Original Article

Mortality and Complications Following Visceral Surgery

A Nationwide Analysis Based on the Diagnostic Categories Used in German Hospital Invoicing Data

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Summary

Background: The in-hospital mortality after visceral surgery in Germany is unknown.

Methods: In this retrospective, descriptive analysis, nationwide hospital billing data based on diagnosis-related groups (DRG) over the period 2009–2015 were studied to determine the in-hospital mortality, complications and their management, and deaths after documented severe complications (failure to rescue, FTR) after visceral surgery in Germany. Organ-system subgroups were defined and subdivided into frequent operations (inguinal hernia repair, appendectomy, thyroid operations, cholecystectomy), colorectal operations, and complex operations (surgery of the esophagus, pancreas, liver, and stomach).

Results: 3 287 199 patients from 1392 hospitals were included in the analysis. The in-hospital mortality after visceral surgery was 1.9%. The lowest mortality was after the frequently performed operations (0.04–0.4%), the highest after complex surgery of the esophagus (8.6%) and stomach (11.7%). Severe complications were most commonly seen after complex surgery of the pancreas (27.7%), liver (24.3%), esophagus (37.8%), and stomach (36.7%). 90.6% of deaths occurred after colorectal or complex operations, which together accounted for 23% of all operations. The FTR rate was 8.4% after appendectomy and cholecystectomy (95% confidence interval [8.34; 8.46]) and 20.3% after esophageal surgery ([19.8; 20.8]).

Conclusion: In Germany, in-hospital mortality after visceral surgery is not uncommon, with a frequency of nearly 2%. Improved complication management after complex operations appears necessary. A limitation of this study is the identification of complications from anonymized billing data.

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Surgery represents a fundamental pillar of treatment for a multitude of diseases. In the case of life-threatening indications such as appendicitis (1) or cancer therapy (e.g., treatment of colorectal liver metastases [2]), a surgical approach is often superior to conservative treatment strategies or, indeed, without alternative. As with all treatments, surgery is also associated with a certain level of morbidity and mortality. From experience, patients and treating physicians alike harbor anxiety about the occurrence of complications in surgical procedures (3). This can result in curative therapies being declined or delayed (4). In addition, recommendations advise that, as part of their consultation and information, patients should be informed about the potential risks of surgery (e.g., mortality, complication rate), as well as the anticipated hospital time (5). There are numerous studies in the literature describing morbidity and mortality following surgical procedures (6–8). These data often do not originate from the German healthcare system or are based on selected patient groups. This produces a problem for physicians working in Germany in terms of data interpretation. In order to obtain a Germany-wide, valid analysis of morbidity and mortality following visceral surgery, nationwide invoicing data for the years 2009–2015 were analyzed for hospital mortality, complications, and survival following severe complications, i.e., failure to rescue (FTR). The failure to rescue index refers to the proportion of patients that die following severe but essentially treatable complications during their hospital stay (9). On the basis of the data presented in this article, patients can be provided with valid information on the morbidity and mortality of relevant surgical procedures,

TABLE 1

Hospital mortality and length of hospital stay per surgical procedure

Surgical procedure/organ system operated	Cases n (%)	Age 0–54 yrs, %	Age 55–75 yrs, %	Age ≥ 75 yrs, %	Mean length of hospital stay, (SD)	Hospital mortality, % [95%CI] (n)
Inguinal hernia	506,383 (15.4)	49.9	35.7	14.4	2.1 (2.2)	0.04 [0.03; 0.05] (207)
Thyroid	393,592 (12.0)	53.2	40.2	6.1	4.3 (4.3)	0.1 [0.09; 0.10] (468)
Appendectomy	709,792 (21.6)	85.2	37.5	14.4	5.1 (4.9)	0.2 [0.19; 0.21] (1668)
Cholecystectomy	952,307 (29.0)	48.6	37.5	14.5	5.7 (5.4)	0.4 [0.39; 0.41] (3498)
Colorectal surgery	577,325 (17.6)	18.9	48.8	33.1	20.2 (16.6)	7.5 [7.43; 7.57] (43461)
Pancreas	66,929 (2.4)	24.5	53.7	21.7	25.4 (19.7)	6.9 [6.71; 7.10] (4658)
Liver	18,849 (0.6)	25.2	57.7	17.1	21.0 (17.5)	7.7 [7.32; 8.1] (1465)
Esophagus	24,582 (0.8)	22.7	61.5	15.8	30.0 (25.8)	8.6 [8.25; 8.95] (2127)
Gastrointestinal system	37,440 (1.1)	17.2	49.2	33.6	24.5 (18.7)	11.7 [11.37; 12.03] (4368)

yrs, Years; CI, confidence interval; n, sample size; SD, standard deviation

particularly in terms of surgical procedure-specific risks. The data can also be used to generate hypotheses on how the treatment of patients in Germany can be improved.

