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Timely cholecystectomy: important factors to improve guideline adherence and patient treatment

Leonard Fehring ,[1,2] Hendrik Brinkmann ,[1] Sven Hohenstein ,[3] Andreas Bollmann ,[3] Patrick Dirks ,[3] Jörg Pölitz ,[3] Christian Prinz [1,2]

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LF and HB are joint first authors.

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[1]Faculty of Health, School of Medicine, Witten/Herdecke University, Witten, Germany
[2]Gastroenterology, HELIOS Universitätsklinikum Wuppertal, Wuppertal, Nordrhein-Westfalen, Germany
[3]Helios Health Institute GmbH, Leipzig, Germany

Correspondence to
Dr Leonard Fehring;
leonard.fehring@uni-wh.de

ABSTRACT

Objective Cholecystectomy is one of the most frequently performed surgeries in Germany and is performed as a treatment of acute cholecystitis (guideline S3 IIIB.8) and after endoscopic retrograde cholangiopancreatography for choledocholithiasis with simultaneous cholecystolithiasis (guideline S3 IIIC.6). This article examines the effects of a guideline update from 2017, which recommends prompt cholecystectomy within 24 hours of admission due to cholecystitis or within 72 hours after bile duct repair. In addition, it aims to identify reasons (eg, financial disincentives) and potential for improvement for non-adherence to the guidelines.

Design Methodologically, a retrospective analysis based on routine billing data from 84 Helios Group hospitals from 2016 and 2022, with a total of 45 393 included cases, was applied. The guideline adherence rate is used as the main outcome measure.

Results Results show the guideline updates led to a statistically significant increase in the proportion of cholecystectomy performed in a timely manner (guideline S3 IIIB.8: increase from 43% to 49%, p<0.001; guideline S3 IIIC.6: increase from 7% to 20%, p<0.001). Medical, structural and financial reasons for non-adherence could be identified.

Conclusion As possible reasons for non-adherence, medical factors such as advanced age, multimorbidity and frailty could be identified. Analyses of structural factors revealed that hospitals in very rural regions are less likely to perform timely cholecystectomies, presumably due to infrastructural and personnel-capacity bottlenecks. A similar picture emerges for maximum-care hospitals, which might be explained by more severe and complex cases on average. Further evaluation indicates that an increase in and better hospital-internal participation of gastroenterologists in remuneration could lead to even greater adherence to the S3 IIIC.6 guideline.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ New scientific findings recommend prompt cholecystectomy for cholecystitis (within 24 hours) or after endoscopic retrograde cholangiopancreatography for choledocholithiasis (within 72 hours).
⇒ As a result, the corresponding guidelines in Germany were adopted in 2017.
⇒ The effects and potential reasons for non-adherence to the updated guidelines are unknown.

WHAT THIS STUDY ADDS

⇒ Study shows that guideline updates lead to a significant improvement in clinical application.
⇒ However, medical, structural and financial factors have been identified that prevent an even higher application rate.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Systematically addressing identified barriers (especially solving financial disincentives) has the potential to make a relevant contribution to significantly improving the treatment of patients with cholecystitis and choledocholithiasis worldwide.

INTRODUCTION

Medical relevance and change of German treatment guidelines

The surgical removal of the gallbladder (cholecystectomy, hereinafter referred to as CHE) is the 11th most common surgery in Germany, with 190 896 cases in 2021.[1] Two common reasons for performing a CHE are the treatment of acute cholecystitis and the follow-up treatment after successful endoscopic cholangiography (hereinafter referred to as ERCP) for choledocholithiasis.[2 3]

Due to new medical findings and health policy efforts, the respective German treatment guidelines in the context of CHE underwent relevant changes.[3]

Acute cholecystitis is the most common complication of gallstone disease. In over 90% of cases of acute cholecystitis, an obstruction of the cystic duct by a gallstone is the cause of the symptoms, which are treated as standard by laparoscopic CHE.[3 4] After a long period of controversy about the period from admission to CHE, new scientific findings (eg, results of the "ACDC study" by Gutt et al. in 2013[5] comparing early versus delayed CHE) show clear advantages in favour of immediate CHE within 24 hours of admission to the hospital in terms of morbidity, hospitalisation time

and total costs for the clinical stay.[3 5–16] Following these latest developments, the current S3 guideline IIIB.8 on 'prevention, diagnosis and treatment of gallstones', dated 30 November 2017, now recommends prompt CHE within 24 hours of hospital admission for acute cholecystitis.[3]

In the past, it was common practice to perform a CHE 4–6 weeks after successful removal of the bile duct stones.[3 17 18] However, more recent studies showed that prompt CHE within 72 hours of endoscopic biliary repair significantly reduced the risk of recurrent biliary events.[19–23] Consequently, the S3 guideline IIIC.6, updated on 30 November 2017, stipulates prompt CHE within the aforementioned time window of 72 hours after successful endoscopic bile duct repair in cases of cholecystolithiasis.[3]

Research questions

In light of the above developments, the primary research question of this research project aims to analyse the extent to which the two updated guidelines are applied with regard to timely CHE. Possible reasons for non-guideline-compliant cases will be derived as part of the secondary research question. Reasons could be of a medical nature (eg, complex cases, comorbidities and age) or have structural factors (eg, low guideline adherence in smaller hospitals without teaching activities; current DRG remuneration, which may set false incentives).

