ORIGINAL ARTICLE

Access to Surgery and Quality of Care for Acute Cholecystitis During the COVID-19 Pandemic in 2020 and 2021 — an Analysis of 12,545 Patients from a German-Wide Hospital Network

Robert Siegel[1,2] · Sven Hohenstein[3] · Stefan Anders[2] · Martin Strik[2] · Ralf Kuhlen[4] · Andreas Bollmann[3]

Abstract

Purpose To determine effects on admission, treatment, and outcome for acute cholecystitis during the course of the COVID-19 pandemic in 2020 and 2021.

Methods Retrospective analysis of claims data from 74 German hospitals. Study periods were defined from March 5, 2020 (start of first wave) to June 20, 2021 (end of third wave) and compared to corresponding control periods (March 2018 to February 2020). All in-patients with acute cholecystitis were included. Distribution of cases, type of surgery, comorbidities, surgical outcome, and length of stay of all cases with acute cholecystitis and cholecystectomy were compared. In addition, we analyzed the type of treatment (non-surgical, cholecystostomy, or cholecystectomy) for all cases with main diagnosis of acute cholecystitis.

Results We could not demonstrate differences in daily admissions over the course of the pandemic (11.2–12.7 patients vs. 11.9–12.6 patients for control periods). Proportion of patients with non-surgical treatment was low and not increased (11.7–17.3% vs. 14.5–18.4%). Cholecystostomy was rare throughout all periods (0–0.5% of all patients). We did not observe an increase in open surgery (proportion of open cholecystectomies 3.4–5.5%). Mortality was generally low (1.5–1.9%) with no differences between periods. Median length of stay was 4 days throughout all periods.

Conclusion The numerous restrictions during the COVID-19 pandemic did not result in an increase of admissions or surgery for acute cholecystitis. Laparoscopic cholecystectomy has been safely applied during the pandemic. Our results may assure the ability to maintain high quality of surgical care even in times of disruptions to the health care system.

Keywords Acute cholecystitis · Emergency surgery · COVID-19 · Laparoscopic cholecystectomy · Morbidity and mortality

Introduction

The COVID-19 pandemic has led to major challenges for the healthcare system worldwide. In addition to the enormous efforts in the treatment and care of patients with COVID-19 disease, the pandemic disrupted the provision of medical, psychiatric, and surgical services.[1–3] There are numerous reports describing changes during the early COVID-19 pandemic;[4–6] however, data on analyses for longer periods and later stages of the pandemic are still scarce.

Before the recent beginning of a fourth wave, Germany experienced a three-wave pattern over a period of 16 months. In March 2020, the German government issued a first nation-wide "lockdown" with closures of schools and daycare and the suspension of all elective surgery. A second wave of infections in Germany started at the end of September 2020 resulting in a second "lockdown" (partial shutdown in November and extended shutdown in December 2020). This wave peaked in December 2020 and went almost continuously into a third wave, which peaked in April 2021. The restrictions of the second "lockdown" have been

✉ Robert Siegel
robert.siegel@helios-gesundheit.de

1   Faculty of Health, Witten/Herdecke University, Witten, Germany

2   Department of General, Visceral and Cancer Surgery, Helios Klinikum Berlin-Buch, Schwanebecker Chaussee 50, 13125 Berlin, Germany

3   Heart Center Leipzig at University of Leipzig and Leipzig Heart Institute, Leipzig, Germany

4   Helios Health, Berlin, Germany

in place most of the time with stepwise loosening starting in May 2021.

After a start of normalization in summer 2020, numbers of elective surgeries plummeted again dramatically in Germany in late autumn 2020 with the second wave. With the burden of fully occupied intensive care units, elective surgery has not been fully resumed before late spring 2021. Fortunately, there have been no reports of discontinuing acute surgery in Germany. Nevertheless, especially during the first wave of the pandemic, some surgical societies in hard hit countries suggested implementation of non-operative management, e.g., appendicitis and acute cholecystitis, whenever possible.[7] Furthermore, some surgeons and OR personnel were alarmed about potential high-risk virus transmission in laparoscopic procedures. Therefore, some hospital may have favored open procedures against laparoscopy.

Laparoscopic cholecystectomy is the gold standard for the treatment of acute cholecystitis (AC) and is superior to percutaneous drainage even in high-risk patients.[8,9] However, in regions hit hard by the first wave of the pandemic, hospitals have implemented conservative treatment for AC instead of surgery, e.g., a survey in Spain revealed that conservative treatment for AC has been selected in 90% of cases during COVID-19 compared to only 18% pre-COVID-19.[10] Percutaneous gallbladder drainage, cholecystostomy, resurged as a management strategy for AC in the initial phase of the pandemic.[11,12]

For Germany, no deviation from the established standard of care for AC has been reported so far. Over the course of the pandemic, some surgeons noticed an increase of patients presenting with AC and more severe intra-operative findings. These findings are mostly subjective estimates; no data has been published demonstrating increase of severity or incidence for AC.