Methods

A retrospective descriptive analysis of Germany-wide individual case data was carried out on the basis of diagnosis-related group (DRG) statistics. Hospital treatment cases with a German "Operations and Procedures Code" (OPS code) for a visceral surgery procedure were selected. Procedures according to OPS code *(eTable 1)*, age, sex *(eTable 2)*, hospital identifier, length of hospital stay, reason for discharge, and diagnoses according to ICD-10-GM *(eTable 3)* were anonymously assigned to each treatment case. All treatment cases from the period 2009–2015 were included. Data were retrieved with the help of the research center of the German Federal Statistical Office. Case data with missing, incomplete, or implausible values were excluded from the investigation in a first step. On the basis of the documented OPS codes, treatment cases were then analyzed in terms of comorbidities and complications *(eTable 1, eTable 3)*.

Typical visceral surgery procedures were grouped according to organ system and increasing complexity, as well as frequent and complex surgery *(Table 1)*. Frequent surgical procedures include:

- Cholecystectomy (laparascopic)
- Appendectomy (laparascopic)
- Hernia surgery (TAPP, TEP, Lichtenstein procedures)
- Thyroid procedures (hemithyroidectomy, thyroidectomy).

Advanced colorectal surgical procedures include:

- Right/left/extended hemicolectomy
- Transverse colon resection
- Sigmoid resection
- Rectal resection.

Complex procedures comprise:

- Pancreatic surgery (distal pancreatectomy and pancreaticoduodenectomy, total pancreatectomy)
- Liver surgery (hemihepatectomy, trisegmentectomy, trisectionectomy)
- Esophageal surgery (partial, complete, extended esophagectomy)
- Gastrointestinal surgery (4/5 gastrectomy, gastrectomy).

Colorectal surgery was recorded as a single group, since, according to the authors, these are procedures that are technically advanced but nevertheless frequently performed. Case data with combinations of frequent surgical procedures (e.g., cholecystectomy and appendectomy) or several complex/extended procedures during one hospital stay were excluded, since it was not possible to generate a meaningful hierarchy between the primary and follow-up procedure. Therefore, 0.06% (frequent procedures) and 0.38% (advanced/complex procedures) were excluded from the subgroups. If a procedure in both the group of frequent and the group of advanced/complex surgical procedures (e.g., cholecystectomy and esophagectomy) was documented for a treatment case, the complex procedure was deemed to be the main procedure for the present study. Statistical analysis was performed using Stata 14 (StataCorp LP, College Station, Texas, USA). Documented comorbidities, complications, length of hospital stay, and hospital mortality were analyzed for each treatment case. The following events were defined as severe complications:

- Peritonitis
- Sepsis
- Pulmonary embolism (PE)
- Myocardial infarction
- Anastomotic leak
- Pneumonia
- Gastrointestinal bleeding.