METHODS

Data

The analyses are based on retrospective, anonymised administrative data of the Helios Group from the years 2016–2022, including 84 hospitals, which consist of a representative sample of the entire hospital landscape. Of these, 66 clinics offer a 24-hour on-call endoscopy service (including ERCP). The period 2016–2022 is intended to ensure comparability between the old guideline (before 30 November 2017) and the updated guideline (after 30 November 2017).

The use of billing data provided, prepared and statistically aggregated by Helios Health Institute enables at least partial tracking of a patient over several hospital stays (within the Helios Group). The partial tracking is necessary because if the guideline is not applied, a CHE can be carried out weeks or months later as part of a separate hospital stay.

It was ensured that all the data analysed did not allow for the identification a patient. In the first step, all personal details (eg, name, insurance number and date of birth) were deleted. Subsequently, needed data attributes were aggregated into groups, which do not allow the data to be traced back to the original patient. For example, the actual time of the surgery or admission is not transmitted, but only the time between admission and surgery is specified in days.

Inclusion and exclusion criteria, as well as data attributes for the two guidelines, can be found in figure 1.[24 25]

Statistical analysis

Administrative data were extracted from QlikView (QlikTech, Radnor, Pennsylvania, USA).

Inferential statistics were based on generalised linear mixed models (GLMMs), specifying hospitals as a random factor.[26] Effects were estimated with the lme4 package (V.1.1–26) in the R environment for statistical computing (V.4.0.2, 64-bit build).[27 28] In all mixed models, we specified varying intercepts for the random

	S3 Guideline IIIB.8 (acute cholecystitis): CHE within 1 d after admission	S3 Guideline IIIC.6 (after ERCP): CHE within 3 d after successful ERCP
Inclusion criteria	▪ Full inpatient treatment ▪ Hospital admission between 01/01/2016 - 29/11/2017 (control cohort) or 30/11/2017 – 31/12/2022 (study cohort)	
	One of the following diagnoses: ▪ Calculus of gallbladder with acute cholecystitis without mention of obstruction of biliary tract (ICD K80.00), ▪ Calculus of gallbladder with acute cholecystitis with obstruction of biliary tract (ICD K80.01), ▪ Cholecystitis (ICD K81)	One of each of the following diagnoses/procedures: ▪ Calculus of gallbladder with acute cholecystitis (ICD K80.0), with other cholecystitis (ICD K80.1), without cholecystitis (ICD K80.2), ▪ Calculus of bile duct with cholangitis (ICD K80.3), with cholecystitis (ICD K80.4), without cholangitis or cholecystitis (ICD K80.5), ▪ Endoscopic surgeries on the bile ducts: Stone removal (OPS 5-513.2)
Exclusion criteria		Cases with Cholecystectomy (OPS 5-511) before stone removal (same case)
Data attributes	▪ Main & secondary diagnoses of the case ▪ Associated DRG (renumeration code) ▪ Age, Elixhauser Comorbidity Index and Hospital Frailty Index of the patient ▪ Information on hospital: o Location type (very central/urban, central/urban, peripheral/rural, very peripheral/rural) defined by German Federal Office for Building and Regional Planning based on spatial analyses of population density [24] o Clinic type as defined by each German federal state, whereby the following classification essentially applies [25]: – Basic and standard care provider: hospitals providing general care in the areas of internal medicine and general surgery – Specialised care provider: hospitals providing a broader range of services (e.g. pediatrics or neurology) – Maximum care provider: hospitals with a very wide range of services and able to treat rare or serious illnesses) ▪ Information on potential patient's anticoagulation defined by following diagnoses coding long-term therapy with anticoagulants (ICD Z92.1) and set of coagulopathies (e.g., factor V Leiden mutation; ICD D66-68)	
	▪ CHE performed yes/no [OPS: 5-511] o If CHE performed: Time between inpatient admission and performance of CHE in days	▪ Duration between endoscopic common bile duct repair [OPS: 5-513.2] and cholecystectomy [OPS: 5-511] in days

Figure 1 Inclusion and exclusion criteria as well as data attributes for the two guidelines.

factor. For all tests, we applied a two-tailed 5% error criterion for significance.

For the description of the patient characteristics of the cohorts and comorbidities, we employed χ^2 tests for categorical variables and two-sample t-tests for numerical variables. We report proportions, means, SD and p values. For the comparison of proportions of selected treatments and outcomes in the different cohorts, we used logistic GLMMs with the logit link function, taking into account the distribution of differences between the clinics as a random factor. We report proportions and ORs together with CIs and p values.

The analysis of the variables associated with the time of the CHE (number of days and number of readmissions) was performed via linear mixed models. Because these variables were positively skewed, we transformed them via the inverse hyperbolic sine in order to roughly approximate normal distributions.[29] We report means, SD, medians, IQRs and p values.

We report statistics for the Elixhauser comorbidity index (ECI) as well as its items. For the weighted ECI, the Agency for Healthcare Research and Quality algorithm was applied.[30 31]

The term 'control group (C)' refers to the group of patients who were admitted to the hospital before the guideline was amended (30 November 2017). The 'study group (S)' refers to the period of the updated guideline.

