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Surgical Site Infections and their economic significance in hepatopancreatobiliary surgery: A retrospective incidence, cost, and reimbursement analysis in a German centre of the highest level of care

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Abstract

Surgical site infections (SSI) in open Hepatopancreatobiliary (HPB) surgery are common complications. They worsen patients' outcomes and prolong hospital stays. Their economic significance in the German diagnosis related groups (DRG) system is mostly unknown. To investigate their economic importance, we evaluated all cases for SSIs as well as clinical and financial parameters undergoing surgery in our centre from 2015 and 2016. Subsequently, we carried out a cost-revenue calculation by assessing our billing data and the cost matrix of the InEK (German Institute for the Payment System in Hospitals). A total of 13.5% of the patients developed a superficial, 9% a deep incisional, and 2.4% of the patients an organ space SSI. Compared with Patients without SSI, Patients with SSI had more comorbidities, were older, and their average length of stay was extended by 19 days ($P < .001$). The financial loss per SSI-case was €-7035.65 despite increased reimbursement, which resulted in a calculated total loss for the hospital of €-802 064.62 in 2015 and 2016. Surgical site infections are common complications of open HPB surgery, which lead to a significant increase in the cost per case. Further prevention strategies need to be developed. Besides, an adjustment of revenues must be demanded.

KEYWORDS

biliary tract surgical procedures (D001662), costs and cost analysis (D003365), length of stay (D007902), liver (D008099), surgical wound infection (D013530)

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[Correction added on 6 November 2020, after first online publication: Projekt Deal funding statement has been added.]

1 | INTRODUCTION

Hepatopancreatobiliary (HPB) surgery includes surgery of the liver, bile ducts, and pancreas. These operations range from resections of the smallest liver lesions to complex hepatic and pancreatic resections lasting hours. The possible complications are as heterogeneous as the operations themselves. These complications range from bile duct stenosis and leaks, fluid collections, anastomotic leakage, bleeding, and liver failure to surgical site infections (SSI).[1] These SSIs are classified according to the centers for disease control and prevention (CDC) classification into superficial, deep incisional, and organ space SSIs.[2]

With 18.4% in Europe in 2016[3] and 21.8% in the USA in 2014,[4] SSIs account for a considerable proportion of hospital-acquired infections. In a recently published guideline of SSI treatment, the WHO underlined the importance of their prevention .[5] However, the evidence of the measures proposed is consistently weak. The frequency of SSIs varies greatly and depends on the author and the particular surgical specialty studied. In HPB-surgery SSI rates of 25.1% after pancreatoduodenectomy[6] and 23.2% after hepatic and pancreatic resections have been reported.[7] The genesis of SSIs is not yet clearly understood. Much research has examined the influence of various extrinsic and intrinsic factors on the genesis of SSIs,[8] but in many cases, this cannot explain the occurrence of SSIs. It is undisputed that SSIs lead to prolonged hospitalisation and readmission,[9] re-operations, and increased costs of treatment.[10] However, the resulting values for the health care system are difficult to assess. In addition to the costs for hospitals resulting from more extended inpatient stays and operations without adequate reimbursement, further economic damages arise from prolonged incapacity to work and outpatient wound care costs. Systematic analyses of the additional expenses caused by wound infections are rare and show massive fluctuations depending on the underlying calculation model, indication area, and author. When interpreting these data, the country of data collection should also be taken into account, as significant differences can exist, particularly in reimbursement. However, all authors describe that an SSI leads to a financial loss despite an additional refund.[11,12] In the strict German diagnosis related groups (DRG) system, Graf et al showed in a matched case-control study in thoracic surgery that the occurrence of an SSI compared to the control population leads to a deficit of €-12 482 versus a gain of €484 despite additional revenue. Wolters et al showed an increase in the debt per treatment case from €1128 to €5471 in patients after cystectomy. German data on the economic relevance of SSIs in HPB surgery are entirely lacking.

Therefore, we aimed to analyse the relevance of SSI in HPB surgery at a German university hospital and to examine the economic consequences in the context of the German DRG system.