TABLE 2

Complications per surgical procedure

Type of complication	Hernia surgery	Thyroid surgery	Appen-dectomy	Chole-cystectomy	Colorectal surgery	Pancreatic surgery	Liver surgery	Esophageal surgery	Gastrointestinal surgery
Ventilation >48 h % [95% CI] (n)	0.05 [0.04; 0.06] (231)	0.43 [0.41; 0.45] (1703)	0.4 [0.39; 0.41] (2676)	0.4 [0.39; 0.41] (3844)	8.5 [8.43; 8.57] (49,004)	10.6 [10.37; 10.83] (6794)	9.5 [9.08; 9.92] (1784)	21.2 [20.69; 21.71] (5209)	13.4 [13.05; 13.75] (5000)
Transfusion ≥ 6 RBBC % [95% CI] (n)	0.04 [0.03; 0.05] (218)	0.1[0.09; 0.11] (360)	0.2 [0.19; 0.21] (1151)	0.2 [0.19; 0.21] (2045)	6.9 [6.83; 6.97] (40.1)	11.8 [11.56; 12.04] (7901)	13.0 [12.52; 13.48] (2456)	14.0 [13.57; 14.43] (3437)	15.07 [14.71; 15.43] (5643)
Peritonitis % [95% CI] (n)	0.1 [0.09; 0.11] (458)	x*	1.0 [0.98; 1.02] (6934)	1.8 [1.77; 1.83] (17,449)	11.3 [11.22; 11.38] (65,445)	10.0 [9.77; 10.23] (6719)	7.2 [6.83; 7.57] (1357)	3.6 [3.37; 3.83] (882)	13.7 [13.35; 14.05] (5144)
Sepsis % [95% CI] (n)	0.1 [0.09; 0.11] (538)	0.1 [0.09; 0.11] (435)	1.4 [1.37; 1.43] (9758)	2.3 [2.27; 2.33] (21,973)	14.9 [14.81; 14.99] (86,145)	14.4 [14.13; 14.67] (9641)	11.4[10.95; 11.85] (2155)	14.3 [13.86; 14.74] (3514)	18.3 [17.91; 18.69] (6831)
PE % [95% CI] (n))	0.01 [0.01; 0.01] (63)	0.04 [0.03; 0.05 (140)	0.05 [0.04; 0.06] (359)	0.1 [0.09; 0.11] (595)	0.8 [0.78; 0.82] (5013)	1.3 [1.21; 1.39] (865)	1.5 [1.33; 1.67] (286)	2.0 [1.82; 2.18] (494)	1.5 [1.38; 1.62] (55)
MI % [95% CI] (n)	0.03 [0.03; 0.03] (154)	0.1 [0.09; 0.11] (191)	0.1 [0.09; 0.11] (427)	0.1 [0.09; 0.11] (1213)	0.9 [0.88; 0.92] (5170)	0.9 [0.83; 0.97} (611)	0.9 [0.77; 1.03] (164)	1.0 [0.88; 1.12] (249)	1.2 [1.09; 1.31] (465)
AL % [95% CI] (n)	x*	x*	x*	x*	6.6 [6.54; 6.66] (38,212)	8.0 [7.79; 8.21] (5331)	x*	12.6 [12.19; 13.01] (3091)	9.7 [9.40; 10.00] (3622)
Pneumonia % [95% CI] (n)	0.1 [0.09; 0.11] (429)	0.3 [0.28; 0.32] (1280)	0.5 [0.48; 0.52] (3802)	0.8 [0.78; 0.82] (7686)	6.7 [6.64; 6.76] (38,999)	8.2 [7.99; 8.41] (5532)	6.1 [5.76; 6.44] (1160)	19.8 [19.3; 20.3] (4864)	12.3 [11.97; 12.64] (4620)
GI bleeding % [95% CI] (n)	0.1 [0.09; 0.11] (273)	0.03 [0.02; 0.04] (129)	0.1[0.09; 0.11] (809)	0.2 [0.19; 0.21] (1919)	3.2 [3.15; 3.25] (18,490)	2.8 [2.68; 2.92] (1876)	1.0 [0.86; 1.14] (202)	2.6 [2.4; 2.8] (655)	6.4 [6.15; 6.65] (2379)
Overall compl. % [95% CI] (n)	0.3 [0.28; 32] (1530)	0.7 [0.67; 0.73] (2759)	2.1 [2.07; 2.13] (14,828)	3.3 [3.26; 3.34] (31,415)	24.6 [24.49; 24.71] (141,707)	27.7[27.36; 28.04] (18,564)	24.3 [23.69; 24.91] (4584)	37.8 [37.19; 38.41] (9302)	36.7 [36.21; 37.19] (13,727)

AL, anastomotic leak; CI, confidence interval; GI, gastrointestinal; MI, myocardial infarction; PE, pulmonary embolism; RBBC, red blood cell concentrate

* x = not analyzed

Interventions indicating a complicated course (mechanical ventilation >24 h or transfusion of more than five red blood cell concentrates) were also included in this group. The FTR rate is calculated from the incidence of severe complications and the observed hospital mortality of patients with severe complications. The respective 95% confidence interval (95% CI) was calculated according to Tsai et al. (10).

Results

During the study period, 3 287 199 surgical procedures were carried out in 1392 hospitals. The most frequently performed procedures, in descending order, were: cholecystectomy (n = 952 307, 29%) and appendectomy (n = 709 792, 22%), followed by colorectal surgery (n = 577 325, 18%), inguinal hernia surgery (n = 506 383, 15%), and thyroid surgery (n = 393 592, 12%). Complex visceral surgical procedures (distal pancreatectomy, pancreaticoduodenectomy, total pancreatectomy, hemihepatectomy, trisegmentectomy, trisectionectomy, partial/complete/extended esophagectomy, 4/5 gastrectomy, gastrectomy) were performed in 5% (n = 147 800) of all patients *(eTable 1)*.

Approximately half of all operated patients were aged under 54 years. Of the operated patients, 52% were female and 48% male. Patients in the complex surgery group (liver/pancreatic/esophageal/gastrointestinal surgery) were older on average compared to patients in the frequent procedures group. The percentage of patients aged over 75 years in the complex surgery group was between 15.8% and 33.6% versus 6.1% and 14.5% in the frequent surgery group. The most common comorbidities included arterial hypertension (29.9%), diabetes mellitus (9.2%), and obesity (7.9%) *(eTable 2)*.