RESULTS

Patient characteristics

A total of 41 956 patients were included in the analyses for S3 guideline IIIB.8 (CHE after hospital admission for acute cholecystitis). Of these, 11 835 patients (28%) were in the C and 30 121 patients (72%) were in the S. The analyses for the S3 guideline IIIC.6 (CHE after successful ERCP) included 3437 patients, of whom 1127 (C: 33%) were included before and 2310 (S: 67%) after the guideline was amended.

For both guidelines, the S and C groups can be considered comparable with regard to the characteristics of age, ECI and hospital frailty index (HFI). A detailed list can be found in figure 2.

S3 guideline IIIB.8: prompt CHE (<24 hours) after hospital admission for acute cholecystitis

The analyses show that the proportion of CHE in acute cholecystitis treated within 24 hours increased significantly from 43% to 49% after the guideline change. This means that almost half of all acute cholecystitis cases are treated in accordance with the guidelines (figure 3). The proportion of cases in which no CHE was performed remained constant at 22%. Thus, no statistical differences and therefore no effects of the guideline can be derived for this parameter.

A more detailed split by days until surgery is depicted in figure 3. Only the proportion of cases treated within the first 24 hours has increased, while the proportion of cases treated after more than 2 days has fallen in all cases. The proportion of CHE cases treated during the same stay in the period between admission and surgery is distributed as follows: day 0 (d0): 32% (C), 34% (S); d1: 30% (C), 33% (S); d2: 13% (C), 12% (S); d3: 7% (C), 6% (S); d4: 4% (C), 3% (S); d5: 3% (C), 2% (S); d6: 2% (C), 1% (S) and d7+: 11% (C), 8% (S).

Characteristic	S3 Guideline IIIB.8			S3 Guideline IIIC.6		
	Control group, N = 11,835[1]	Study group, N = 30,121[1]	p-value[2]	Control group, N = 1,127[1]	Study group, N = 2,310[1]	p-value[2]
Age	63.4 (17.6)	63.4 (17.8)	0.934	65.9 (17.9)	66.7 (18.0)	0.217
Age group			< 0.001			0.008
<60 years	4,592 (38%)	11,575 (38%)		358 (32%)	700 (30%)	
60–69 years	2,196 (19%)	5,926 (20%)		183 (16%)	420 (18%)	
70–79 years	2,710 (23%)	6,186 (21%)		306 (27%)	521 (23%)	
≥ 80 years	2,337 (20%)	6,434 (21%)		280 (25%)	669 (29%)	
Sex			0.043			0.185
Male	5,776 (49%)	15,032 (50%)		487 (43%)	1,055 (46%)	
Female	6,059 (51%)	15,089 (50%)		640 (57%)	1,255 (54%)	
Elixhauser comorbidity index			0.047			0.198
<1	5,684 (49%)	14,832 (49%)		466 (42%)	965 (42%)	
1-4	752 (6.4%)	1,999 (6.6%)		113 (10%)	189 (8.2%)	
≥ 5	5,399 (46%)	13,290 (44%)		548 (49%)	1,156 (50%)	
Elixhauser comorbidity score	7.2 (11.8)	6.9 (11.5)	0.006	6.8 (10.2)	6.9 (9.8)	0.887
Hospital frailty risk index			0.043			0.45
< 5	8,287 (70%)	21,405 (71%)		803 (71%)	1,647 (71%)	
5-15	2,608 (22%)	6,509 (22%)		256 (23%)	546 (24%)	
> 15	940 (7.9%)	2,207 (7.3%)		68 (6.0%)	117 (5.1%)	
Hospital frailty risk score	4.4 (6.2)	4.2 (6.0)	0.016	4.1 (5.6)	4.1 (5.3)	0.904

[1] Mean (SD); n (%) | [2] Welch Two Sample t-test; Pearson's Chi-squared test

Figure 2 Patient characteristics.

