The Impact of Complications on Costs of Major Surgical Procedures

A Cost Analysis of 1200 Patients

René Vonlanthen, MD, Ksenija Slankamenac, MD,* Stefan Breitenstein, MD,* Milo A. Puhan, MD, PhD,†‡ Markus K. Muller, MD,* Dieter Hahnloser, MD,* Dimitri Hauri,† Rolf Graf, PhD,* and Pierre-Alain Clavien, MD, PhD, FACS, FRCS**

Objective: To assess the impact of postoperative complications on full in-hospital costs per case.

Background: Rising expenses for complex medical procedures combined with constrained resources represent a major challenge. The severity of postoperative complications reflects surgical outcomes. The magnitude of the cost created by negative outcomes is unclear.

Patients and Methods: Morbidity of 1200 consecutive patients undergoing major surgery from 2005 to 2008 in a tertiary, high-volume center was assessed by a validated, complication score system. Full in-hospital costs were collected for each patient. Statistical analysis was performed using a multivariate linear regression model adjusted for potential confounders.

Results: This study population included 393 complex liver/bile duct surgeries, 110 major pancreas operations, 389 colon resections, and 308 Roux-en-Y gastric bypasses. The overall 30-day mortality rate was 1.8%, whereas morbidity was 53.8%. Patients with an uneventful course had mean costs per case of US$ 27,946 (SD US$ 15,106). Costs increased dramatically with the severity of postoperative complications and reached the mean costs of US$ 159,345 (SD US$ 151,191) for grade IV complications. This increase in costs, up to 5 times the cost of a similar operation without complications, was observed for all types of investigated procedures, although the magnitude of the increase varied, with the highest costs in patients undergoing pancreas surgery.

Conclusion: This study demonstrates the dramatic impact of postoperative complications on full in-hospital costs per case and that complications are the strongest indicator of costs. Furthermore, the study highlights a relevant savings capacity for major surgical procedures, and supports all efforts to lower negative events in the postoperative course.

(*Ann Surg* 2011;254:907–913)

Health care expenditures are increasing worldwide, and at a faster pace than in any other industry, and therefore are a leading focal point in the search for cost containment. In 2008, the United States spent US$ 2.3 trillion, which reflected 16.2% of the gross domestic product (GDP), 4.4% more than in 2007.[1] There is a comparable situation in Switzerland, with expenditures for health care at almost US$ 60 billion, representing over 11.5% of the GDP in 2008. About 35% of total health care costs in Switzerland are generated by hospitals, and one third of those are generated by surgical departments.[2] These rising expenses, combined with limited resources and a lack of clinical practice standards, have triggered the interest of health care payers (government or insurance) and providers to accurately measure the precise economic impact of quality of care delivery. In the surgical field, postoperative complications are the most sensitive surrogate marker for quality.[3–6] As a prerequisite for a valuable quality-cost assessment, relevant data on outcomes, and on their respective cost, must be obtained in a standardized and reproducible manner.[7,8]

Only a few relevant studies on cost relative to the quality of care are available in the surgical fields, all indicating that structure and process variables as well as postoperative complications genuinely influence the cost of a procedure.[3,9–15] Such data are somewhat expected, but the magnitude of this impact remains obscure.

To further dissect the origin of costs, complete datasets require the description of the patient population, convincing documentation on the case mix of patients, and, importantly, standardization of the definition of the severity of postoperative complications.[4–6] For analysis of cost assessment this data set needs to include solid cost reports that may vary from hospital to hospital and may depend on the bookkeeping system. A cost analysis within the same hospital might shed light on simple questions, eg, on the actual costs of surgical therapies and on the impact of complications, even though the absolute figures may change from hospital to hospital.

A few scoring systems of postoperative negative events are available[16–19] and may offer new tools to calculate the economic impact of a procedure based on the severity of the postoperative course. We developed and validated a therapy-oriented complication score system ranking complications by severity into 5 grades.[8,20]

Although the cost of a given surgical procedure and care can be determined fairly accurately, subsequent complications confound the cost estimation. The most appropriate and accurate—but also the most complex—method to track resource use and assign costs requires an accurate and detailed cost accounting system.[21]

We designed a study to comprehensively assess the economic consequences of complications, following a variety of general surgical procedures, including hepato-pancreato-biliary (HPB) and colorectal as well as bariatric operations.

MATERIALS AND METHODS

Study Design and Population

Each specialized division in the Department of Surgery collects patient data prospectively, including data pertaining to outcomes and complications.

We conducted a cohort study and included consecutive patients undergoing elective liver, pancreas, colorectal, and Roux-en-Y gastric bypass (RYGP) surgeries between 1 January 2005 and 31 December 2008 in a single tertiary care center. Endpoints were clinical outcomes as well as full in-hospital costs. All clinical data

From the *Department of Surgery and †Horten Center for Patient Oriented Research, University Hospital Zurich, Zurich, Switzerland; and ‡Department of Epidemiology, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD.

Disclosure: Supported by the Liver and Gastro-Intestinal Diseases Foundation (LGID).