The shortest average length of hospital stay was seen in patients undergoing inguinal hernia procedures (2.1 ± 2.2 days) and thyroid surgery (4.3 ± 4.3 days). The length of hospital stay for colorectal procedures was 20.2 ± 16.6 days. The longest hospital stays were seen in the group undergoing complex pancreatic and esophageal surgical procedures: 25.4 ± 19.7 days and 30.0 ± 25.8 days, respectively *(Table 1)*.

The most frequent complications to be coded were sepsis (4.3%), peritonitis (3.2%), and ventilation over 48 h (3.2%). In contrast, pulmonary embolism or myocardial infarction occurred far more rarely at 0.3% each. Hospital mortality for the total collective was 1.9% *(eTable 2)*. Hospital mortality for frequent procedures was between 0.04% (95% CI: [0.03; 0.05]) and 0.4% [0.39; 0.41]. Significantly higher mortality was seen following colorectal procedures (7.5% [7.43; 7.57]). The highest hospital mortality rate was observed following complex gastrointestinal surgical procedures (11.7% [11.37; 12.03]) *(Table 1)*.

Severe complications occurred relatively rarely in the frequent visceral surgical procedures. The overall complication rate here was between 0.3% [0.28; 0.32] and 3.3% [3.26; 3.34]. The lowest complication rate was seen for hernia (0.3% [0.28; 0.32]) and thyroid surgical procedures (0.7% [0.67; 0.73]). Pulmonary embolism (0.01 [0.01; 0.01]–0.1% [0.09; 0.11]) or myocardial infarction (0.03 [0.03; 0.03]–0.1% [0.09; 0.11]) occurred significantly more rarely in the frequent surgery group compared to septic complications (pneumonia 0.1% [0.09; 0.11]–0.8% [0.78; 0.82], peritonitis 0.1% [0.09; 0.11]–1.8% [1.77; 1.83], and sepsis 0.1% [0.09; 0.11]–2.3% [2.27; 2.33]).

The risk of complications rose in colorectal and complex procedures compared to frequent procedures: severe complications occurred in over a third of patients operated in the complex gastrointestinal and esophageal surgery group (36.7% [36.21; 37.19]/37.8% [37.19; 38.41]).

Pulmonary complications most frequently occurred in complex esophageal procedures: 19.8% [19.3; 20.3] of operated patients developed pneumonia and 21.2% [20.69; 21.71] required mechanical ventilation. In complex gastrointestinal procedures, a transfusion of more than five red blood cell concentrates was the most frequently required measure (15.07% [14.71; 15.43]). The least frequently coded complications were PE (0.8% [0.78; 0.82]–2.0% [1.82; 2.18]) and myocardial infarction (MI) (0.9% [0.88; 0.92]–1.2% [1.09; 1,31]). However, the percentage of both complications was significantly higher compared to the frequent procedures group (PE 0.01% [0.01; 0.01]–0.1% [0.09; 0.11]; MI 0.03% [0.03; 0.03]–0.1% [0.09; 0.11]). Gastrointestinal bleeding occurred most frequently in colorectal (3.2% [3.15; 3.25]) and complex gastrointestinal surgery (6.4% [6.15; 6.65]).

In summary, a comparison of simple and complex surgical procedures shows that the overall complication rate for complex procedures is around 10-fold higher compared to simple procedures *(Table 2)*.

The FTR rate is defined as the proportion of patients for whom at least one severe complication is documented and who died in hospital. In a comparison of all surgical procedures, the present analysis found markedly increased hospital mortality if a documented severe complication had occurred.

Overall, the rate of failure to rescue following documented complications in frequent surgical procedures was between 8.4% [8.34; 8.46] (appendectomy/cholecystectomy) and 12.5% [12.40; 12.60] (thyroid surgical procedures). The FTR rate was 25.4% [25.29; 25.51] in colorectal surgical procedures, 20.3% [19.8; 20.8] in esophageal surgical procedures, and highest in liver surgery at 28.9% [28.25; 29.55] *(Table 3)*.