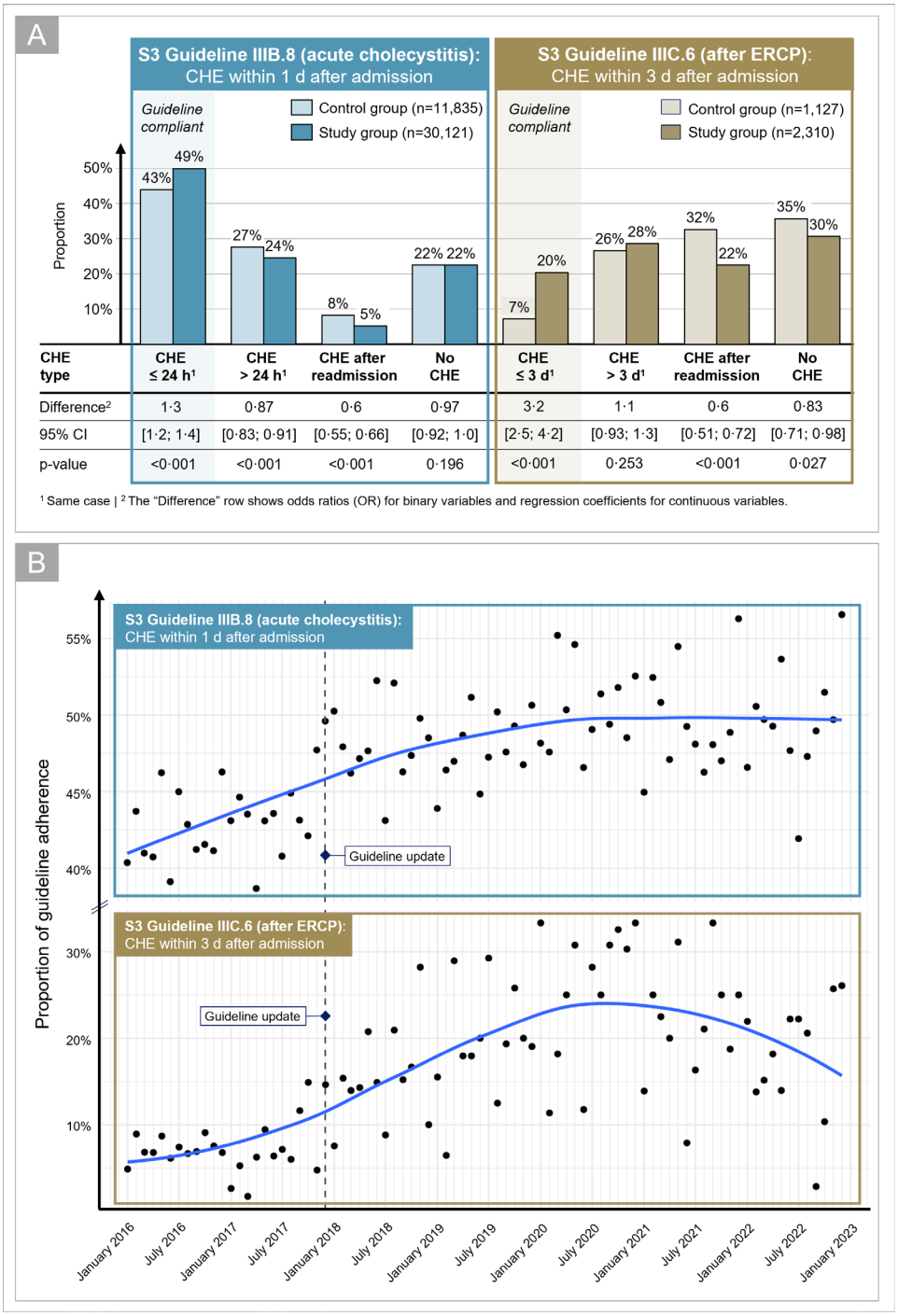
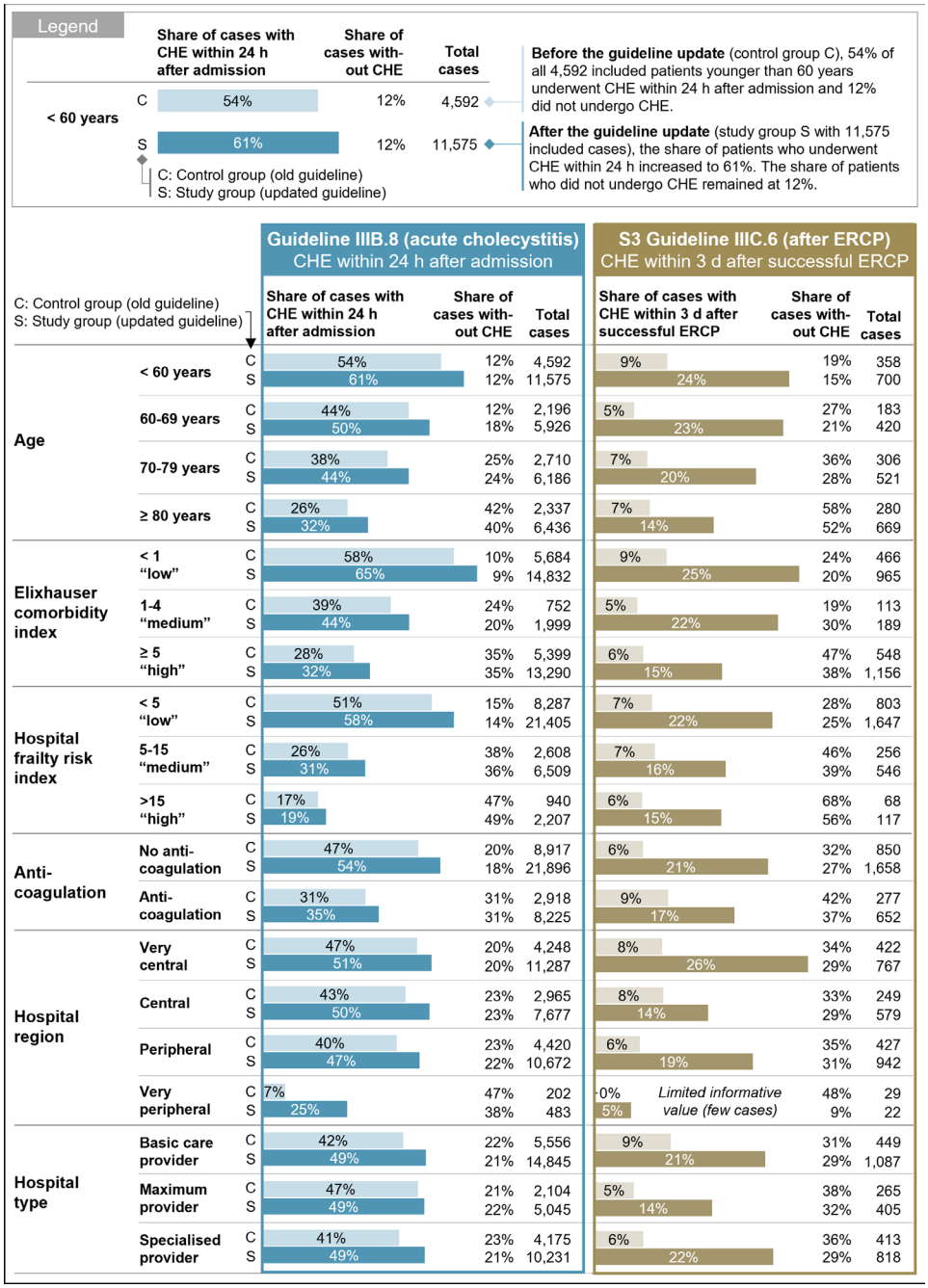