R.V. and K.S. contributed equally to this work.

Reprints: Pierre-Alain Clavien, MD, PhD, FACS, FRCS, Department of Surgery, University Hospital Zurich, Raemistrasse 100, CH-8091 Zurich, Switzerland. E-mail: clavien@access.uzh.ch.

ISSN: 0003-4932/11/25406-0907
DOI: 10.1097/SLA.0b013e31821d4a43

was collected prospectively using standardized forms, and entered into the database. Cost data was provided by the financial department of the hospital. The study was approved by the institutional review board for human studies, internationally registered at clinicaltrials.gov (NCT00855387), and was reported according to the STROBE statement.[22]

Outcome Measures

The database was filled with general information about the patient and postoperative events. Each chart was additionally reviewed in detail by 1 co-author (KS) to ensure full and correct extraction of the data about pre- and postoperative outcome parameters and hospital costs. Complications were graded according to a standardized, validated therapy-oriented complication score on a 5-point scale[8] (Table 1). As with the original publication, patients were divided according to their most severe complication, representing the most relevant clinical event. Data were also analyzed for the total number of complications per patient. Because of the insufficient number of grade IVa and IVb complications, those events were combined in one group for comparative cost analyses. Costs for complication grade V (death) were not included in the comparative statistical analysis because of the possible distortion of the statistical analysis by a nonsurvivor bias. Nevertheless, we also performed a sensitivity analysis including death events in the linear regression model to assess whether their inclusion would change the overall results. The assessment of intraoperative parameters included operating time and type of surgery. Additional postoperative parameters were length of hospital stay (LOS) and intensive care unit stay.

Cost Analysis

The cost analysis was performed for all of the patients with the support of the financial department of the hospital. The costs were calculated according to the standardized and well established cost accounting guidelines of the association of Swiss hospitals called REKOLE®[7] using the SAP system (SAP, Business Warehouse, Walldorf, Germany). This full cost analysis integrated complete in-hospital expenses including variable and fixed costs. The cost splitting started with the allocation of costs to the receiving cost units. Costs were directly attributed to the case, according to the services offered on the investigational/treatment and bed accompanying areas.

Statistical Analysis

We first assessed the distribution of variables for patient characteristics, outcomes, and costs using means and standard deviations (SD) for normally distributed data and medians (ranges) for nonnormally distributed data. For costs, we used means and SD independently of whether the data were normally or nonnormally distributed because this is commonly reported for economic analysis. Linear regression analysis was used to assess the association of the grade of complications and costs whereas adjusting for age, gender, American Society of Anesthesiologists-score (ASA-score),[23] nutrition risk score (NRS), Charlson Index,[24] type of surgery, and duration of surgery. Including costs without transformation led to regression models that violated the assumption of normally distributed errors and constant variance. Therefore, we used the natural logarithm of costs as the dependent variable that led to regression models fulfilling the assumptions of linear regression. We also used linear regression analyses with the natural logarithm of costs as the dependent variable to assess its association with the type of major surgery (liver, pancreas, colorectal, or RYGP), operation time, and the total number of complications. Finally, we assessed which of the preoperative parameters (age, gender, ASA-score,[23] Charlson Index,[24] NRS,[25] surgery time, and type of surgery) predicted increased in-hospital costs using multivariate models. We conducted all analyses using STATA (STATA for Windows, version 11, Stata Corp; College Station, TX, USA).

TABLE 1. Complication Grades According to the Clavien-Dindo Classification[8,20]

Grade	Definition
Grade I	Any deviation from the normal postoperative course without the need for pharmacological treatment or surgical, endoscopic, and radiological interventions
Grade II	Requiring pharmacological treatment with drugs other than those allowed for grade I complications
Grade III	Requiring surgical, endoscopic, or radiological intervention;
Grade IIIa	Intervention not under general anesthesia
Grade IIIb	Intervention under general anesthesia
Grade IV	Life-threatening complication (including CNS complications) requiring IC/ICU-Management;
Grade IVa	Single-organ dysfunction (including dialysis)
Grade IVb	Multi-organ dysfunction
Grade V	Death of a patient

RESULTS

Patient Selection

One thousand two hundred and twenty consecutive patients undergoing major elective abdominal surgery were assessed for eligibility in this study; only 20 patients (1.6%) were excluded due to incomplete data records. Consequently, 1200 patients with a median age of 56 years (range: 20–84 years) were assessed in this study. Table 2 shows patient characteristics; 393 patients (32.8%) underwent a major liver or bile duct surgery, 110 patients (9.1%) a pancreas surgery, 308 (25.7%) a RYGP, and 389 (32.4%) a colorectal operation.

Intra- and Postoperative Parameters

Intra- and postoperative parameters are summarized in Table 2. More than half of 1200 patients (53.8%) developed at least 1 complication, and 309 patients (26%) had more than 1 complication (Table 2). Patients were further analyzed according to their most severe complication: 12.6% had a grade I complication, 19.5% a grade II, 5.4% a grade IIIa, 7.4% a grade IIIb, and 5.6% a grade IV complication. Overall mortality rate was 1.8% (grade V).