Over half of all patients that required mechanical ventilation for longer than 48 h following complex liver or gastrointestinal surgery did not survive their hospital stay. The highest risk of death due to gastrointestinal bleeding was seen following complex liver surgery. Approximately one third of patients died during their inpatient stay following transfusion of more than five red blood cell concentrates. The

TABLE 3

Death following a complication (failure to rescue) per surgical procedure

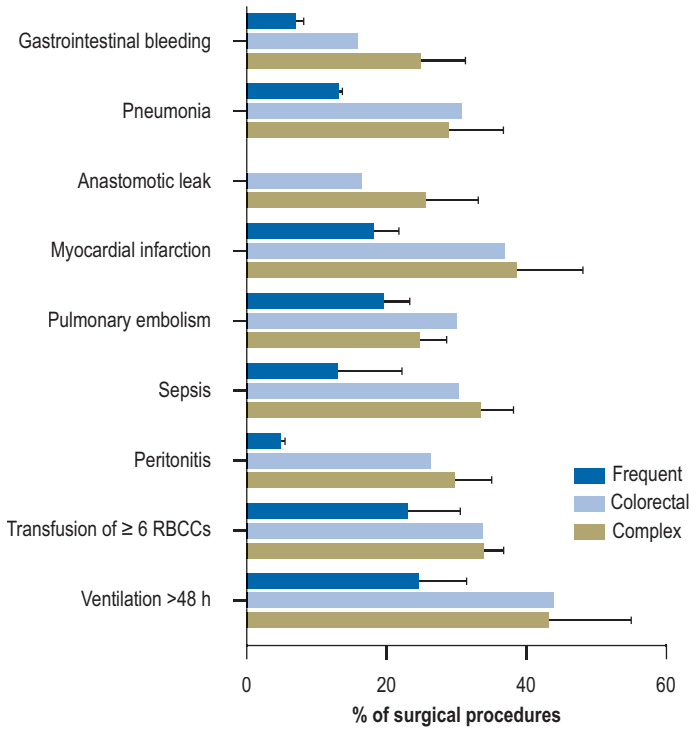
Type of complication	Hernia surgery	Thyroid surgery	Appen-dectomy	Chole-cystectomy	Colorectal surgery	Pancreatic surgery	Liver surgery	Esophageal surgery	Gastrointestinal surgery
Ventilation >48 h % [95% CI] (n)	22.5 [22.38; 22.62] (52)	16.0 [15.89; 16.11] (272)	26.4 [26.30; 26.50] (707)	32.6 [32.51; 32.69] (1 252)	43.7 [43.57; 43.83] (21,421)	40.0 [39.73; 40.47] (2714)	53.6 [52.89; 54.31] (957)	27.5 [26.94; 28.06] (1432)	50.9 [50.39; 51.41] (2543)
Transfusion ≥ 6 RBCC % [95% CI] (n)	11.9 [11.81; 11.99] (26)	27.8 [27.66; 27.94] (100)	26.7 [26.60; 26.80] (307)	25.1 [25.01; 25.19] (513)	33.4 [33.28; 33.52] (13,447)	31.0 [30.65; 31.35] (2448)	36.6 [35.91; 37.29] (898)	31.6 [31.02; 32.18] (1087)	36.0 [35.51; 36.49] (2034)
Peritonitis % [95% CI] (n)	5.5 [5.44; 5.56] (25)	x*2	4.1 [4.05; 4.15] (281)	4.4 [4.36; 4.44] (772)	26.1 [25.99; 26.21] (17,056)	23.4 [23.08; 23.72] (1570)	29.0 [28.35; 29.65] (393)	30.3 [29.73; 30.87] (267)	36.2 [35.71; 36.69] (1863)
Sepsis % [95% CI] (n)	9.1 [9.02; 9.18] (49)	26.9 [26.76; 27.04] (117)	7.8 [7.74; 7.86] (761)	7.5 [7.45; 7.55] (1656)	30.1 [29.98; 30.22] (25,946)	26.9 [26.56; 27.24] (2594)	35.8 [35.12; 36.48] (771)	32.4 [31.81; 32.99] (1137)	37.9 [37.41; 38.39] (2589)
PE % [95% CI] (n))	19.1 [18.99; 19.21] (12)	14.3 [14.19; 14.41] (20)	23.1 [23.00; 23.20] (83)	21.3 [21.22; 21.38] (127)	29.8 [29.68; 29.92] (1498)	22.0 [21.69; 22.31] (190)	25.5 [24.88; 26.12] (73)	21.5 [20.99; 22.01] (106)	29.7 [29.24; 30.16] (166)
MI % [95% CI] (n)	14.9 [14.80; 15.00] (23)	16.23 [16.11; 16.35] (31)	23.2 [23.10; 23.30] (99)	17.5 [17.42; 17.58] (213)	36.7 [36.58; 36.82] (1897)	32.1 [31.75; 32.45] (196)	48.8 [48.09; 49.51] (80)	29.3 [28.73; 29.87] (73)	44.1 [43.60; 44.60] (205)
AL % [95% CI] (n)	x*2	x*2	x*2	x*2	16.4 [16.30; 16.50] (6267)	22.1 [21.79; 22.41] (1179)	x*2	20.1 [19.6; 20.6] (612)	34.0 [33.52; 34.48] (1230)
Pneumonia % [95% CI] (n)	12.8 [12.71; 12.89] (55)	13.2 [13.09; 13.1] (169)	12.9 [12.82; 12.98] (492)	13.6 [13.53; 13.67] (1043)	30.5 [30.38; 30.62] (11,904)	24.7 [24.37; 25.03] (1366)	39.2 [38.50; 39.90] (455)	20.9 [20.39; 21.41] (1018)	30.3 [29.83; 30.77] (1398)
GI bleeding % [95% CI] (n)	6.8 [6.73; 6.87] (16)	8.5 [8.41; 8.59] (11)	6.8 [6.74; 6.86] (55)	5.9 [5.85; 5.95] (113)	15.8 [15.71; 15.89] (2921)	19.7 [19.40; 20.00] (370)	34.2 [33.52; 34.88] (69)	22.9 [22.37; 22.43] (150)	22.3 [21.88; 22.72] (530)
Failure to rescue % [95% CI]	8.6 [8.52; 8.68]	12.5 [12.40; 12.60]	8.4 [8.34; 8.46]	8.4 [8.34; 8.46]	25.4 [25.29; 25.51]	22.0 [21.69; 22.31]	28.9 [28.25; 29.55]	20.3 [19.80; 20.80]	28.5 [28.04; 28.96]