Figure 3 (A) Share of CHE split by CHE type/time after initial admission for S3 guideline IIIB.8 (in blue box) and IIIC.6 (in brown box). (B) CHE according to updated guidelines for S3 guidelines IIIB.8 (in blue box) and IIIC.6 (in brown box) on a weekly basis from January 2016 until December 2022 (curve calculated based on locally estimated scatterplot smoothing). CHE, cholecystectomy.

In order to investigate which factors may have prevented a higher or even 100% application rate of the guideline, further analyses regarding patient-specific (age, comorbidities, frailty and anticoagulation) and structural (hospital location and type) factors were carried out (figure 4). To reduce the scope of the report, the following analyses focus on the two options: 'CHE according to updated guidelines' and 'no CHE'.

Regarding age, the analyses show that the application rate of the guideline decreases steadily with increasing age. At the same time, the proportion of CHE performed within 1 day has increased across all age groups. A look at the cases without CHE shows the opposite picture: with increasing age, the proportion of cases in which no CHE was carried out rises significantly.



			Guideline IIIB.8 (acute cholecystitis) CHE within 24 h after admission: Share of cases with CHE within 24 h after admission	Share of cases without CHE	Total cases	S3 Guideline IIIC.6 (after ERCP) CHE within 3 d after successful ERCP: Share of cases with CHE within 3 d after successful ERCP	Share of cases without CHE	Total cases
Age	< 60 years	C	54%	12%	4,592	9%	19%	358
		S	61%	12%	11,575	24%	15%	700
	60-69 years	C	44%	12%	2,196	5%	27%	183
		S	50%	18%	5,926	23%	21%	420
	70-79 years	C	38%	25%	2,710	7%	36%	306
		S	44%	24%	6,186	20%	28%	521
	≥ 80 years	C	26%	42%	2,337	7%	58%	280
		S	32%	40%	6,436	14%	52%	669
Elixhauser comorbidity index	< 1 "low"	C	58%	10%	5,684	9%	24%	466
		S	65%	9%	14,832	25%	20%	965
	1-4 "medium"	C	39%	24%	752	5%	19%	113
		S	44%	20%	1,999	22%	30%	189
	≥ 5 "high"	C	28%	35%	5,399	6%	47%	548
		S	32%	35%	13,290	15%	38%	1,156
Hospital frailty risk index	< 5 "low"	C	51%	15%	8,287	7%	28%	803
		S	58%	14%	21,405	22%	25%	1,647
	5-15 "medium"	C	26%	38%	2,608	7%	46%	256
		S	31%	36%	6,509	16%	39%	546
	>15 "high"	C	17%	47%	940	6%	68%	68
		S	19%	49%	2,207	15%	56%	117
Anti-coagulation	No anti-coagulation	C	47%	20%	8,917	6%	32%	850
		S	54%	18%	21,896	21%	27%	1,658
	Anti-coagulation	C	31%	31%	2,918	9%	42%	277
		S	35%	31%	8,225	17%	37%	652
Hospital region	Very central	C	47%	20%	4,248	8%	34%	422
		S	51%	20%	11,287	26%	29%	767
	Central	C	43%	23%	2,965	8%	33%	249
		S	50%	23%	7,677	14%	29%	579
	Peripheral	C	40%	23%	4,420	6%	35%	427
		S	47%	22%	10,672	19%	31%	942
	Very peripheral	C	7%	47%	202	0%	48%	29
		S	25%	38%	483	5%	9%	22
Hospital type	Basic care provider	C	42%	22%	5,556	9%	31%	449
		S	49%	21%	14,845	21%	29%	1,087
	Maximum provider	C	47%	21%	2,104	5%	38%	265
		S	49%	22%	5,045	14%	32%	405
	Specialised provider	C	41%	23%	4,175	6%	36%	413
		S	49%	21%	10,231	22%	29%	818

Figure 4 Share of cases with timely CHE (bars), share of cases without CHE and total cases before and after guideline update, split by patient-specific and structural characteristics. CHE, cholecystectomy; ERCP, endoscopic cholangiography.

The analyses of patients' comorbidities show that the degree of guideline compliance fell continuously from 58% (C) or 65% (S) in patients with no or only minor comorbidities (ECI<1) to 28% (C) or 32% (S) in patients with high comorbidity (ECI≥5).