Key Messages

- SSIs are frequent complications in opened HPB-surgery
- intrinsic factors seem to have a more significant influence on SSI-occurrence than extrinsic factors
- SSIs dramatically prolong the length of inpatient stay
- SSIs lead to higher cost not covered by reimbursement
- beside higher reimbursement in case of SSI, prevention strategies have to be investigated

2 | MATERIALS AND METHODS

2.1 | Study design

In this retrospective study, we analysed 431 patients who underwent open HPB-surgery in 2015 and 2016 at the University Medical Center Regensburg (UKR) for the primary endpoint, occurrence of SSI. These were mostly complex hepatic resections, highly complex operations on the bile ducts and pancreas resections, and liver transplants. The case-mix-index of the examined cases was seven, which underlines the complexity of the treatments.

2.2 | Collection of variables

All variables were determined by studying patient records. Besides socio-demographic information such as height, weight, body mass index, and age, previous illnesses were recorded as well as personal risk scores such as American Society of Anaesthesiologists (ASA) classification and wound contamination class. All measured variables are listed in Tables 1 and 2. Target variable SSI was recorded by evaluating the standardised wound documentation sheets of the nursing documentation and by evaluating physicians letters and medical documentation. During the inpatient stay, the SSIs were classified as superficial, deep incisional, and organ space SSI according to the depth of infection following the centers for disease control and prevention (CDC) guidelines.

TABLE 1 Patient characteristics (n = 431)

Variable		No SSI (n = 323)		SSI (n = 108)		*P* value
Age	<50	79	(85.9%)	13	(14.1%)	.006
	≥50	243	(71.9%)	95	(28.1%)	
Gender	Male	180	(69.5%)	79	(30.5%)	.001
	Female	143	(83.1%)	29	(16.9%)	
ASA score	1	20	(87%)	3	(13%)	<.001
	2	124	(82.7%)	26	(17.3%)	
	3	148	(70.8%)	61	(29.2%)	
	4	15	(55.6%)	12	(44.4%)	
	5	2	(50%)	2	(50%)	
Diabetes	No	260	(76.9%)	78	(23.1%)	.070
	Yes	63	(67.7%)	30	(32.3%)	
Malignancy	No	118	(74.2%)	41	(25.8%)	.790
	Yes	205	75.4%)	67	(24.6%)	
Anaemia	No	125	(83.9%)	24	(16.1%)	.020
	Yes	198	(70.2%)	84	(29.8%)	
CAD	No	290	(77.1%)	86	(22.9%)	.006
	Yes	33	(60%)	22	(40%)	
COPD	No	308	(75.9%)	98	(24.1%)	.760
	Yes	15	(60%)	10	(40%)	
Smoker	No	268	(74.7%)	91	(25.3%)	.756
	Yes	55	(76.4%)	17	(23.6%)	
Alcohol	No	289	(75.9%)	92	(24.1%)	.228
	Yes	34	(68%)	16	(32%)	
Immobility	No	283	(77.7%)	81	(22.3%)	.002
	Yes	40	(59.7%)	27	(40.3%)	
Chronic kidney disease	No	297	(76.3%)	92	(23.7%)	.040
	Yes	26	(61.9%)	16	(38.1%)	
Liver cirrhosis	No	282	(77%)	84	(23%)	.017
	Yes	41	(63.1%)	24	(36.9%)	
Body mass index [kg/m^2]	Mean	25.8		26.7		.098
	SD	5.54		5.28		
Anti-coagulation	No	265	(77.7%)	76	(22.3%)	.003
	Yes	57	(64%)	32	(36%)	

2.3 | Statistical analysis

Categorical variables are presented as absolute and relative frequencies, and continuous variables either as mean (standard deviation) or as median (first quartile, third quartile), depending on the underlying distribution. Normality was assessed using the Shapiro–Wilk test. Nominally scaled variables were compared using the Chi-squared test of independence, ordinal, and skewed variables were compared using the Kruskal–Wallis test, and normally distributed variables were compared by using an analysis of variance (ANOVA). All *P*-values less than .05 were considered statistically significant. Statistical analyses were performed by using IBM SPSS statistics 25.