Studies investigating the effect of the COVID-19 pandemic on surgical care are limited to the early phase. For acute appendicitis, these studies almost uniformly report a reduction of both admissions and surgical procedures compared to pre-pandemic times, but there are conflicting results on whether or not more patients presented with complicated appendicitis.[13–16] Data on AC is scarce, because studies analyzed predominantly volume of cholecystectomies, independent of diagnosis or urgency.[17,18] In additions, these reports mostly focused on number of admissions or procedures performed, but less on patients' outcomes or adherence to standard of care. The aim of this study was to assess the incidence and severity of AC as well as quality of surgical treatment throughout different phases of the COVID-19 pandemic. To our knowledge, this is the first analysis of outcomes of acute surgery over three waves and the corresponding resumption period of the COVID-19 pandemic, a period from the first peak early 2020 and up to the end of the third wave in summer of 2021.

Material and Methods

Data Collection

We retrospectively analyzed claims data of consecutive patients with acute cholecystitis from 74 Helios hospitals involved in general surgery and emergency admission. The information used is based on diagnoses coded via the International Statistical Classification of Diseases and Related Health Problems (ICD-10-GM [German Modification]) and procedures coded via the Operations and Procedures codes (OPS, German adaption of the International Classification of Procedures in Medicine of the World Health Organization). Administrative data were extracted from QlikView (QlikTech, Radnor, Pennsylvania, USA). Data were stored pseudonymized and data use was approved by the Helios Kliniken GmbH data protection authority. The Ethics Committee at the Medical Faculty, Leipzig University, approved this study (#490/20-ek).

All patients with the diagnosis of an ICD-10-code for AC (K81.0), calculus of gallbladder with AC (K80.00 and K80.01), or obstruction, hydrops, and perforation of the gallbladder (K82.0, K82.1, K82.2) were included in the study. We analyzed all patients with a surgical procedure for AC, using the combination of the ICD-codes above with the OPS-codes for cholecystectomy (OPS 5–511.0, 5–511.1, and 5–511.2), as well as patients with AC and an OPS-code for cholecystostomy (OPS 5–510).

Study Cohorts and Time Periods

Based on admission dates, the study periods were defined from March 2020 (03/05/2020, first wave in Germany) to June 2021 (06/20/2021, end of third wave in Germany) and compared to corresponding control periods of the previous years (March 2018 to February 2020, "pre-COVID"-months).

Study and control periods were divided into first wave phase, the phase between waves, second and third wave phases, determined by change points estimated with segmented regression analyses of daily national SARS-CoV-2 infection incidences (Robert Koch Institute, Germany). The first wave phase is defined from 5 March 2020 to 1 May 2020, the phase between waves from 2 May 2020 to 19 September 2020, the second wave phase from 20 September 2020 to 13 February 2021, and the third wave phase from 14 February 2021 to 20 June 2021.

Admission, Type of Treatment, and Quality of Surgical Care

Hospital admissions were classified as urgent and non-urgent. Urgent admission presented via the emergency department.

We compared the frequency and type of surgery for AC between study and control period for all phases. We analyzed all patients undergoing surgery for the ratio of open (OPS 5–510.40) versus laparoscopic (OPS 5–511.1) procedures, rate of conversion (OPS 5–511.2), cholecystostomy (OPS 5–510), post-operative outcome, and in-house-mortality as well as length of stay. For the analysis of in-hospital mortality, we excluded cases with discharge due to hospital transfer or unspecified reason. Length of stay was defined as number of nights during hospital stay. Reoperation was defined as any surgical procedure (*defined by any additional surgical procedure code OPS 5-xxx*) after the initial cholecystectomy during the same hospital stay.

In addition, all patients with the main diagnosis of AC have been compared according to treatment: cholecystectomy (OPS 5–511.0–2), cholecystostomy (OPS 5–510), or non-surgical treatment.

Statistical Analysis

Inferential statistics were based on generalized linear mixed models (GLMM) specifying hospitals as random factor.[19] We employed Poisson GLMMs for count data. Effects were estimated with the lme4 package (version 1.1–26)[20] in the R environment for statistical computing (version 4.0.2, 64-bit build).[21] For all tests, we apply a two-tailed 5% error criterion for significance.

