**−1.1%**	+37 (+0.2)	**+2.7%**
Conservative treatment, *n* (%)	41,143 (93.1)	36,189 (93.2)	35,594 (92.9)	−4,954 (+0.1)	**+0.1%**	−595 (−0.3)	**−0.3%**
CT, *n* (%)	11,412 (25.8)	10,276 (26.5)	10,158 (26.5)	−1,136 (+0.6)	**+2.4%**	−118 (+0.1)	**+0.2%**
vWs, median (IQR)	0 (0–5)	0 (0–5)	0 (0–5)	0	**0.0%**	0	**0.0%**
vWs, mean (± SD)	2.4 (5.1)	2.5 (5.2)	2.6 (5.3)	+0.1	**+4.2%**	+0.1	**+4.6%**
Elixhauser score, median (IQR)	1 (0–2)	1 (0–2)	1 (0–2)	0	**0.0%**	0	**0.0%**
Elixhauser score, mean (± SD)	1.4 (1.5)	1.4 (1.5)	1.5 (1.6)	0.0	**0.0%**	+0.1	**+5.2%**

Abbreviations: d, days; IQR, interquartile range; vWs, van Walraven score; y, years.

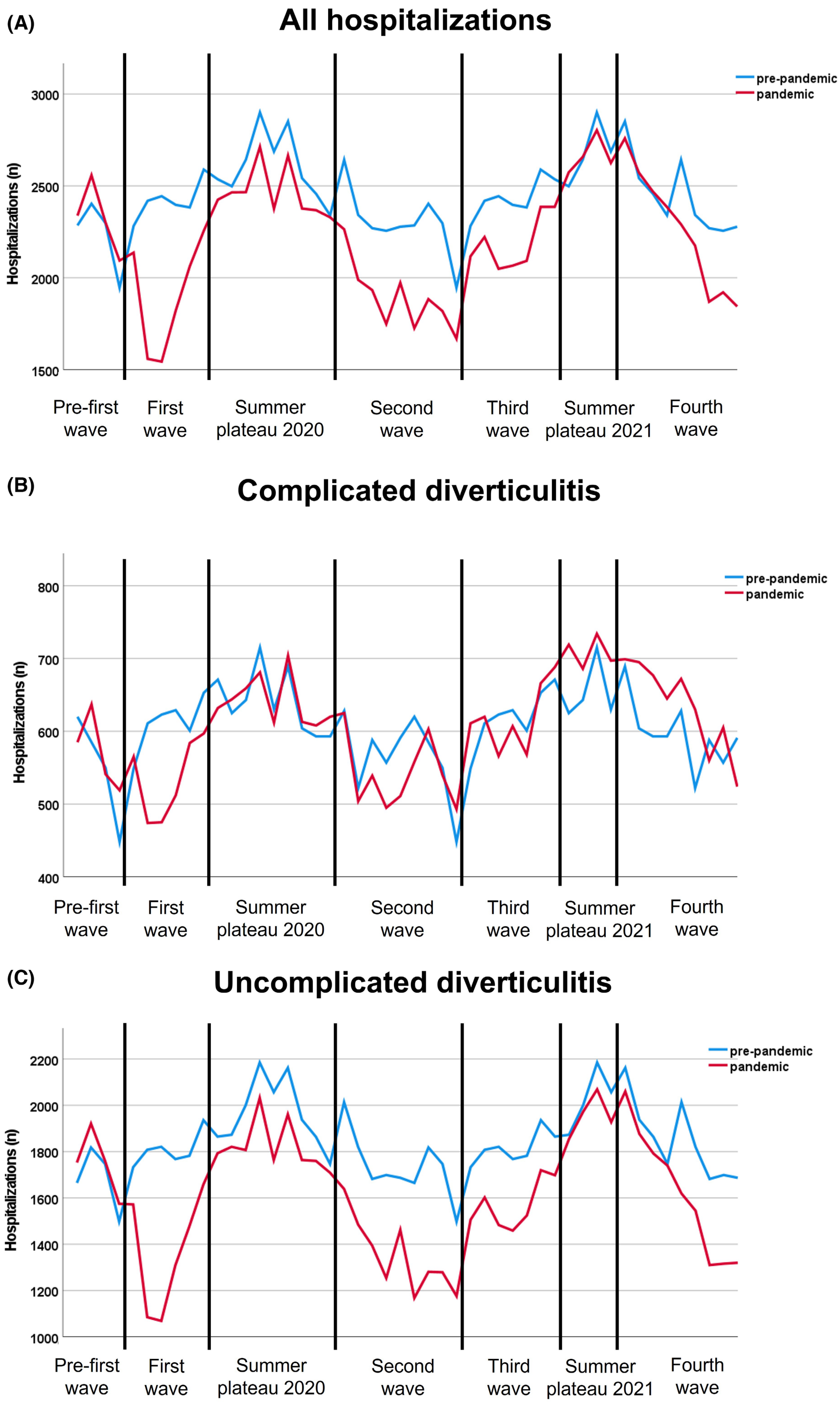

FIGURE 2 Comparison of all hospitalizations (A), hospitalizations for complicated diverticulitis (B) and hospitalizations for uncomplicated diverticulitis (C) between the pre-pandemic and the pandemic time periods.

because of delayed diagnosis and/or treatment. The higher rate of in-hospital mortality caused by uncomplicated diverticulitis might be a result of the increased comorbidity burden observed for these patients, reflected by increases in both the Elixhauser score and the vWs between 2019 and 2020 and between 2020 and 2021.

The main risk factors for in-hospital mortality in patients with acute complicated diverticulitis are advanced stages of disease and the point in time when treatment started[34–36]. In our multivariable logistic regression model, significantly higher in-hospital mortality was found for all hospitalizations and hospitalizations for complicated diverticulitis when surgical treatment was given compared with conservative treatment. These results are explained by the general risks of visceral surgery with an average in-hospital mortality of 7.5% for colorectal surgery in Germany between 2009 and 2015 [35] and the advanced disease stages in patients receiving surgical treatment [36]. Hospitalizations in which a CT scan was performed showed significantly increased in-hospital mortality (almost 30%) compared to these in which no CT scan was performed. These findings can also be explained by the fact that patients with more advanced disease stages and with complications (e.g., more severe pain and other symptoms suggesting perforation) receive CT more often than do patients with mild complications (e.g., small abscesses), which can also be diagnosed by ultrasound. Conversely, this is also a clear indication against systematic and unnecessary overuse of CT in the context of diagnosis of suspected diverticulitis.