The analyses of patients' frailty assessed by the HFI show a similar picture. As frailty increases, guideline compliance decreases from 51% (C) and 58% (S) for low frailty to 17% (C) and 19% (S) for high frailty. At the same time, the proportion of non-cholecystectomised patients increases.

As anticoagulation can be a contraindication for a timely CHE, this aspect was also analysed. The data show that the proportion of timely CHEs is significantly lower in anticoagulated patients (31% (C) or 35% (S)) than in non-anticoagulated patients (47% (C) or 54% (S)).

Analyses concerning the location of the hospital show that the proportion of patients undergoing prompt CHE decreases significantly for hospitals located in rural/peripheral areas compared with hospitals located in very central/urban areas. It is noticeable that patients in very peripheral hospitals are comparatively often not cholecystectomised.

Before the guideline update, the proportion of patients undergoing timely CHE was significantly higher for maximum care providers (47%) than for basic and

standard care providers (42%) and specialised providers (41%). In contrast, this proportion increased to 49% for all hospital types after the updated guidelines. No significant differences were found with regard to the proportion of non-cholecystectomised patients.

S3 guideline IIIC.6: prompt CHE (<72 hours) after ERCP for choledocholithiasis with simultaneous cholecystolithiasis

With regard to the primary research question, the analyses show that the proportion of CHE cases of cholecystolithiasis performed within 72 hours of successful ERCP increased significantly from 7% before the guideline update to 20% after the change. This means that, on average, one in five patients is treated in accordance with the updated guideline (figure 3).

At the same time, it can be observed that the proportion of cases that were not treated within the 3 days stipulated by the guideline but within the same stay increased from 26% to 28%. In total, therefore, 15% more patients were treated during the same stay who had previously either been called in again for CHE or for whom no CHE was performed. Specifically, the proportion of cases with CHE as part of readmission fell from 32% to 22% and the proportion of non-cholecystectomised cases fell significantly from 35% to 30% in both cases.

A closer examination of the time between ERCP and CHE for the subset of cases in which both procedures were performed during the same hospitalisation shows that the proportion of cases in which CHE was performed within 1, 2 or 3 days increased significantly: d0: 1% (C), 2% (S); d1: 7% (C), 15% (S); d2: 7% (C), 14% (S) and d3: 5% (C), 10% (S). At the same time, the proportion of cases with a waiting time of 4, 5 and 6 days remained at a similarly low level as before the guideline change: d4: 6% (C), 4% (S); d5: 4% (C), 3% (S) and d6: 5% (C), 4% (S). The statistically significant decrease from 63% to 45% in the proportion of patients undergoing CHE after more than 7 days during the same stay indicates a shift from very late (≥ 7 days) to guideline-compliant, timely CHEs.

Looking at the proportion of CHEs performed in accordance with the updated guideline over time, a regression curve shows an S-shaped increase from 2016 to summer 2020 to a maximum application rate of 24%. From then on, there is a continuous decrease in guideline adherence to a value of 16% by the end of the analysis in December 2022 (figure 3).

Addressing the secondary research question, the age-related analyses show a similar picture to the other guideline examined: the older the patient, the less frequently CHE was performed within the 3-day interval defined by the updated guideline. With increasing age, the proportion of cases in which CHE is no longer performed following a successful ERCP also increases.

The analyses of comorbidities (ECI) and frailty (HFI) again show negative correlations regarding the degree of guideline application and positive correlations with regard to not undergoing subsequent CHE. The last-mentioned correlation is particularly evident in patients with high frailty: approximately 6 out of 10 patients do not undergo CHE.

The effect of anticoagulation on timely CHE is less pronounced compared with the other guidelines: non-anticoagulated patients underwent prompt CHE in 6% (C) and 21% (S), while this was the case for anticoagulated patients in 9% (C) and 17% (S).

Analyses of the hospital region show that there is a comparatively high level of guideline adherence in very centrally located hospitals, while this level is lower for hospitals in more peripheral areas. Before the guideline change, the proportion of timely CHE in these regional types was at a similarly low level of 6%–8%. This means that the proportion of timely CHE increased more than threefold, particularly in very central and peripheral clinics.

Prior to the guideline update, the highest number of timely CHEs were performed at basic and standard care providers (9%), closely followed by specialised providers (6%) and maximum providers (5%). After the guidelines were changed, the first two provider types mentioned were able to increase this proportion to 21% and 22%, respectively, while the proportion of maximum providers rose to just 14%. Specialised providers in particular thus increased the share of timely CHE significantly to more than three times.

DISCUSSION

For both guidelines analysed, a significant effect can be demonstrated with regard to the timely performance of CHE, which in our view is attributable to the updated guidelines. In the case of CHE for acute cholecystitis, an already relevant proportion of timely CHE was significantly increased from 43% before to 49% after the change, and this high level has been continuously maintained in recent years. In the case of CHE after successful ERCP and in cholecystolithiasis, the effect of the guideline change is even greater.

Despite this overall positive development, the question arises as to what the reasons for non-guideline-compliant treatment are. Advanced age, high multimorbidity, frailty and anticoagulation appear to be medically plausible and statistically significant contraindications for prompt CHE, or, in many cases, for CHE at all. In particular, very frail patients do not undergo CHE in about half of all cases. This proportion is only slightly lower in patients on anticoagulation. Overall, from a medical perspective, the data therefore indicate an upper limit regarding the maximum degree of guideline conformity, which is roughly estimated to be in the order of 60% in the case of acute cholecystitis or 50% after successful ERCP.