For the description of the patient characteristics of the cohorts, we employed χ^2 tests for binary variables and analysis of variance for numeric variables. For the comparison of proportions of symptoms as well as selected treatments and outcomes in the different cohorts, we used logistic GLMMs with logit link function. The analysis of the outcome variable length of stay was performed via LMMs. For these analyses, we log-transformed the dependent variables. The computation of *p* values is based on the Satterthwaite approximation for degrees of freedom.

We report statistics for Elixhauser comorbidity index as well as its items. For the weighted Elixhauser comorbidity index, the AHRQ algorithm was applied.[22]

Results

Characterization of the Study Population

Within the study period from 5 March 2020 to 20 June 2021, 5604 patients with the diagnosis of AC have been admitted to 74 German Helios Hospitals. For the control period of the previous 2 years (6 March 2018 to 20 September 2019), 6941 patients with AC have been identified.

Comparing patients characteristics, we have noted only slight differences between the study and control group;

significantly more patients in the study groups (phases between waves, second and third wave) presented with an Elixhauser comorbidity index ≥ 5, more patients had renal failure and hypertension (phases between waves and second wave), complicated diabetes as well as congestive heart failure (phase between waves). For more details, see Table 1 and Tables at the Supplementary files.

Case Number and Distribution of Cases

Case number and distribution of all AC cases are shown at Fig. 1. The distribution mostly follows a reverse pattern of the German-wide COVID-19 incidences, with dips in admissions during the peaks of the pandemic. With the exemption of 4 weeks at the end of the second wave (in January and February 2021), all number of admissions over the course of the pandemic remained within the range of the pre-pandemic years.

Over the course of the pandemic, no significant differences in daily admissions of patients with AC could be demonstrated. During the first wave, 11.2 patients have been admitted daily compared to 12.6 patients in the previous years (incidence ratio rate (*IRR*) 0.94 (*CI* 0.80–1.10), *p* 0.46). Between the waves, there was a daily admission of 12.6 patients compared to 11.9 in 2018 and 2019 (*IRR* 1.10 (*CI* 0.94–1.29), *p* 0.22). Similar numbers have been documented for the second wave (11.7 patients compared to 12.3; *IRR* 0.97 (*CI* 0.83–1.13), *p* 0.68) and for the third wave (12.7 patients daily in the study group compared to 12.4 in the control group; *IRR* 1.07 (*CI* 0.91–1.24), *p* 0.41).

Treatments and Outcomes

The COVID-19 pandemic did not decrease the frequency of surgical therapy for inpatients with main diagnosis of AC. Patients admitted for AC during the pandemic were even more likely to be treated by surgery than patients of the control periods, with significant differences in favor of surgery during the first wave (Table 2). Unaffected by the pandemic and the different phases, most of the patients (66–67%) were operated within the first 2 days after admission. Cholecystostomy was performed very rarely through all periods (0 to 0.5% of all patients with AC; Table 2). In addition, our data suggests that the proportion of patients with AC and conservative treatment decreased over the years, almost unaffected by the COVID-19 pandemic, with non-surgical treatment as low as 11.7% of all patients with AC during the study period of the first wave (Table 2 and Tables at the Supplementary files).

There was no increase in open surgery for patients admitted with AC over the course of the pandemic. Figure 2a shows the weekly proportions of open cholecystectomy (primarily open and converted procedures). During the first