AL, anastomotic leak; CI, confidence interval; GI, gastrointestinal; MI, myocardial infarction; PE, pulmonary embolism; RBBC, red blood cell concentrate

*1 to calculate FTR: Example—thyroid surgery: 393 592 thyroid surgical procedures were performed, 468 of these operated patients died *(Table 1)*; a total of 2759 severe complications occurred following thyroid surgery *(Table 2)*.
The respective FTR value can be calculated for individual complications, since the same complication cannot be counted multiple times in one patient: 1703 patients received ventilation for longer than 24 h following thyroid surgery *(Table 2)*; 272 patients that received ventilation for longer than 24 h following thyroid surgery died, making 16% *(Table 3)*.

*2 x = not analyzed

FIGURE



Failure to rescue following visceral surgical procedures.
The mean of the listed complication ± standard deviation per group is shown. Since colorectal procedures represent only one group, no standard deviation can be calculated.
RBCC, red blood cell concentrate

mortality rate following anastomotic leak is highest in the complex gastrointestinal surgery group at 34.0% [33.52; 34.48] *(Table 3)*.

The FTR rate for a specific complication was always significantly lower following frequent surgical procedures compared to complex surgery *(Figure)*.

Discussion

This Germany-wide investigation analyzed mortality, complication rates, and failure to rescue in visceral surgery for the period 2009–2015. In summary, hospital mortality following visceral surgical procedures in Germany is 1.9%. Complication rates, hospital mortality, and FTR rates rise with the complexity of the procedure. Whereas there is a relatively low complication rate of under 3.3% for frequent visceral surgical procedures, this rises significantly to almost 40% for complex surgery.

In an international comparison, hospital mortality and documented complications following frequent visceral surgical procedures, such as appendectomy and cholecystectomy, are similar to those in the UK and the US (11, 12). Differences emerge if one compares mortality following colorectal surgery in Germany with rates in other industrial nations (13). A national study of 84 000 patients in France revealed a mortality rate following colorectal cancer surgery of 5% (14). A US analysis of the SEER database (The Surveillance, Epidemiology, and Ends Results [SEER] Program]) reported hospital mortality following oncological colorectal surgery of 5.9% (15). The available data show that hospital mortality in Germany following oncological colorectal surgery is 7.5%.

The failure to rescue rate is generally used as an indicator of hospital quality (16). The FTR rate here describes the management of complications by comparing the proportion of patient deaths following the onset of a severe but essentially treatable complication with the complication rate. The percentage of patients to whom failure to rescue applies depends on the size of the hospital, the number of procedures performed per hospital, surgeon experience, as well as other variables such as a hospital's safety structure and management (6, 9, 17). As with mortality, the data from visceral surgery presented in this article show a significantly higher rate of complications and FTR in complex surgical procedures compared to simple and frequent procedures. However, one must conclude, albeit with restrictions, that the causal link between the occurrence of the complication and the death of the patient cannot be reliably demonstrated on the basis of the data here, despite the fact that this is assumed in the literature (9).