The sensitivity analysis including death events in the statistical analysis showed that in-hospital costs for a death event are significantly higher than costs of grade I to IIIb complications. But the costs of death events are significantly lower than grade IV complications ($P < 0.001$) regardless of the type of surgery. On the basis of these results the inclusion of death events in the final analysis may mislead the interpretation of the results. Therefore, we performed the entire statistical analysis excluding all death events.

Cost Analysis

Overall mean in-hospital costs of the whole population studied were US$ 45,924 (SD US$ 56,075). Mean in-hospital costs of all patients without complications were US$ 27,946 (SD US$ 15,106), whereas mean costs of all patients with at least 1 complication of any severity was US$ 62,392 (SD US$ 72,47), a highly significant increase of 2.3 times (Table 3).

We further investigated the impact of a complication grade on costs. Compared with an intervention without complication (US$ 27,946), a grade I complication, for example, created significant additional costs of US$ 2793 and a grade IV of over US$ 130,000 (Fig. 1 and Table 3).

TABLE 2. (A) Patient's Characteristics and (B) Intra- and Postoperative Parameters

	All Patients n = 1200 (100%)	Liver Surgery n = 393 (32.8%)	Pancreas Surgery n = 110 (9.1%)	RYGP n = 308 (25.7%)	Colorectal Surgery n = 389 (32.4%)
(A) Patient's Characteristics					
Age (years)	56 (20–84)	59 (12–90)	63 (16–87)	39 (17–68)	61 (16–89)
Gender, male/female (%)	568/632 (47.3%/52.7%)	235/158 (59.8%/40.2%)	49/61 (44.6%/55.4%)	78/230 (25.3%/74.7%)	206/183 (53.0%/47.0%)
ASA score	2 (1–4)	2 (1–4)	2 (1–4)	2 (1–4)	2 (1–4)
I	114 (9.5%)	56 (14.3%)	12 (10.9%)	4 (1.3%)	39 (10%)
II	648 (54%)	227 (57.8%)	64 (58.2%)	167 (54.2%)	176 (45.2%)
III	449 (37.4%)	107 (27.2%)	33 (30.0%)	136 (44.2%)	157 (40.4%)
IV	24 (2%)	3 (0.7%)	1 (0.9%)	1 (0.3%)	17 (4.4%)
Charlson index	2 (0–13)	6 (0–12)	2 (0–11)	0 (0–7)	2 (0–13)
Nutrition risk score (NRS)					
<3	1,066 (88.8%)	320 (81.4%)	81 (73.6%)	305 (99.0%)	331 (85.1%)
≥3	169 (11.2%)	73 (18.6%)	29 (26.4%)	3 (1.0%)	58 (14.9%)
(B) Intra- and Postoperative Parameters					
Intraoperative parameters					
Surgery time (minutes)*	234.3 (116.5)	291.1 (118.6)	309.6 (134.6)	164.5 (79.4)	210.5 (90.2)
Blood loss (mL)*	274.2 (557.8)	426.7 (454.2)	613.9 (1,269.3)	68.5 (143.4)	190.3 (462.1)
Postoperative parameters					
30-days Mortality (days)	22 (1.8%)	12 (3.1%)	4 (3.6%)	0%	6 (1.5%)
Morbidity (%)	646 (53.8%)	220 (56.0%)	82 (74.6%)	109 (35.4%)	213 (54.8%)
More than 1 complication (%)	309 (25.8%)	114 (29.0%)	48 (43.6%)	26 (8.4%)	110 (28.3%)
Length of ICU stay (days)†	0 (0–77)	1 (0–77)	1 (0–61)	0 (0–28)	0 (0–34)
Length of hospital stay (days)†	10 (1–172)	12 (5–137)	16.5 (6–87)	8 (2–143)	11 (1–172)

All results in median and interquartile range.
ASA indicates the American Society of Anesthesiologists; ICU, intensive care unit ; RYGP, Roux-en-Y gastric bypass.
*All results in mean and standard deviation.
†All results in median and interquartile range.

TABLE 3. Mean Costs of Major Surgery

Highest Grade of Complication	All Types of Surgery (n = 1200)	Liver Surgery (n = 393)	Pancreas Surgery (n = 110)	RYGB (n = 308)	Colorectal Surgery (n = 389)
All patients	45,924 (56,075)	49,289 (54,529)	71,111 (78,688)	29,689 (18,171)	48,822 (66,564)
Without complications	27,946 (15,106)	31,028 (13,625)	31,809 (12,832)	26,426 (5,927)	26,420 (21,913)
With complications	62,392 (72,471)	61,967 (69,369)	82,576 (87,970)	35,648 (28,613)	66,929 (84,467)
I	30,739 (15,318)	36,363 (12,201)	42,803 (11,910)	28,418 (12,032)	29,166 (19,106)
II	42,338 (29,967)	37,620 (15,965)	51,038 (26,611)	29,757 (9,465)	43,370 (29,399)
IIIa	53,388 (28,150)	51,617 (24,515)	62,203 (32,801)	36,725 (12,772)	59,822 (37,330)
IIIb	97,001 (72,928)	82,982 (53,732)	168,427 (110,347)	80,980 (56,543)	95,550 (70,362)
IVa + IVb	159,345 (151,191)	143,748 (136,345)	–*	–*	–*

Mean costs in US Dollar ($) with standard deviation (SD).
I–IVb indicates grades of complications according to the Clavien-Dindo classification;[8] RYGP, Roux-en-Y gastric bypass.
*Data were not reported due to a small number (n ≤ 10).