Table 1 Patients' characteristics — comparison of patient cohorts

Group	First wave Proportion (n) Control period	First wave Proportion (n) Study period	First wave P value	Between waves Proportion (n) Control period	Between waves Proportion (n) Study period	Between waves P value	Second wave Proportion (n) Control period	Second wave Proportion (n) Study period	Second wave P value	Third wave Proportion (n) Control period	Third wave Proportion (n) Study period	Third wave P value
Number of cases	1378	634		3195	1731		3446	1673		2951	1566	
Age (years)												
Mean (SD)	61.0±17.4	60.4±17.4	0.44	60.9±17.8	61.8±17.4	0.11	61.0±17.4	61.9±17.8	0.09	61.0±17.6	61.1±17.8	0.85
≤59	43.1% (594)	46.2% (293)	0.21	43.9% (1,403)	42.0% (727)	0.21	43.5% (1,499)	41.7% (698)	0.24	44.1% (1,300)	43.8% (686)	0.90
60–69	21.0% (290)	19.1% (121)	0.34	19.6% (627)	19.6% (339)	1.00	20.2% (695)	20.3% (339)	0.97	19.7% (580)	18.8% (295)	0.53
70–79	19.8% (273)	20.8% (132)	0.64	19.7% (631)	20.3% (352)	0.65	21.2% (730)	18.8% (315)	0.05	20.4% (601)	20.4% (319)	1.00
≥80	16.0% (221)	13.9% (88)	0.24	16.7% (534)	18.1% (313)	0.24	15.1% (522)	19.2% (321)	<0.01	15.9% (470)	17.0% (266)	0.38
Sex												
Male	50.2% (692)	52.2% (331)	0.43	47.9% (1,531)	50.5% (875)	0.08	48.0% (1,655)	49.0% (819)	0.55	49.4% (1,459)	48.3% (757)	0.50
Female	49.8% (686)	47.8% (303)		52.1% (1,664)	49.5% (856)		52.0% (1,791)	51.0% (854)		50.6% (1,492)	51.7% (809)	
Elixhauser comorbidity index												
Mean (SD)	3.7±9.1	3.5±9.0	0.65	4.1±9.4	4.9±9.7	<0.01	4.0±9.4	4.6±9.7	0.05	3.8±9.0	4.3±9.3	0.07
<0	30.7% (423)	35.0% (222)	0.06	29.5% (941)	28.9% (500)	0.70	30.8% (1,060)	30.7% (514)	1.00	30.6% (903)	28.9% (453)	0.26
0	30.6% (421)	27.0% (171)	0.11	29.8% (951)	25.8% (447)	<0.01	30.6% (1,054)	26.6% (445)	<0.01	30.1% (888)	28.5% (447)	0.29
1–4	7.3% (101)	4.9% (31)	0.05	7.2% (229)	7.5% (129)	0.76	6.0% (208)	6.3% (105)	0.78	7.1% (210)	7.4% (116)	0.76
≥5	31.4% (433)	33.1% (210)	0.48	33.6% (1,074)	37.8% (655)	<0.01	32.6% (1,124)	36.4% (609)	<0.01	32.2% (950)	35.1% (550)	0.05

Fig. 1 Case number and distribution of cases. A 4-week IRRs for the comparison between 2020/2021 and the average of 2018/2019. Based on Poisson GLMMs with sliding 4-week intervals
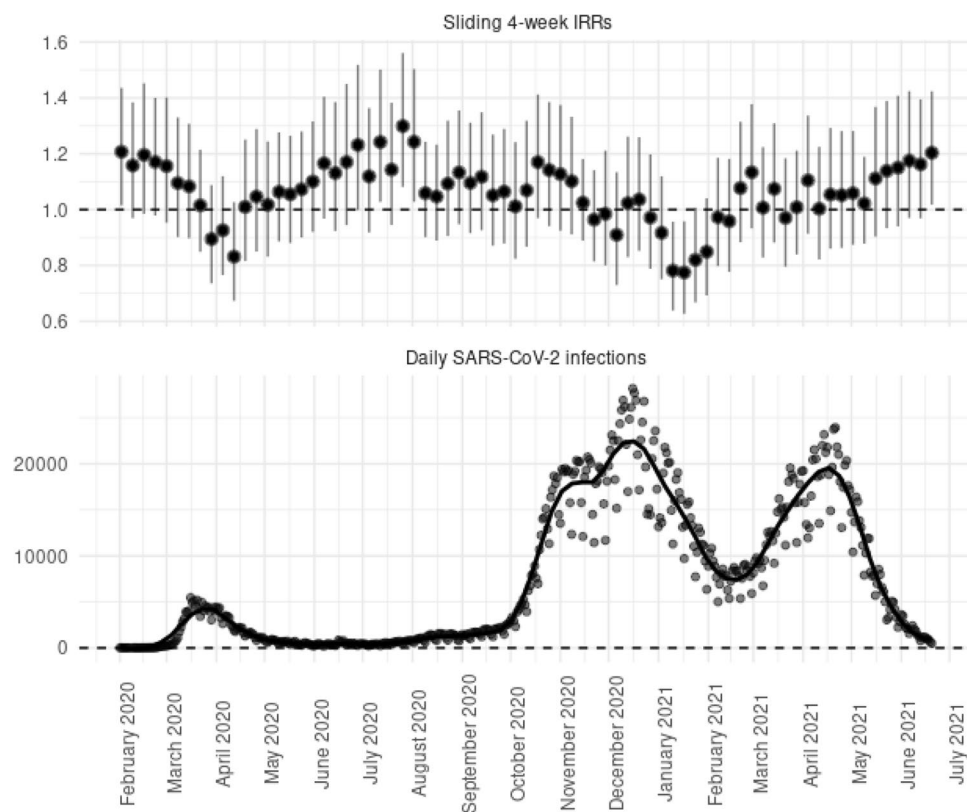