Hospitalizations receiving sole percutaneous drainage for complicated diverticulitis did not show higher in-hospital mortality than hospitalizations receiving conservative treatment. These results might emphasize the importance of percutaneous drainage as a possible adjunct to conservative treatment in selected cases. However, the results of the present study might be biased because of the small sample size of hospitalizations treated with percutaneous drainage and selection of hospitalizations for mild complications of acute diverticulitis.

In the present study, the in-hospital mortality rate of complicated diverticulitis was significantly lower in women. Previous studies analysing nationwide data in the United States reported increased mortality and both an increased incidence of hospitalizations and a higher incidence of mortality from diverticular disease in women [29, 37, 38]. Our findings of lower mortality in women might be explained as follows: we only included in-hospital mortality; and we were not able to follow-up the patients after discharge from the hospital. These findings are in line with those of Sell et al., who reported that men are more likely to die in hospital, whereas the place of death for women was more likely to be in a nursing home or in a hospice [37, 38].

During the first year of the pandemic, there was a decline in hospitalizations for acute diverticulitis and a relative increase in hospitalizations for complicated diverticulitis, resulting in a slight absolute decrease (of -582) overall of hospitalizations for diverticulitis. These findings are consistent with previous studies from other countries [39–41]. Explanations might be patients' fear of infection during hospitalization, lockdown measures and social distancing, as well as reallocation of hospital's resources to prevent collapse of the healthcare system. Therefore, conservative treatment and outpatient care may have been preferred for patients with uncomplicated diverticulitis [15]. As the present study only includes inpatients, we cannot report on trends of outpatient care for acute diverticulitis during the SARS-CoV-2 pandemic. Further studies investigating these trends are necessary and might show a relative increase of outpatient care during the lockdown measures.

Interestingly, no subsequent increase was recorded between the two waves of SARS-CoV-2 in summer 2020. By contrast, we additionally observed a decline of hospitalizations during this period compared with the same period in 2019. But what happened to those patients? Two scenarios are conceivable: the rate of patients who received outpatient care was higher during the SARS-CoV-2 pandemic, or the rate of undetected acute diverticulitis was higher during the waves of SARS-CoV-2.