Complications classified as grade IIIb (intervention under general anesthesia) or higher led to a highly significant increase in costs compared with procedures without postoperative complications ($P < 0.001$). This phenomenon was seen for all types of surgery. Pancreatic surgery with any degree of complications led to dramatic cost increase whereas RYGB surgery showed a less impressive increase (Table 3).

In the multivariate analysis of predictors of cost (its logarithm, respectively) ASA-score ≥ 3 (vs. <3, $P < 0.001$), NRS ≥ 3 (vs. <3, $P = 0.011$), Charlson Index ≥ 3 (vs. <3, $P = 0.006$), pancreas resection (vs. RYGP, $P < 0.001$) and duration of surgery ≥210 minutes (vs. <210 minutes, $P < 0.001$) were independently associated with cost, whereas age ≥60 years (vs. < 60 years, $P = 0.34$), and sex ($P = 0.36$) were not (Table 4). Table 4 also presents that the severity of complications (≥grade II–IV) have higher standardized beta coefficients than the other predictors.

The impact of the types of the most severe complications, eg, infection, fistula, bleeding, etc., on cost is shown in Table 5. The most relevant complications were general- and wound infections classified as grade II complications and fistulas or leaks graded as IIIb or IV complications. Cardiopulmonary events were also frequently registered as grade II or IV complications.

We observed a strong association between the severity of the type of complication and cost. For example, a patient developing a fistula classified as a complication grade I cost US$ 31,329 (SD US$ 6710), in contrast to a grade IIIb fistula with a cost of US$ 121,531 (SD US$ 76,291). Among the various types of complications, fistulae, infections, cardiopulmonary, and bleeding events had the most relevant impact on costs.

Each type of surgery (pancreas, liver, RYGB, and colorectal) led to organ specific complications. Therefore, the incidence of complications and related costs were analyzed separately for each organ

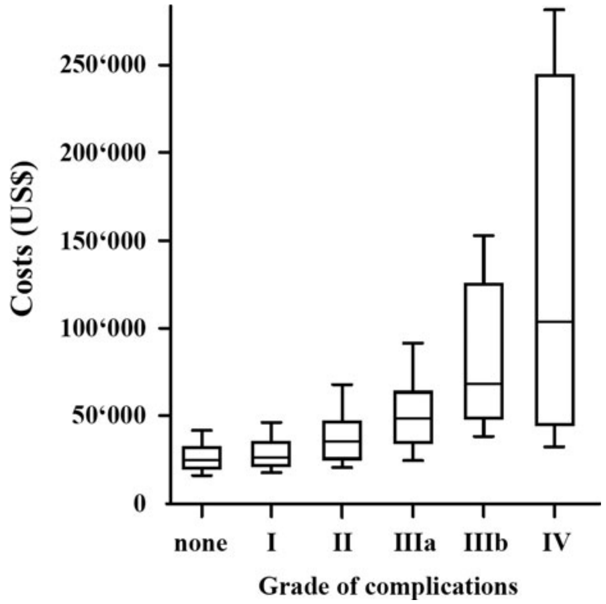

FIGURE 1. Overall costs according to the severity of complications.

TABLE 4. Predictors of In-Hospital Costs

Parameter	Standardized Beta Coefficients (*P*)
Complications	
None complication	Reference
Grade I	0.050 ($P = 0.023$)
Grade II	0.153 ($P < 0.001$)
Grade IIIa	0.172 ($P < 0.001$)
Grade IIIb	0.391 ($P < 0.001$)
Grade IVa + IVb	0.440 ($P < 0.001$)
Age	
<60	Reference
≥60	−0.023 ($P = 0.337$)
Gender	
male	Reference
female	0.020 ($P = 0.356$)
ASA-score	
≤II	Reference
>II	0.128 ($P < 0.001$)
Nutrition Risk Score	
0–2	Reference
≥3	0.058 ($P = 0.011$)
Surgery time	
<210 minutes	Reference
≥210 minutes	0.148 ($P < 0.001$)
Charlson Index	
<3	Reference
≥3	0.070 ($P = 0.006$)
Type of surgery	
Roux-en-Y gastric bypass	Reference
Liver resection	0.020 ($P = 0.539$)
Pancreas resection	0.095 ($P < 0.001$)
Colon resection	–0.004 ($P = 0.891$)

ASA indicates the American Society of Anesthesiologists.