Table 2 Treatment for acute cholecystitis. Proportion of surgical and interventional treatments for acute cholecystitis

Period	Control period Proportion (n)	Study period	Odds ratio (95% CI)	P value
Cholecystectomy (laparoscopic, open and conversion)				
First wave	84.0% (1,135)	88.3% (561)	1.42 (1.06–1.90)	0.020
Between waves	83.2% (2,613)	84.7% (1,447)	1.14 (0.96–1.35)	0.139
Second wave	82.1% (2,825)	84.0% (1,383)	1.13 (0.96–1.34)	0.147
Third wave	83.2% (2,409)	85.4% (1,295)	1.17 (0.97–1.40)	0.100
Cholecystostomy (procedure 5–510)				
First wave	0.1% (1)	0.0% (0)		0.851
Between waves	0.2% (6)	0.3% (5)	1.65 (0.49–5.55)	0.422
Second wave	0.2% (7)	0.2% (4)	1.25 (0.36–4.39)	0.726
Third wave	0.1% (3)	0.5% (7)	4.68 (1.19–18.38)	0.027

Cohort of patients with full inpatient treatment, main diagnosis of acute cholecystitis, and admission to relevant hospital (at least one procedure 5–511 per year)

and the second wave, there was 1 week each where the proportion of open surgery was above the range of the previous years, but looking at the whole time periods of these waves, there were no significant differences. Even more, within the third phase, significantly less open cholecystectomies were performed at all hospitals compared to the control period (Table 3).

Figure 2b illustrates the weekly in-hospital mortality of patients with cholecystectomy for AC over the course of the pandemic. Similar to the weekly proportions of open

cholecystectomy (Fig. 2a), there is 1 week during the peak of the second wave, where mortality has been above the range of the previous years, but comparing the defined periods, there are no significant differences. In-hospital mortality for surgery of AC was very low during all periods and did not differ significantly between the phases of the pandemic nor compared to the pre-COVID years (1.5 to 1.9%, Table 4).

Although we saw no differences between study and control groups for injury of the common bile duct (ICD S36.18), a peritonitis due to bile (ICD K56.8) has been documented

Fig. 2 **A** Proportions of open cholecystectomy. Weekly proportions of open cholecystectomy (primarily open and converted procedures). The box-and-whiskers plot (left hand) represents the distribution of weekly proportion of open cholecystectomy in 2018 and 2019. **b** In-hospital mortality all patients with cholecystectomy. Weekly in-hospital mortality. The box-and-whiskers plot (left hand) represents the distribution of weekly in-hospital mortality in 2018 and 2019
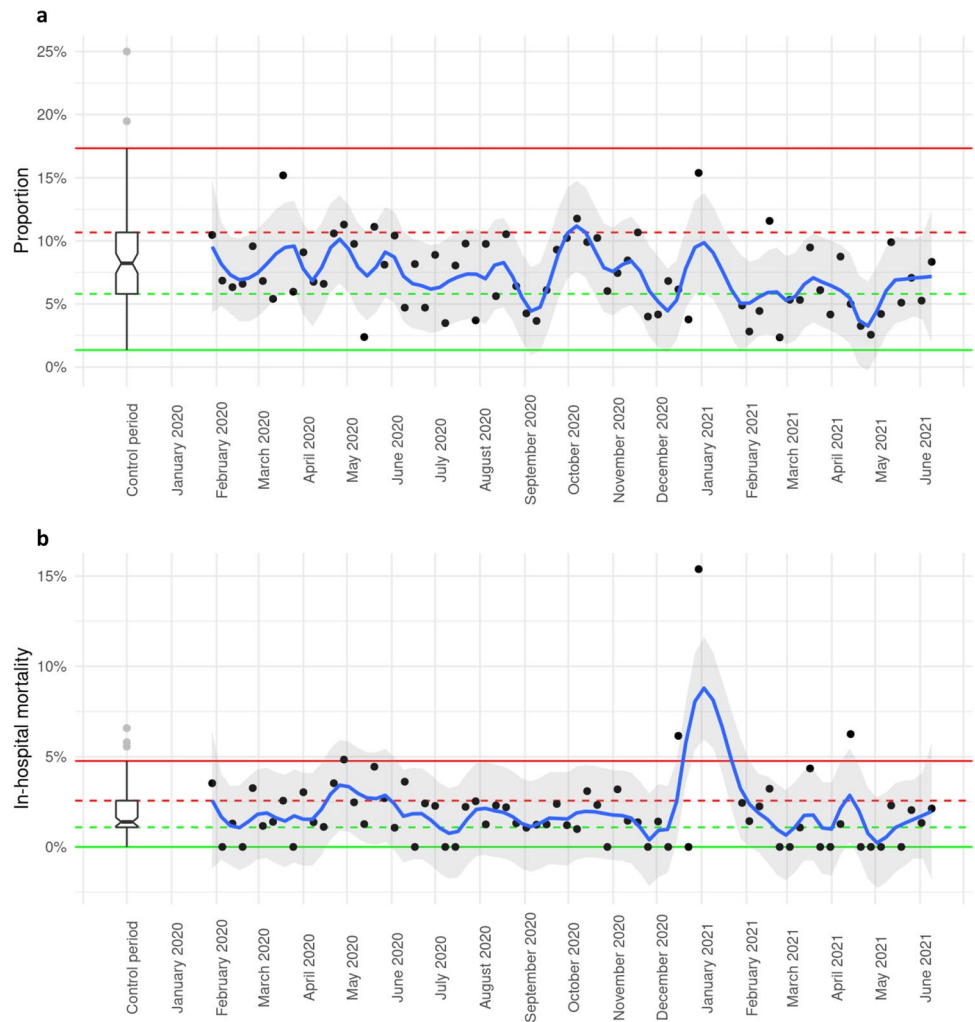