While hospital mortality was 1.9% relative to the total collective, it is 8.5% if one considers complex surgical procedures in isolation. Colorectal and complex visceral surgical procedures account for 23% of all surgical procedures in Germany. A total of 90.6% of all postoperative deaths occur following these two types of surgery. Therefore, a general improvement in care can be achieved particularly effectively through progress in these subgroups.

Of course, an adequate preoperative risk assessment and optimization should be carried out for all patients (18, 19). However, the primary success factor in reducing hospital mortality is not only the avoidance of complications, but, more particularly, also the competent and successful management of the ones that do occur (9). Compared to other surgical disciplines, one sees the strongest link between the management of complications relative to hospital volumes and postoperative mortality in visceral surgery (20).

Hospital mortality for pancreatic (10.1%) and esophageal procedures (9.5%) is higher in Germany compared to other European countries (pancreas 3.6%, esophagus 3.9–4.7%) and North America (pancreas 6.8%, esophagus 4.7%) (21–25). For this reason, current minimum spending by the German Joint Federal Committee for these procedures has now become a subject of discussion (22, 26, 27). The findings presented here demonstrate that hospital mortality is also high in complex liver and gastrointestinal surgery. A study on 9000 patients

(a cohort study using the US Nationwide Inpatient Sample database) showed a hospital mortality rate following elective surgical procedures for gastric cancer of 3%. In the case of emergency surgical procedures, mortality was 8% (28). Another analysis of data from the NSQIP (American National Surgical Quality Improvement Program) revealed a 30-day mortality rate following oncological gastrectomy of 4.1% (29). Various oncological gastrointestinal procedures were pooled in the data, yielding a hospital mortality rate of 11.7%. In a US cohort study, hospital mortality following oncological liver surgery was 2–4% (Germany 7.7%) (7). A comparison between the US studies and the German data is possible only to a limited extent due to the sometimes varying modes of patient data selection and evaluation. An improvement in complication management is needed nevertheless, especially following complex surgical procedures. Therefore, other studies are required in order to achieve an improvement in patient treatment.

The retrospective nature of the present study represents a limitation. In addition, a distortion of diagnosis-related-group data due to incorrect or selective hospital coding is theoretically possible. However, it should be possible to minimize this aspect via a review of the documentation by the medical service of the health insurance companies in Germany (*Medizinischer Dienst der Krankenkassen*, MDK). The US data also show that administrative data is readily comparable to the medical data (30). The use of the institution identifier to distinguish individual hospitals can also lead to a certain degree of inaccuracy in the number of hospitals. There is a possibility that two or more hospitals submitted their data under the same code number (31). It must also be borne in mind that no causal links can be generated in this retrospective study.

A further limitation lies in the fact that it is not possible to draw any conclusions on a change in the frequency of complications or the rate of FTR over the study period. However, studies dealing specifically with individual procedures show no change in mortality in recent years for complex and colorectal procedures (13, 21, 22).

A major advantage of the present analysis is the complete and non-selected picture it provides of the German health system across all patients. The rate of excluded cases due to lacking data was extremely low at under 1%.

In summary, it can be concluded that, in an international comparison, mortality in frequent visceral surgical procedures in Germany is similarly low. Approximately 90% of all deaths following surgery are related to advanced or complex procedures. Since FTR reflects the quality of care in the management of complications, one should evaluate which measures are needed in terms of infrastructure and personnel in order to reduce the FTR rate following complex procedures.

Key messages

- Nationwide hospital mortality following visceral surgical procedures in Germany is 1.9%.
- The most common severe complications are sepsis (4.3%), peritonitis (3.2%), and the need for mechanical ventilation for longer than 48 h (3.2%).
- At 11.7%, complex gastrointestinal surgery has the highest hospital mortality rate of all visceral surgical procedures in Germany.
- A total of 90.6% of all deaths related to visceral surgery occur following colorectal and complex visceral surgical procedures.
- The highest failure to rescue rate (28.9%) was seen for gastrointestinal surgery.

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Conflict of interests
The authors declare that no conflict of interest exists.