(Table 6). Pancreatic surgery was the most expensive, but interestingly, in the absence of complications, the mean costs were quite comparable among the organs (Table 3, Fig. 2); differences ranged between US$ 800 and US$ 6,000. However, we found differences in costs for a specific grade of complication among the various types of procedures. For example, if any complication arises during pancreatic surgery, mean costs per case are US$ 20,000 to US$ 47,000 higher, compared with liver surgery or RYGB, respectively (Table 6). In the presence of any type of complication, costs rise significantly for all surgical procedures, but we observed significant differences in the magnitude of the increase between the different types, with the highest figures for pancreatic surgery (Table 6).

DISCUSSION

Assessing the quality of care and its associated cost is critically important at a time when the allocation of resources in many societies is done on a competitive basis. This study provides a number of interesting observations. First, although, as expected, the cost increased with the development of complications after a standard procedure, the magnitude of this extra cost seemed higher than what would have been presumed. Second, severe complications dramatically overrode the overall cost of procedures, eg, by more than 5 times in the presence of a grade IV complication. Third, although the costs of uneventful procedures were largely comparable, the development of complications had very different effects on cost depending on the type of surgery. For example, the procedures on the pancreas were significantly more expensive with the development of similar degrees of complications. Finally, the type of complication (infections, fistulas and leaks, cardiovascular events, etc.) had much less influence on costs than the severity.

Pressure from patients and payers to compare the quality of specific treatments among centers will only increase in the future, and will likely become part of public knowledge. Therefore, the use of complication rates (morbidity) as surrogate parameters for medical quality, particularly in surgery, is widespread. As a prerequisite for a precise and convincing outcome assessment, complications need to be ranked convincingly in a standardized and reproducible manner, which greatly depends on the perspective taken. A classification integrating medical, payer, and patient perspectives is not feasible, as the correlation between these different perspectives is poor.[8]

None of the previously published analyses on the cost of surgical procedures used any standardized outcome system.[9–12] A few studies used terms such as minor and major complications,[9,10] although those terms were rarely defined and thus may vary within the studies, and inevitably among studies from different centers. Hence, interpretations and comparisons are unreliable. However, not only the severity, but also the simple recording of complications lacks standardization. Two studies evaluating the influence of postsurgical complications on cost described an overall complication rate of 6.5% (patient number of $n = 5875$ on 6 surgical services)[26] and 6.8% (patient number of $n = 7457$).[11] Such low complication rates may be credible only if the patient collectives included minor surgeries. However, it is more probable that the identification of postoperative events was incomplete, which is a well-known “negative bias” in outcome reporting.[27–29] In contrast to our analysis, this may explain the conclusion of the study of Davenport et al,[26] showing a stronger correlation of costs with preoperative risk factors than with complications. In this study, we convincingly show that the severity of complications had a much stronger impact on costs than any other parameter on full in-hospital costs.

Although all grades of complications were associated with increased costs, when compared with an uneventful postoperative course, the stronger impacts on costs were more severe complications, such as grade IIIb and grade IV events, increasing the mean costs per case by a factor of 5. Therefore, the prevention of grade IIIb and grade IV complications is obviously crucial. In this study,

TABLE 5. Type and Severity of Complications and Associated Costs (n = 646)

Type of Complication*	Grade I (n = 155)	Grade II (n = 241)	Grade IIIa (n = 67)	Grade IIIb (n = 92)	Grade IVa/IVb (n= 69)	Grade V (n = 22)
Wound infection, superficial and deep	n = 21	n = 34	n = 37	n = 12	n = 1	–
	42,400 (29,494)	41,513 (32,946)	57,207 (26,103)	60,640 (29,445)	–	–
General infection	n = 5	n = 67	n = 1	n = 2	n = 2	n = 3
	24,488 (6,788)	41,194 (21,866)	–	–	–	–
Fistula/Leak	n = 5	n = 12	n = 6	n = 38	n = 20	n = 4
	31,329 (6,710)	55,601 (33,071)	60,459 (37,787)	121,531 (76,291)	234,374 (195,886)	
Cardiopulmonary	n = 7	n = 41	n = 9	n = 2	n = 22	n = 8
	33,046 (7,964)	36,107 (21,817)	44,049 (18,896)		138,971 (136,895)	87,039 (27,233)
DGE/Nausea/Vomiting	n = 19	n = 30	n = 4	n = 11	n = 2	–
	32,808 (15,496)	53,343 (54,220)		79,135 (59,259)		
Bleeding	n = 6	n = 15	n = 4	n = 14	n = 8	n = 1
	24,143 (7,995)	38,208 (13,731)	–	98,227 (78,638)	149,582 (133,690)	-
Liver insufficiency	n = 2	–	–	–	n = 3	n = 4
Acute renal failure	n = 1	n = 3	–	n = 1	n = 3	n = 1
Others	n = 89	n = 39	n = 6	n = 12	n = 8	n = 1
	28,034 (10,407)	40,555 (23,684)	60,624 (49,309)	74,406 (49,166)	96,829 (98,408)	–

Mean costs ($) and standard deviation (SD); n < 5 not analyzed. General infection includes urinary tract infection, catheter infection, pneumonia, etc., others include neurologic complications, pain, pancreatitis, etc.