The analysis of possible structural influences shows no relevant differences between hospital locations ranging from very centralised to peripheral areas. However, in very peripheral hospitals, a timely CHE appears to have been carried out in significantly fewer cases. We suspect that these are often smaller hospitals, which in many cases

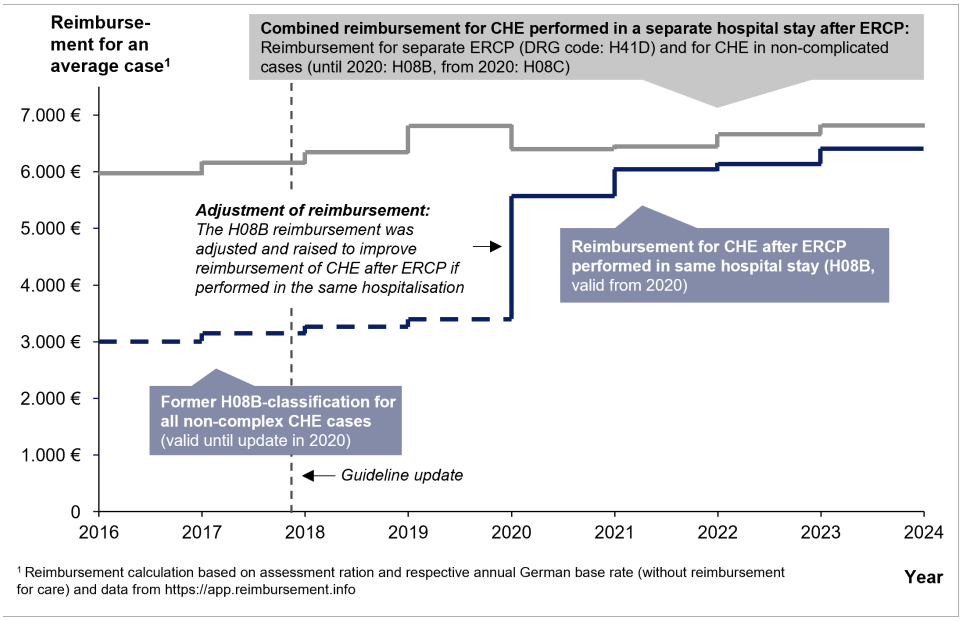


Figure 5 Comparison of reimbursements for performing CHE after successful ERCP (guideline IIIC.6) during the same hospitalisation (blue curve) versus during a separate hospitalisation (grey curve).

do not have the necessary infrastructural or personnel resources to carry out a CHE promptly. It is also possible that, in many cases, a transfer to another hospital takes place, which could explain the relevantly high proportion of non-performed CHE.

In the case of the guideline on acute cholecystitis, the analysis of the type of hospital shows that the proportion of prompt CHEs could be significantly increased by the guideline change, particularly for basic and standard care as well as specialised providers. At the same time, the proportion of maximum providers has increased only slightly and is at the bottom of the list for CHE after successful ERCP, with an application rate of only 14%. We explain this by the average number of more complex cases that are treated at maximum care centres, and as described above, that do not medically allow prompt CHE.

Another reason for a limited application rate for the CHE guideline after ERCP could lie in the reimbursement. On the one hand, as part of the guideline update at the turn of the year 2019/2020, a dedicated Diagnosis-Related Group (DRG, German reimbursement classification) was introduced for the guideline-compliant performance of CHE after ERCP during the same hospitalisation (ie, DRG H08B). On the other hand, however, this DRG is compensated at a lower rate than the total remuneration (ie, DRGs H41D+H08C) that a hospital receives if it only performs the CHE as part of a later, separate stay after the ERCP (figure 5). A look at the development of guideline adherence over time (see figure 3B) shows that the significant increase in guideline adherence already occurred before the introduction of the better reimbursed DRG H08B (from 6% at the beginning of 2016 to 23% at the end of 2019). In the subsequent period following the DRG adjustment, adherence to guidelines initially reached its highest value in summer 2020 (24%), before continuously falling to 16% at the end of 2022. We believe that this is due to the still lower remuneration and financial incentives compared with the case of CHE in a separate hospital stay (DRGs H41D+H08C). For this reason, we think that an increase in H08B reimbursement would have a positive effect on the proportion of cases with timely CHE and should be pursued politically. A further conflict of interest could be that in the case of prompt CHE, the surgical department receives H08B reimbursement, and the internal medicine department receives no reimbursement despite high costs for the ERCP. Direct or indirect internal reimbursement could mitigate this conflict of interest in favour of patients.

The COVID-19 pandemic is another factor whose influence on adherence to the guidelines needs to be discussed. A separate evaluation of all CHEs and ERCPs performed in Helios clinics (independent of the guidelines analysed here; see online supplemental appendix 1) shows that the frequency of CHEs decreased significantly, primarily during the Germany-wide COVID-19 lockdowns. This decrease is consistent with other scientific studies that investigated the effects of the COVID-19 pandemic.[32–34] Analyses in this regard also indicate that during the pandemic, there was an increase in the use of conservative treatment methods for acute cholecystitis, a relative increase in the severity of the disease and an increase in the length of stay in patients over 70 years of age.[32–34] Considering this evidence and the age profile of the patient cohort we studied (approximately half of all included patients are over 70 years of age), we believe that the pandemic had a negative effect on adherence rates to the guidelines we studied and consequently, without these influences, higher guideline adherence would

have been expected. In our view, this effect is limited to the immediate and subsequent lockdown periods and is followed by a normalisation of the situation.