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► **Supplementary material**

eTables:
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Supplementary material to:

Mortality and Complications Following Visceral Surgery

A Nationwide Analysis Based on the Diagnostic Categories Used in German Hospital Invoicing Data

by Philip Baum, Johannes Diers, Sven Lichthardt, Carolin Kastner, Nicolas Schlegel, Christoph-Thomas Germer, and Armin Wiegering

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eTABLE 1

Surgical procedures performed in Germany in the period 2009–2015

	n	%	OPS codes
Frequent surgical procedures			
Cholecystectomy	952 307	29%	5-511.1
Appendectomy	709 792	22%	5-470.0, 5-470.1
Inguinal hernia surgery	506 383	15%	5-530.31, 5-530.32, 5-530.33, 5-530.34
Thyroid surgery	393 592	12%	5-061.0, 5-061.2
Colorectal surgical procedures			
Colorectal surgery	577 325	18%	5-455.4, 5-455.5, 5-455.6, 5-455.7, 5-455.9, 5-455.a, 5-455.b, 5-455.c, 5-455.d, 5-456, 5-484.3,5-484.5, 5-484.6, 5-485.0, 5-485.2, 5-485.3,5-458, 5-484, 5485
Complex surgical procedures			
Complex pancreatic surgery	66 929	2%	5-524.0, 5-524.1, 5-524.2, 5-524.3, 5-524.4, 5-525.0, 5-525.1, 5-525.2
Complex esophageal surgery	24 582	1%	5-423.0, 5-423.1, 5-423.2, 5-423.3, 5-424.0, 5-424.1, 5-424.2, 5-425.0, 5-425.1, 5-425.2, 5-426.0, 5-426.1, 5-426.2, 5-427.0, 5-427.1, 5-438.0, 5-438.1, 5-438.2, 5-438.3
Complex gastrointestinal surgery	37 440	1%	5-435.0, 5-435.1, 5-435.2, 5-437.0, 5-437.1, 5-437.2, 5-437.3, 5-437.4, 5-437.5, 54376
Complex liver surgery	18 849	1%	5-502.1, 5-502.2, 5-502.3
Total	**3 287 199**	**100%**	**–**

OPS, German "Operations and Procedures Code"

eTABLE 2

Age, sex, comorbidities, complications, and overall mortality in visceral surgery

	n	%
0–54 Years	1 639 997	49.9%
55–74 Years	1 174 804	35.7%
≥ 75 Years	472 398	14.4%
Females	1 713 786	52.0%
Males	1 573 413	48.0%
Heart valve disease	26 353	0.8%
Cachexia/malnutrition	36 278	1.1%
Chronic liver disease	65 174	2.0%
Heart failure/cardiomyopathy	124 147	3.8%
Coagulopathy	137 595	4.2%
Chronic kidney failure	142 393	4.3%
Chronic heart failure	179 494	5.5%
Obesity	260 530	7.9%
Diabetes mellitus	302 595	9.2%
Arterial hypertension	981 531	29.9%
Pulmonary embolism	8374	0.3%
Myocardial infarction	8644	0.3%
Gastrointestinal bleeding	26 732	0.8%
Acute kidney failure	52 842	1.6%
Anastomotic leak	54 809	1.7%
Transfusion ≥ 6 red blood cell concentrates	63 298	1.9%
Ventilation >48 h	76 245	2.3%
Peritonitis	104 427	3.2%
Sepsis	140 990	4.3%
Number of hospitals	1392	Not specified
Number of in-hospital deaths	61 920	1.9%

eTABLE 3

Coding of comorbidities/complications using the ICD-10 coding system

Comorbidity/complication	ICD code or OPS code
Ventilation >48 h	J953
Hypertension (without heart/kidney failure)	I10, I119, I129, I139, I15
Heart failure/cardiomyopathy	I50, I110, I130, I132, I420, I426, I427, I428 ,I429
Chronic heart failure	I25
Heart valve disease	I340, I342, I350, I351, I352, I050, I051, I052, I060, I061, I062, Q231, Q232, Q233
Chronic lung disease	J41, J42, J44, J45, J47
Chronic liver disease	B18, I864, I982, K70, K73, K74, K760, K761, K765, K766, K767, Q446, Q447
Chronic kidney failure	I129, I131, I132, N03, N04, N05, N07, N08, I129, I131, I132, N03, N04, N05, N07, N08, N11, N12, N14, N15, N16, N18, N19, Z992
Diabetes mellitus	E10, E11, E12, E13, E14
Obesity	E66
Cachexia and malnutrition	R64, R634, E43, E44
Coagulopathy	D66, D67, D680, D681, D682, D684, D685, D686, D688, D689, D691, D693, D694
Pulmonary embolism	I260, I269
Peritonitis	K650, K658, K659
Sepsis	A40, A41, R572, R650-
Myocardial infarction	I21, I22
Anastomotic leak	K918
Pneumonia	J12–J18, J100, J110, U6900
Acute kidney failure	N17
Gastrointestinal bleeding	K92
Blood transfusion ≥ 6 RBCCs	OPS 8800c1–8800cr, 880070–88007e, 88007g, 88007h

RBCC, red blood cell concentrate