DGE indicates delayed gastric emptying.

*Type of highest complication per patient.

TABLE 6. (A) Cost Differences Between Different Organs for all Patients, (B) for Those Patients Without Complications, (C) for Those Patients with any Complication

(A) Cost Differences Between Different Surgical Types for All Patients Including Complications

All Patients	RYGP 29,689 (18,171)	Colorectal 48,822 (66,564)	Liver 49,289 (54,529) +
Pancreas: 71,111 (78,688)	Δ 41,422 (p < 0.001)	Δ 22,289 (p = 0.016)	Δ 21,822 (p = 0.04)
Liver: 49,289 (54,529)	Δ 19,600 (p = 0.001)	Δ 467 (p = 0.319)	
Colorectal: 48,822 (66,564)	Δ 19,133 (p = 0.006)		

(B) Cost Differences Between Different Surgical Types with no Complication

No complication	RYGP 26,426 (5,927)	Colorectal 26,420 (21,913)	Liver 31,028 (13,625)
Pancreas: 31,809 (12,832)	Δ 5,383 (p = 0.312)	Δ 5,389 (p = 0.303)	Δ 781 (p = 0.579)
Liver: 31,028 (13,625)	Δ 4,602 (p = 0.215)	Δ 4,608 (p < 0.001)	
Colorectal: 26,420 (21,913)	Δ 6 (p = 0.008)		

(C) Cost Differences Between Different Surgical Types with any Complication

Any complication	RYGP 35,648 (28,613)	Colorectal 66,929 (84,467)	Liver 61,967 (69,967)
Pancreas: 82,576 (87,970)	Δ 46,928 (p < 0.001)	Δ 15,647 (p = 0.089)	Δ 20,609 (p = 0.337)
Liver: 61,967 (69,967)	Δ 26,319 (p = 0.002)	Δ 4,962 (p = 0.151)	
Colorectal: 66,929 (84,467)	Δ 31,281 (p = 0.025)		

Mean costs with standard deviation (SD) and reported in US Dollars ($).

RYGP indicates Roux-en-Y gastric bypass; Δ, difference of mean costs in US$.

*Adjusted for age, gender, ASA, NRS, Charlson Index, duration of surgery and type of surgery.

complications of grade IIIb and above represented over 75% of the total expenses related to complications (data not shown). The avoidance of grade I to IIIa complications may also be relevant due to their total number. This raises an important question: How can complications in major surgery be avoided? It is now well established that mortality is significantly reduced by a high hospital volume and surgical experience.[3,30,31] Of note, recent evidence suggests that the total number of complications may not differ much among low and high volume centers, but rather that the difference may reside in the ability to rescue patients from a negative postoperative event in experienced centers, thereby preventing more serious complications including death.[32] This finding would even further support the strength of high-volume centers in preventing severe and costly complications through improved processes and structures.[32]

Knowledge of preoperative risk factors and their impact on outcome, including added cost, is grossly lacking in the literature.[11,26] We studied a number of readily available parameters, identifying ASA-score ≥3, NRS ≥3, Charlson Index ≥3, and duration of surgery ≥210 minutes as contributing significantly to higher cost. For our patient population, complications are superior to these parameters in

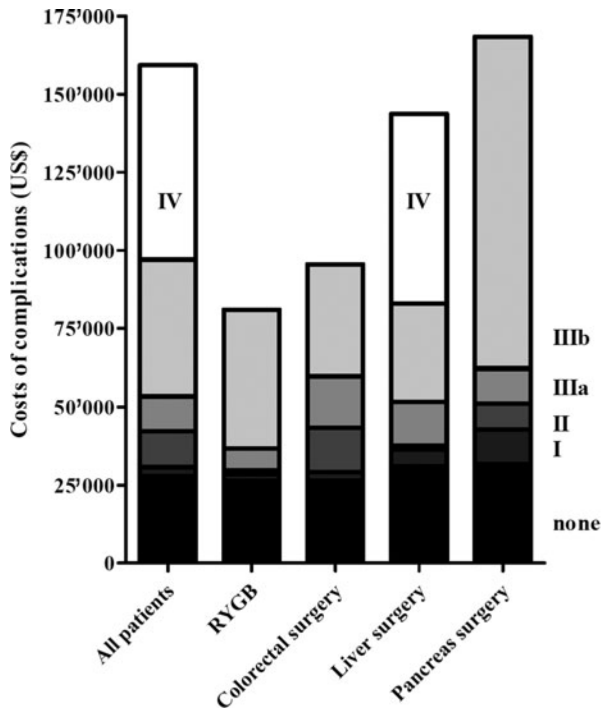

FIGURE 2. Mean costs according to the severity of complications by types of surgery.

predicting costs. Our multivariate analysis, however, failed to identify any association between the age of a patient and the total in-hospital costs. This finding is consistent with recent reports that age per se does not correlate with complications, and, therefore, a procedure should not be denied solely on the basis of age.[33,34]

The costs of pancreatic surgeries were significantly higher compared with all other procedures, although the cost of an uneventful postoperative course was comparable to the surgery on other organs. The finding that the costs associated with similarly severe complications vary by type of surgery has not been previously described.[11,12,26] Further investigations in different surgical areas are required to confirm this variability.