Table 3 Treatment for acute cholecystitis. Comparison of type of surgery in all patients with cholecystectomy

Period	Control period Proportion (n)	Study period	Odds ratio (95% CI)	P value
Open surgical cholecystectomy				
First wave	4.4% (61)	5.5% (35)	1.31 (0.85–2.03)	0.222
Between waves	5.1% (164)	4.2% (72)	0.78 (0.59–1.04)	0.092
Second wave	4.7% (162)	4.2% (71)	0.88 (0.66–1.18)	0.402
Third wave	5.0% (149)	3.4% (53)	0.67 (0.49–0.93)	0.016
Laparascopic cholecystectomy				
First wave	93.0% (1,281)	91.6% (581)	0.80 (0.56–1.14)	0.222
Between waves	91.4% (2,920)	92.7% (1,604)	1.22 (0.98–1.53)	0.074
Second wave	91.5% (3,153)	92.5% (1,547)	1.18 (0.95–1.48)	0.139
Third wave	92.2% (2,720)	93.6% (1,466)	1.24 (0.97–1.59)	0.085
Switch laparascopic — open surgical				
First wave	2.6% (36)	2.8% (18)	1.09 (0.61–1.95)	0.773
Between waves	3.5% (111)	3.2% (55)	0.90 (0.64–1.26)	0.543
Second wave	3.8% (131)	3.3% (55)	0.83 (0.60–1.15)	0.274
Third wave	2.8% (82)	3.0% (47)	1.05 (0.72–1.53)	0.796

slightly more often during the different waves of the pandemic, with a significant increase in the third wave (compared to the control period). Table 5 presents comparison of all documented outcomes in the different cohorts.

Median length of stay was 4 days for all study and control periods. Patients in the study periods between waves, second and third wave had a slightly decreased length of stay compared to control periods (between waves: control period mean $6.6 \pm$ SD 8.2, median 4.0 [*IQR* 3, 7] vs study period 6.3 ± 9.4, 4.0 [*IQR* 3, 7], ratio 0.94 (0.92–0.96, 95% *CI*), $p < 0.01$; second wave: control period 6.4 ± 7.2, 4.0 [*IQR* 3, 7] vs study period 6.0 ± 7.4, 4.0 [*IQR* 3, 6], 0.95 (0.92–0.97), $p < 0.01$; third wave: control period 6.3 ± 7.2, 4.0 [*IQR* 3, 7] vs study period 6.2 ± 8.0, 4.0 [*IQR* 3, 6], 0.97 (0.94–0.99), $p < 0.01$) (see Tables at the Supplementary files).

Discussion

During the COVID-19 pandemic, and especially during the lockdown periods, visits to GPs and hospital admissions were restricted to urgent treatment only. Therefore, elective surgery for gallstone disease with minor symptoms and absence of acute inflammation was postponed for several months.[18] Patients with gallstones will develop gallstone-related complications with an incidence of 1–3% annually.[9] Following the idea that delayed surgery for gallstone disease could lead to an increase of presentations with AC, admissions and frequency of surgery for AC should show an increase during the course of the pandemic. Furthermore, stress and anxiety may trigger unhealthy nutrition habits with increased fat consumption. During the pandemic, a more widely use of high fat diet together with less physical exercise (due to stay home orders and closure of sports clubs and gyms) could have increased the risk for the development of gallstones

and the development of AC. Nevertheless, as we could demonstrate with our data, no increase of admissions nor increase in surgery for AC has so far been observed during the COVID-19 pandemic in Germany. Even during the resumption after the first wave and also later in the course of the pandemic, we could not demonstrate higher numbers of cases with AC compared to the "pre-COVID" control periods.