2.4 | Analysis of the cost/income statement

Our controlling department provided data about the length of stay, respective DRG, and reimbursement per case. The costs per case were calculated using the cost matrix of the

TABLE 2 Perioperative characteristics

Variable		SSI No (%)		SSI Yes (%)		P value
Emergency procedure	No	296	(76.1%)	93	(23.9%)	.093
	Yes	27	(64.3%)	15	(35.7%)	
Contamination class	Clean-cont.	284	(76.1%)	21.5	(23.9%)	.194
	Contaminated	30	(66.7%)	29.5	(33.3%)	
	Dirty-Infected	9	(69.2%)	16.7	(30.8%)	
Incision	Median	168	(78.5%)	46	(21.5%)	.117
	Transversal	39	(79.6%)	10	(20.4%)	
	L-formed	103	(70.5%)	43	(29.5%)	
	Subcostal	12	(57.1%)	9	(42.9%)	
Packing	No	300	(77.7%)	86	(22.3%)	.000
	Yes	23	(51.1%)	22	(48.9%)	
Preoperative biliary drainage	No	283	(75.9%)	90	(24.1%)	.55
	PTCD	19	(67.9%)	9	(32.1%)	
	ERCP	6	(60%)	4	(40%)	
	ERCP + Stent	15	(75%)	5	(25%)	
Duration of operation (min)	Mean	241		266		.113
	SD	108		128		

TABLE 3 Surgical Site Infections in HPB-surgery

	Overall HPB-procedures (n = 431)		Hepatic procedures (n = 289)		Pancreatic procedures (n = 79)		Biliary procedures (n = 63)		
No SSI	323	(74.9%)	211	(73.0%)	64	(81.0%)	48	(76.2%)	$P = .337$
SSI	108	(25.1%)	78	(27.0%)	15	(19.0%)	15	(23.8%)	
Incisional SSI	58	(13.5%)	39	(13.5%)	9	(11.4%)	10	(13.5%)	
Deep incisional SSI	39	(9.0%)	29	(10.0%)	5	(6.3%)	5	(7.9%)	
Organ Space SSI	11	(2.6%)	10	(3.5%)	1	(1.3%)	0	(2.6%)	

InEK and compared to the compensation per case. In order not to overestimate the effect, we have chosen a conservative calculation model. Since not every patient with SSI required a re-operation, and some patients without SSI required one, we did not include the calculated surgery costs of the initial DRG in the calculation of the additional costs. We underestimated the actual costs at best.

3 | RESULTS

3.1 | Frequency of SSIs

A total of 108 (25.1%) patients developed a surgical site infection. Superficial SSIs occurred in 58 (13.5%), deep incisional SSIs in 39 (9%), and organ space SSIs were the least frequent in 11 (2.4%) cases (Table 3). The interventions were heterogeneously distributed over the operations of HPB surgery.

Most of the operations investigated were hepatic resections. These patients also showed the highest probability of occurrence of SSIs. Of the 289 patients, 78 (27%) developed SSI. In 79 pancreatic operations, SSIs occurred in 15 (19%) patients, and in 63 biliary procedures, 15 patients developed an SSI (24%). The statistical analysis showed no significant difference between the three indications ($P = .523$).

Incisional and deep incisional SSIs were detected in 17.4% of median, 18.4% of transverse, 27.5% of L-shaped, and 42.9% of subcostal incisions ($P = .117$).

The cohort also includes 13 patients who underwent hemihepatectomy or left-lateral liver resection for living donor liver transplantation. In contrast to the other hemihepatectomy-patients, none of them developed an SSI (P = .010).

3.2 | Patient- and perioperative characteristics

As shown in Table 1, SSIs occurred more frequently in patients aged over 50 years (28.1% / 14.1%, P = .006) and in males (30.5%/ 16.9%, P = .001). As the American Society of Anaesthesiologists (ASA) score increased, so did the rate of SSI (P < .001). As a further expression of multimorbidity, SSIs occurred more frequently in immobile patients (40.3%/ 22.3%, P = .002), patients with coronary heart disease (40%/ 22.9%, P = .006), and chronic kidney disease (38.1% / 23.7%, P = .040). Similarly, more patients with liver cirrhosis (36.9%/ 23%, P = .017) and postoperative anaemia (29.8%/ 16.1%, P = .020) developed SSIs. After intraabdominal packing during initial surgery, SSI occurred more often than without (48.9%/ 22.3%, P < .001). Other examined, patient-centred (Table 1) as well as procedural characteristics (Table 2) showed no statistically significant impact for the development of a SSI.