Regarding a specific type of complication (eg, infection, fistula and leaks, etc.), we wondered whether one type could influence costs more than another. A type of complication occurred in every grade of severity (I–V), but fistulas and leaks had the greater influence on costs per case because these complications seemed mainly as grade IIIb and IV complications.

Diagnosis-related groups (DRG) have been, or will be, implemented in many countries. They provide a tool for assigning a standardized "price" to a certain procedure, determined by cost analysis. Certain procedures bearing a higher risk for complications, such as those on the pancreas or liver, should logically be adjusted for appropriate reimbursement, particularly when a complicated course occurs (eg, high outliers). There is, however, no gold standard to adjust for those outliers and often only preoperative risk factors or LOS are taken into account. We now contend that high outliers can be rewarded based on the grade of complication, particularly with inappropriate coverage in the presence of a grade IIIb or higher complication. To prevent that, a system based on the reimbursement of complications by severity may favor hospitals with poor quality; such a strategy must be used only in a center that adheres to standardized quality measures. In the US the National Surgical Quality Improvement Program (NSQIP) has been developed to improve the quality of surgical care on a national level, offering also a competitive benchmark for quality.[35]

We limited our analysis to one high-volume center, where all relevant data was prospectively recorded. Thus, the extrapolation of this data and results to other centers and countries requires further analysis. The absolute cost value of a procedure is center specific, but tendencies and relative values are likewise robust, irrespective of location.

Another bias among cost studies is the methodology used to assess costs. Detailed systems, which permit comparative, uniform cost accounting for complications to compare costs among centers, are not yet fully developed. Some studies only assess variable costs, others exclude wages, and, in most of the publications, the methodology of the acquisition and the evaluation of cost-data are described in a superficial manner.[36] Economically, a full cost assessment, as used in this study, is the most precise and appropriate cost-evaluation method, and, therefore, represents a standard for economic analysis within the medical field.[21,37]

In summary, this study demonstrates the dramatic impact of postoperative complications on full in-hospital costs of a procedure, increasing the cost by more than 5 times due to severe complications. Furthermore, this study highlights a possible savings capacity by avoiding a grade I or II complication becoming, eg, a grade IV. This may be achieved by centralization in "centers of excellence." Our results support the idea that grades of complications may be a simple and additional variable of high outliers within the DRG system in centers with a competitive benchmark for quality assessment.

ACKNOWLEDGMENTS

We would like to thank D. Raptis (University of Zurich) for valuable insights into statistical data interpretations, V. Ulrich (University of Bayreuth, Germany) and H. Schellhorn (University of Hohenheim, Germany) for their advice on health economics, H. Keune (head of the financial department, University Hospital Zurich, Switzerland) for his support in cost data collection, and F. Franzeck and R. Schott (University of Zurich) for clinical data collection.

REFERENCES

1. Sisko A, Truffer C, Smith S, et al. Health spending projections through 2018: recession effects add uncertainty to the outlook. *Health Aff (Millwood)*. 2009;28:w346–357.
2. Bundesamt für Statistik. http://www.bfs.admin.ch/bfs/portal/de/index/themen.html 2010 (10.06).
3. Birkmeyer JD, Dimick JB, Birkmeyer NJ. Measuring the quality of surgical care: structure, process, or outcomes? *J Am Coll Surg*. 2004;198:626–632.
4. Barkun JS, Aronson JK, Feldman LS, et al. Evaluation and stages of surgical innovations. *Lancet*. 2009;374:1089–1096.
5. Ergina PL, Cook JA, Blazeby JM, et al. Challenges in evaluating surgical innovation. *Lancet*. 2009;374:1097–1104.
6. McCulloch P, Altman DG, Campbell WB, et al. No surgical innovation without evaluation: the IDEAL recommendations. *Lancet*. 2009;374:1105–1112.
7. Besson P. *Cost Object Accounting* (Die Kostenträgerrechnung). Vol. 253–286. Bern: Stämpfli Publikationen, 2008.
8. Dindo D, Demartines N, Clavien PA. Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. *Ann Surg*. 2004;240:205–213.
9. Hemmila MR, Jakubus JL, Maggio PM, et al. Real money: complications and hospital costs in trauma patients. *Surgery*. 2008;144:307–316.
10. Dimick JB, Chen SL, Taheri PA, et al. Hospital costs associated with surgical complications: a report from the private-sector National Surgical Quality Improvement Program. *J Am Coll Surg*. 2004;199:531–537.
11. Khan NA, Quan H, Bugar JM, et al. Association of postoperative complications with hospital costs and length of stay in a tertiary care center. *J Gen Intern Med*. 2006;21:177–180.