For acute appendicitis, there is conflicting evidence whether or not the COVID-19 pandemic led to an increase in complicated appendicitis. Most of the studies describing more severe cases of appendicitis focus on the early periods of the pandemic, and often include some 60 patients only for the study period.[14,15,23,24] These findings are usually explained by a delay in consulting the emergency department,[15] or because patients with mild appendicitis may hesitate to seek help.[25] Although studies based on claims data from German insurance companies demonstrate a significantly reduced number of appendectomies, this drop affected mostly simple acute and non-acute appendicitis, but not complicated acute appendicitis.[13,26]

Compared to appendectomies, which are almost exclusively performed for acute appendicitis, cholecystectomies are predominantly performed as elective procedures for gallstone disease. Acute or emergency cholecystectomy is reserved for AC only, whereas almost all appendectomies are performed as urgent operations. The significant reduction in cholecystectomies observed during the pandemic has been explained by canceled or postponed non-urgent operations.[17,18] This is supported by our data, which demonstrate no significant change of admissions nor surgery for AC. Although some surgeons anecdotally reported a subjective increase of more severe cases of acute cholecystitis with difficult intraoperative presentations, no data has been published so far to support these findings. The severity of AC is not routinely assessed with validated scores nor is there a good breakdown for severity or complications within the ICD-system. Because of the limitation of our study to routine claims data relying mostly on ICD- and OPS-codes, we could not prove an increase of severity or complicated AC. The slightly higher proportion of patients with an Elixhauser comorbidity index ≥ 5 and renal failure may be interpreted as systemic symptoms and organ damage at time of admission, which could be caused by severe AC.[27] In addition, the slight increase in cases with documented peritonitis due to bile could be a surrogate for a perforation or necrosis of the gallbladder, and thus a sign of a severe case.[28] On the other hand, complications like hemorrhage, injury of common bile duct, or reoperations were similar between study and control periods (or even slightly lower within the pandemic). Finally, based on surrogate parameters like conversion from laparoscopic to open surgery as well as morbidity and mortality after surgery, we could demonstrate that outcome of

Table 4 Mortality (In-hospital mortality all patients with cholecystectomy)

Period	Control period Proportion (*n*)	Study period	Odds ratio (95% *CI*)	*P* value
First wave	1.6% (21)	1.9% (12)	1.24 (0.61–2.53)	0.559
Between waves	1.7% (52)	1.9% (32)	1.13 (0.73–1.76)	0.585
Second wave	1.8% (61)	1.8% (29)	0.97 (0.62–1.52)	0.902
Third wave	1.5% (44)	1.6% (24)	1.02 (0.62–1.69)	0.931

Based on 16,187 cases (97.7%), we excluded cases with discharge due to hospital transfer or unspecified reason

Table 5 Morbidity (Complications of all patients with cholecystectomy)