With regard to the limitations of our analysis, it should be mentioned that only cases from Helios clinics were included. Although this is only a subset of all German hospitals, we assume sufficient representativeness in view of the number of hospitals (n=84) and cases included (41 956 patients for guideline IIIB.8 and 3437 patients for guideline IIIC.6). Since Helios is a privately owned clinic group, it could be exposed to higher economic pressure, potentially affecting the representativeness of the data subset analysed. Another possible limitation is the accuracy of the coding time of codes for diagnoses (ICD) and procedures (OPS), which in everyday clinical practice may not fully correspond to the actual time of the provision of treatment in all cases and therefore deviations in the range of hours may be possible. However, we are of the opinion that these are effects that apply to the same extent in the period before and after the guidelines were adopted and therefore do not diminish the significance of the comparison. In addition, the time differences of 24 and 72 hours defined in the guidelines must be seen as approximate guide values, so that, in our opinion, a slight deviation can be tolerated here.

It might be added that the analyses of guideline IIIB.6 only consider the time interval between CHE and hospital admission, not the onset of symptoms. In addition to challenges regarding data availability, the reason for this is the intention to model the guideline as accurately as possible, which, contrary to previous common practice, only considers the time of hospital admission.[3] For the same reason of ensuring an adequate representation of the guidelines, the results presented above include the 'no CHE' group of non-cholecystectomised patients, even if this group is not the focus of the guideline changes that only refer to the time until CHE. In addition, the consideration of non-cholecystectomised patients allows certain conclusions to be drawn regarding basic operability and shows in the case of the ERCP guideline that the proportion of non-cholecystectomised patients has fallen from 35% to 30% (p=0.027). We suspect that this decrease is due to the guideline update, which recommends ERCP during the same stay and thus reduces the risk of ERCP being forgotten or not performed for other reasons during a later, separate stay. However, in order to be able to evaluate the change in the timing of CHE separately from the group of non-cholecystectomised patients, an identically structured analysis was performed without the subgroup of 'no CHE' patients. This analysis shows the same effects and trends as presented above to a greater extent (see online supplemental appendix 2). The proportion of patients undergoing CHE within 24 hours due to acute cholecystitis (guideline IIIB.8) increased from 55% to 63% after the guideline update (p=0.001; compared with analysis with the 'no CHE' subgroup: increase from 43% to 49%). In the case of guideline III.C6, the proportion of patients who underwent CHE within 3 days increased from 10% to 26% (p=0.001; compared with analysis with the 'No CHE' subgroup: increase from 7% to 20%). The results regarding the secondary research question lead to the same conclusions as discussed above (further analysis results are in online supplemental appendix 3).

Finally, we conclude that, with regard to the primary research question, a high degree of guideline-compliant CHE treatment can be determined. As part of the investigation of the secondary research question, we were able to show that in many cases, medical factors and possibly personnel and infrastructural limitations, especially in very peripheral clinics, stand in the way of guideline adherence. We see the potential for improvement for even greater guideline compliance, especially for guideline IIIC.6, in particular by defusing the economic conflict of interest by increasing the remuneration of DRG H08B for combination cases (ERCP+CHE) and optimising clinic internal remuneration processes. We are convinced that a consistent improvement of the mentioned factors can increase the application rate of the guidelines up to the above estimated medical application limits, in the order of 60% in the case of acute cholecystitis or 50% after successful ERCP.

Contributors All authors contributed to the conception of the research project. HB and LF designed the study and contributed equally to this paper. HB prepared the project materials, including the creation of the study protocol, analysis of concepts and preparation of the data collection and anonymisation. SH and AB conducted the data aggregation and created statistical reports. JP and PD advised on ethical and legal issues and accompanied related processes. HB, LF and CP reviewed, analysed and translated the statistical reports. HB wrote the first version of the manuscript. All authors reviewed and commented on the preliminary versions of the manuscript before they reviewed and approved the final manuscript. LF coordinated the research project as the responsible project leader, is responsible for the overall content as guarantor and serves as the corresponding author. All authors confirm that they had full access to all the data in the study and accept responsibility for submitting it for publication.

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Data availability statement Data are available upon reasonable request. The data and materials of this research project are not publicly available due to data privacy reasons. The underlying data privacy statement concretely states that personal data is not shared with third parties and that the anonymized data, that is, raw data, is only stored for up to 10 years. Analysis outputs and selected other data and materials can be shared upon reasonable request and submitted to the corresponding author.

ORCID iDs
Leonard Fehring http://orcid.org/0000-0002-3322-3724
Hendrik Brinkmann http://orcid.org/0009-0005-6651-384X
Sven Hohenstein http://orcid.org/0000-0002-9708-1593
Andreas Bollmann http://orcid.org/0000-0002-5441-3906
Patrick Dirks http://orcid.org/0009-0008-3789-864X
Jörg Pölitz http://orcid.org/0009-0005-6543-1391
Christian Prinz http://orcid.org/0009-0008-3829-7248

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