12. Dimick JB, Pronovost PJ, Cowan JA, et al. Complications and costs after high-risk surgery: where should we focus quality improvement initiatives? *J Am Coll Surg*. 2003;196:671–678.
13. Lang M, Niskanen M, Miettinen P, et al. Outcome and resource utilization in gastroenterological surgery. *Br J Surg*. 2001;88:1006–1014.
14. Ferguson TB, Jr., Ferguson CL, Crites K, et al. The additional hospital costs generated in the management of complications of pacemaker and defibrillator implantations. *J Thorac Cardiovasc Surg*. 1996;111:742–751; discussion 751–752.
15. Pronovost P, Garrett E, Dorman T, et al. Variations in complication rates and opportunities for improvement in quality of care for patients having abdominal aortic surgery. *Langenbecks Arch Surg*. 2001;386:249–256.
16. Clavien PA, Sanabria JR, Strasberg SM. Proposed classification of complications of surgery with examples of utility in cholecystectomy. *Surgery*. 1992;111:518–526.
17. Pomposelli JJ, Gupta SK, Zacharoulis DC, et al. Surgical complication outcome (SCOUT) score: a new method to evaluate quality of care in vascular surgery. *J Vasc Surg*. 1997;25:1007–1014; discussion 1014–1015.
18. Gawande AA, Thomas EJ, Zinner MJ, et al. The incidence and nature of surgical adverse events in Colorado and Utah in 1992. *Surgery*. 1999;126:66–75.
19. Veen MR, Lardenoye JW, Kastelein GW, et al. Recording and classification of complications in a surgical practice. *Eur J Surg*. 1999;165:421–424; discussion 425.
20. Clavien PA, Barkun J, de Oliveira ML, et al. The Clavien-Dindo classification of surgical complications: five-year experience. *Ann Surg*. 2009;250: 187–196.
21. Pronovost P, Angus DC. Cost reduction and quality improvement: it takes two to tango. *Crit Care Med*. 2000;28:581–583.
22. von Elm E, Altman DG, Egger M, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *Lancet*. 2007;370:1453–1457.
23. Menke H, Klein A, John KD, et al. Predictive value of ASA classification for the assessment of the perioperative risk. *Int Surg*. 1993;78:266–270.
24. Charlson ME, Pompei P, Ales KL, et al. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. *J Chronic Dis*. 1987;40:373–383.
25. Kondrup J, Rasmussen HH, Hamberg O, et al. Nutritional risk screening (NRS 2002): a new method based on an analysis of controlled clinical trials. *Clin Nutr*. 2003;22:321–336.
26. Davenport DL, Henderson WG, Khuri SF, et al. Preoperative risk factors and surgical complexity are more predictive of costs than postoperative complications: a case study using the National Surgical Quality Improvement Program (NSQIP) database. *Ann Surg*. 2005;242:463–468; discussion 468–471.
27. Dindo D, Hahnloser D, Clavien PA. Quality assessment in surgery: riding a lame horse. *Ann Surg*. 251:766–771.
28. Feldman L, Barkun J, Barkun A, et al. Measuring postoperative complications in general surgery patients using an outcomes-based strategy: comparison with complications presented at morbidity and mortality rounds. *Surgery*. 1997;122:711–719; discussion 719–720.
29. Hutter MM, Rowell KS, Devaney LA, et al. Identification of surgical complications and deaths: an assessment of the traditional surgical morbidity and mortality conference compared with the American College of Surgeons-National Surgical Quality Improvement Program. *J Am Coll Surg*. 2006;203: 618–624.
30. Choti MA, Bowman HM, Pitt HA, et al. Should hepatic resections be performed at high-volume referral centers? *J Gastrointest Surg*. 1998;2: 11–20.
31. Fong Y, Gonen M, Rubin D, et al. Long-term survival is superior after resection for cancer in high-volume centers. *Ann Surg*. 2005;242:540–544; discussion 544–547.
32. Ghaferi AA, Osborne NH, Birkmeyer JD, et al. Hospital characteristics associated with failure to rescue from complications after pancreatectomy. *J Am Coll Surg*. 2010;211:325–330.
33. Petrowsky H, Clavien PA. Should we deny surgery for malignant hepato-pancreatico-biliary tumors to elderly patients? *World J Surg*. 2005;29: 1093–1100.
34. Balcom JHt, Rattner DW, Warshaw AL, et al. Ten-year experience with 733 pancreatic resections: changing indications, older patients, and decreasing length of hospitalization. *Arch Surg*. 2001;136:391–398.
35. Ingraham AM, Richards KE, Hall BL, et al. Quality improvement in surgery: the American College of Surgeons National Surgical Quality Improvement Program approach. *Adv Surg*. 2010;44:251–267.
36. Roberts RR, Frutos PW, Ciavarella GG, et al. Distribution of variable vs fixed costs of hospital care. *JAMA*. 1999;281:644–649.
37. Azoulay A, Doris NM, Filion KB, et al. The use of the transition cost accounting system in health services research. *Cost Eff Resour Alloc*. 2007; 5:11.