Period	Control period Proportion (n)	Study period	Odds ratio (95% CI)	P value
Reoperation with complications				
First wave	1.2% (17)	1.7% (11)	1.41 (0.66–3.04)	0.375
Between waves	2.6% (83)	1.8% (31)	0.68 (0.44–1.03)	0.069
Second wave	1.8% (63)	1.4% (24)	0.78 (0.49–1.26)	0.308
Third wave	1.8% (52)	1.6% (25)	0.90 (0.55–1.46)	0.672
Disruption of operation wound or infection following a procedure				
First wave	0.9% (12)	1.1% (7)	1.27 (0.49–3.26)	0.621
Between waves	1.5% (49)	1.2% (20)	0.73 (0.43–1.23)	0.239
Second wave	1.2% (40)	1.0% (16)	0.83 (0.46–1.50)	0.545
Third wave	1.3% (37)	0.9% (14)	0.70 (0.38–1.31)	0.266
Pneumonia				
First wave	3.4% (47)	3.0% (19)	0.93 (0.53–1.61)	0.788
Between waves	3.0% (95)	2.8% (48)	0.93 (0.65–1.32)	0.691
Second wave	3.0% (103)	4.1% (69)	1.40 (1.02–1.91)	0.036
Third wave	3.1% (91)	3.4% (53)	1.12 (0.79–1.58)	0.540
Peritonitis due to bile				
First wave	1.8% (25)	2.8% (18)	1.87 (0.98–3.56)	0.058
Between waves	1.7% (54)	1.7% (30)	1.04 (0.65–1.64)	0.882
Second wave	1.9% (65)	2.5% (42)	1.33 (0.89–1.99)	0.168
Third wave	1.7% (49)	4.3% (67)	2.74 (1.87–4.03)	<0.001
Injury of common bile duct				
First wave	0.3% (4)	0.0% (0)		0.998
Between waves	0.2% (6)	0.1% (2)	0.61 (0.12–3.05)	0.551
Second wave	0.1% (5)	0.3% (5)	2.01 (0.58–7.01)	0.273
Third wave	0.2% (6)	0.3% (4)	1.26 (0.35–4.46)	0.723
Hemorrhage				
First wave	2.4% (33)	1.9% (12)	0.80 (0.41–1.57)	0.510
Between waves	2.3% (74)	2.4% (42)	1.08 (0.74–1.60)	0.682
Second wave	1.8% (62)	2.1% (35)	1.18 (0.77–1.80)	0.451
Third wave	2.5% (73)	1.6% (25)	0.66 (0.41–1.06)	0.086

Hemorrhage was defined as a diagnosis of ICD T81.0

AC during all phases of the pandemic did not differ from the previous years, with or without increase of severity.

The early calls of some surgical societies and health care providers for an implementation of non-operative management for acute cholecystitis were comprehensible facing an anticipated collapse of hospital capabilities. From a present-day perspective, this tendency towards a more non-operative management in the decision-making process for treatment of AC and the advice against laparoscopic surgery were probably not justified. The initial recommendations and reports for non-surgical management or cholecystostomy instead of cholecystectomy represented a major deviation from the previous, evidence-based best practice. Our analysis did not reveal a sustained increase of cholecystostomy nor of the proportion of non-surgical treatment over the course of the pandemic. At all German Helios hospitals, the proportion of open cholecystectomy for AC and the cases of conversion were remarkable low and unaffected by the pandemic (less than 5% for primary open surgery and around 3% for conversions, in both the study and control periods). Even during the peaks with a very high incidence of COVID-19, the weekly proportions of open cholecystectomy stayed within the range of the previous years.

Limitations

The present study was based on claims data collected for reimbursement purposes. An intrinsic limitation of this approach is that results largely depend on quality of encoded diagnoses and procedures.[29,30]

Due to the strong restrictions and suspension of elective surgery, some hospitals may have declared a few cases of symptomatic gallstone disease with almost no signs of

inflammation as an AC in order to justify surgery. However, this may have applied to previous years, and especially the fear of the population to ask for emergency consultation without severe symptoms may have limited these cases as well. We were not able to prove the diagnosis through pathology reports, whether an acute or chronic cholecystitis or even absence of inflammation has been finally diagnosed. Nonetheless, final coding of diagnosis should always be based on pathology results and will be routinely checked after patients discharge.

This study is based on administrative data of German Helios hospitals. The Helios hospital group operates metropolitan and regional hospitals ranging from basic primary care to maximum care and tertiary referral centers. Nevertheless, our findings may not be universally attributed to public hospitals or other countries.

Conclusions

The restrictions during the COVID-19 pandemic did not result in an increase of admissions or surgery for AC. Initial advice for conservative treatment and against laparoscopic procedures is not justified. Laparoscopic surgery for AC can be, and has been, safely applied during the COVID-19 pandemic. While the COVID-19 pandemic is still in progress and new waves looming, our results may assure patients and surgeons of the sustained high quality of surgical care provided for AC even in times of disruptions to the health care system.

Author Contribution RS contributed to the study concept and design, analyzed and interpreted the data, and drafted the manuscript. SH and AB acquired, analyzed and interpreted the data, and revised the article critically. SA and MS contributed to the study concept and design. RK contributed to the study concept and design and revised the article critically. All authors read and approved the final version of the article.

Data Availability The data supporting the conclusions of this article is included within the article and its additional files. The datasets generated and/or analyzed during the current study are not publicly available due to federal and corporate data protection, but are available from the corresponding author on reasonable request.

Declarations

Ethics Approval and Consent to Participate The Ethics Committee at the Medical Faculty, Leipzig University, approved this study (#490/20-ek). The requirement for obtaining informed consent from patients was waived because the data were stored pseudonymized. Data use was approved by the Helios Kliniken GmbH data protection authority.

Competing Interests The authors declare no competing interests.

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