In 2021, during the second year of the SARS-CoV-2 pandemic, we observed a slight increase in the absolute number of hospitalizations (+600) with an increase especially in the number of hospitalizations for complicated diverticulitis (+1,127), compared with 2020. By contrast, the number of hospitalizations for uncomplicated diverticulitis further decreased (-527) during the same time period (2020–2021). Also, during the second to fourth waves of SARS-CoV-2, as well as during the summer plateaus, a decrease in hospitalizations was observed together with slightly decreasing trends (−21.6% during the first wave compared with −7.7% during the fourth wave). These findings might be explained by implementation of hygiene measures, reduction by patients in fear of infection with SARS-CoV-2 and encouragement of patients to seek medical care in emergent cases during the ongoing pandemic [7, 42].

Similar trends regarding the distribution of hospitalizations with complicated and uncomplicated diverticulitis were also observed during 2021. Interestingly, also during the summer plateau in 2021, no rebound was recorded, suggesting an increasing rate of hospitalizations receiving outpatient care and selection of hospitalizations with more advanced disease stages to receive in-patient treatment.

Our data only cover the first 2 years of the SARS-CoV-2 pandemic; further studies are necessary to investigate trends during the third year of this pandemic with potential rebound effects (resulting from the accumulation of delayed and potentially more severe episodes of acute diverticulitis).

The percentage of percutaneous drainage increased, especially during the second and fourth waves of SARS-CoV-2 compared with the pre-pandemic period, with a relative increase of up to 61.2% in hospitalizations for complicated diverticulitis. A smaller study reported similar data [43] and discussed that these observations may be explained by a bridging treatment to postpone/avoid surgery [15].

This study has several limitations. We report healthcare data that do not include patients' clinical parameters, such as symptom severity, disease classification according to the German Classification of diverticular disease, short-term and long-term outcomes and complications (e.g., peritonitis, sepsis). Healthcare data reflect administrative data that are collected to receive financial compensation for treatment procedures. Therefore, a bias due to economic reasons cannot be excluded. All codes were collected manually; accordingly, coding errors might occur. A small number of percutaneous drainages (e.g., 6–20 cases/year) were reported for hospitalizations for uncomplicated diverticulitis. Drainage is only performed in patients with complicated diverticulitis; in patients with a complicating course of primary uncomplicated diverticulitis, the ICD-10 code ought to be changed. Therefore, these few numbers might be related to coding errors or to patients receiving percutaneous drainages for other pathologies. The rate of surgery for uncomplicated diverticulitis is mainly explained by the surgical treatment of recurrent diseases [44].

Finally, the data report on individual hospitalizations rather than on individual patients. Therefore, patients with two or more hospital admissions for the ICD-10 code K57 are recorded as two or more hospitalizations; this might therefore introduce a bias, especially for patients with recurrent diverticulitis and a need for multiple hospital admissions. This fact might also affect multivariable regression analyses; the results shown here present data for individual admissions and not individual patients. Recurrent diverticulitis within the same year is about 18% [1, 28]. However, in contrast to other chronic or recurrent diseases, treatment for recurrent acute diverticulitis is often not based on previous treatments. Furthermore, the data on treatment are based on individual hospitalizations, whereas mortality (and also other outcomes) are based on individual patients, which might also introduce an unavoidable bias.

From 2010 to 2019, the rate of admissions for acute complicated diverticulitis has increased steadily and the in-hospital treatment of complicated diverticulitis has shifted from surgical to conservative approaches with a significant increase in treatment with percutaneous drainage.

In the first 2 years of the SARS-CoV-2 pandemic, a relative increase in hospitalizations for complicated diverticulitis was observed, whereas the overall number hospitalizations for acute diverticulitis decreased, which was associated with a substantial increase in in-hospital mortality. The explanations for this might be patients' fear of seeking medical care during the pandemic, a selection of patients with more advanced stages of diverticulitis, a reallocation of resources and a higher rate of outpatient care for patients with uncomplicated diverticulitis.

AUTHOR CONTRIBUTIONS

Thomas Kröncke: Writing – review and editing; supervision; project administration; resources. **Josua A. Decker:** Conceptualization; investigation; methodology; writing – original draft; visualization; data curation; formal analysis. **Christian Scheurig-Münkler:** Conceptualization; writing – review and editing; methodology; validation; supervision; project administration. **Jan H. Luitjens:** Data curation; investigation; writing – review and editing. **Florian Schwarz:** Writing – review and editing; supervision. **Stefanie Bette:** Conceptualization; writing – original draft; methodology; validation; visualization; formal analysis; data curation; investigation; software.

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CONFLICT OF INTEREST STATEMENT

The authors state that there are no conflicts of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ETHICS STATEMENT

Ethical approval was not required due to analysis of fully anonymized data.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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