3.3 | Length of hospital stay

As a basis for further economic studies, we determined the median length of hospital stay (LOS) with and without SSI. The median LOS of all patients with HPB surgery was 17 (11, 30) days. Patients without SSI stayed 15 (10, 24) days while patients with superficial stayed 24 (17, 37), with deep incisional 40 (29, 56) with organ space SSI 50 (34, 74) days. The occurrence of an SSI prolonged the median hospital stays up to 34 days (P < .001) (Figure 1). Since other serious complications naturally occur in HPB surgery and can, in principle, influence the LOS, we only analysed those patients who did not develop any other complications in further analysis (n = 321). Here the median LOS was 14 (10, 20) days without, 20 (15, 28)) days with superficial and 36.5 (29, 42) days with deep incisional SSI. Superficial SSIs, therefore, seem to prolong the LOS about 6 days, deep incisional SSIs about 22.5 days.

3.4 | Economic aspects of wound infections in HPB surgery

The economic analysis of all patients revealed that patients stayed in the hospital, on average, 1.1 days longer than the average LOS specified in the respective DRG. Therefore, the revenue-loss calculation results in a deficit of €-681 per patient. If a wound infection was present, the deficit per patient increased to €-7.303. Since the patients also had other complications such as bile leakage, hematomas, or fluid retentions, we also analysed only those patients who did not show any further complications. In this 253 Patients containing group, we calculated a deficit per patient of €-116. Here, the average length of stay deviates only a few hours from the average LOS calculated in the DRG. In the case of an SSI (n = 54), we recorded a deficit of €-5.676. All economic aspects are shown in Table 4.

4 | DISCUSSION

HPB surgery represents a heterogeneous field of surgery from simple cholecystectomy to highly complex, multistage oncological liver resections. To investigate the economic aspects of HPB surgery, we developed a cost-profit

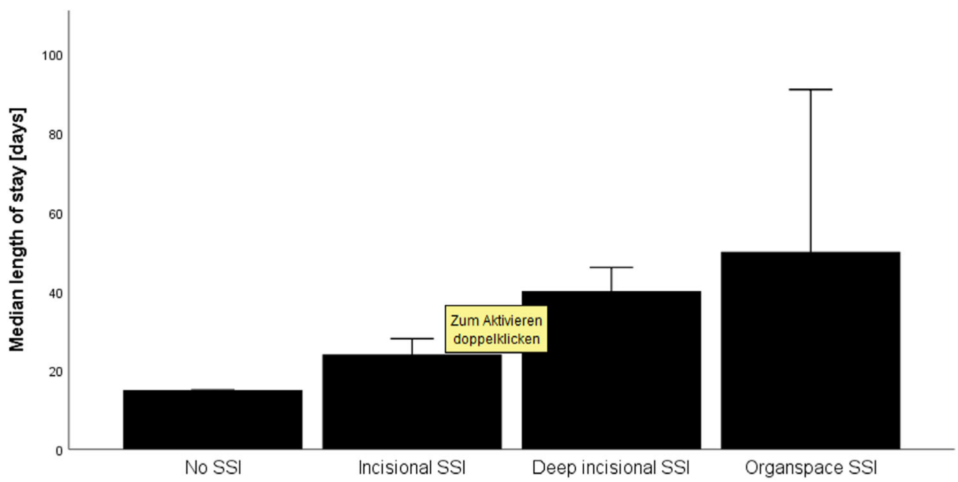

FIGURE 1 The median length of stay of patients in hpb-surgery. Patients without SSI remained 15 (10, 24) days in the hospital, patients with superficial SSI 24 (17, 37), with deep incisional SSI 40 (29, 56), and with organ space infection 50 (34, 74) days. Error bars represent 95% CI

TABLE 4 Cost−/ reimbursement calculation of SSI in HPB-surgery

	Overall			Without other complications		
	No SSI	SSI	*P*-value[a]	No SSI	SSI	*P*-value[a]
Calculated mean costs per case	€21 663	€45 646	<.001	€17 694	€27 477	<.001
Mean reimburse-ment per case	€20 982	€38 343	<.001	€17 579	€21 800	<.001
Mean profit / loss	€-681	€-7303	<.001	€-116	€-5676	<.001
Overall profit loss	€-212 353	€-781 369		€-29 232	€-306 524	
Number of cases	349	114		253	54	

[a]Mann–Whitney *U* test was used.

model based on the German DRG system. Calculations based on this cost-profit model, which allow us also to depict costs of highly complex cases, show that in a centre of the highest level of care, cost coverage cannot be achieved. In our cohort with a casemix index of 7, treatments are complicated and lead to prolonged hospital stays. The median LOS of all patients without SSI in our collective was 17 days. With this, the patients already exceeded the average LOS based on DRG regulations by 1 day, which meant an average deficit of - €681 per patient. Due to SSIs, the median LOS increased dramatically up to 34 days, which was reflected in the economic analysis. Since inpatient care is organised differently in other health care systems than in Germany, data on LOS are only comparable to a limited extent. For example, other authors found only an extension of the LOS after pancreatoduodenectomy from 7 to 8 days for superficial and 11 days for deep incisional SSIs.[13] The average LOS calculated in the DRG for comparable pancreatic surgery in Germany is 11 days. As already mentioned above, an increase in the LOS is only reimbursed in additional charges once the DGR-specific upper limit of stay has been exceeded, but this is far from covering the additional costs.

The median prolongation of LOS of 19 days in case of SSI results in financial losses, which are not adequately reimbursed by the German DRG system. The €5676 additional costs per incisional SSI determined in our study show that also in HPB surgery, SSI represents a considerable economic burden for care providers, especially since the cost calculation we made is a cautious estimation. In our cohort, it resulted in a calculated total loss of -€781 369 in patients with SSI. Already Wolters et al showed additional costs of €5628 per patient with SSI in a German urological cohort.[14] Graf et al showed additional charges of €12 482 in cardiac surgery patients who developed deep sternal SSI. We assume that, especially in a hospital of the highest level of care, such as ours, the costs are significantly higher due to the substantially larger maintenance of material, equipment, and personnel. Within the DRGs, the treatments performed are very heterogeneous; however, interventions of varying degrees and risks are reimbursed by the same amount. Typically, this is compensated if a hospital performs a mixture of many "easy" and few "complex" procedures summarised under one DRG. If a hospital like ours and many other university hospitals and large tertiary referral centres are highly specialised and perform almost only "complex" procedures of one DRG, this leads to a severe underfinancing of these "expert" centres. The cost analysis within Germany cannot, of course, be transferred to other health care systems without restrictions. Badia et al were able to show in their review of comprehensive data on the costs of SSI in various indication areas that SSI in these systems also represent an economic burden for the service providers, as there is no total cost-covering reimbursement.[15] It is necessary to demand that the costs of SSIs have to be more clearly reflected within the DRG system. These costs also have to be compensated by the insurance companies using additional charges if necessary. The analysis does not consider the economic follow-up costs of SSIs due to prolonged follow-up treatment, incapacity to work, and in some cases, the need for long-term care and the socio-economic importance for patients. In the worst-case, an SSI can significantly worsen the oncological outcome of the patient.

Therefore, it must be the aim of all surgical disciplines to develop strategies to reduce the number of SSIs. Extrinsic factors appear to be easier to influence than patient-centred ones. Nevertheless, the comparison of living liver donors with comparable patients gives indications of a more significant influence of intrinsic variables on the genesis of SSIs (SSI 0% / 32%, $P < .001$). As one of these strategies, we are currently investigating the benefit of epicutaneous negative pressure wound therapy in post-operative wound treatment for the prevention of SSI in HPB surgery intending to reduce the SSI rate by economically reasonable means. The findings of the present study have been used intensively for study planning and the subsequent economic evaluation of these and other preventive measures. In addition to further efforts to reduce wound infections, however, full cost coverage by the health insurance funds must also be demanded. Otherwise, the hospitals could be increasingly forced in the economic interest to discharge patients with wounds that heal secondarily and thus shift the costs to the outpatient sector. This practice would certainly be to the detriment of patients and would lead to a significant increase in the price of the overall treatment for the health insurance funds. The current system penalises hospitals that primarily treat particularly ill patients and allows cost-covering work only for hospitals that carry out risk-stratified patient selection.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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