Original article

Outcome and resource utilization in gastroenterological surgery

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Background: **A small minority of patients undergoing gastroenterological surgery are at high risk for postoperative complications, which may lead to prolonged hospital stay, disproportionate use of resources and increased mortality. The nature and frequency of, and predictive factors for, postoperative complications were studied and the impact of complications on resource utilization was assessed.**

Methods: **A prospective observational study was undertaken of 503 patients undergoing gastroenterological surgery in a tertiary care centre. The incidence of cardiorespiratory, infective and surgical complications was assessed. The need for reoperation, intensive care and length of hospital stay, readmission, death at 6 months and costs were evaluated.**

Results: **Some 235 patients (47 per cent) had at least one complication, most commonly delayed oral intake (*n* = 70). Complications were associated with cardiovascular disease, prolonged operation, high Physiological and Operative Severity Score for the enUmeration of Mortality and morbidity, and increased number of Shoemaker's criteria. The length of hospital stay of patients with complications was longer than that of those without complications (11 *versus* 6 days). Morbidity resulted in a twofold increase in median costs.**

Conclusion: **High-risk patients could be identified by simple clinical criteria, although the commonly used risk criteria were not very sensitive. A reduction in postoperative complication rates would result in marked cost savings.**

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Introduction

Recovery from surgery is fast and uncomplicated in most patients and the overall mortality rate after non-cardiac surgery is approximately 1–2 per cent[1–3]. Several patient- and operation-related factors increase the risk of complications. Established risk factors include increasing age, impaired cardiovascular function and type of surgery[1,4–7]. In gastrointestinal surgery postoperative complications occur more frequently and the mortality rate is higher (4 per cent) than in many other surgical specialties[1,8–15]. Patients who develop complications and whose hospital stay is prolonged may consume a disproportionately larger share of the available resources[7,16]. Postoperative morbidity may not only increase the costs of care but also lead to prolonged sick leave and to permanent incapacity.

Recent studies suggest that preoperative screening may facilitate the selection of patients for appropriate perioperative management[15,17], and that perioperative interventions on high-risk patients undergoing major surgery may be beneficial and reduce the risk of death or the length of hospital stay[18,19]. Definitions of complications and risk factors related to gastroenterological surgery vary extensively[8,9,13,20,21]. The reported incidence of complications is also greatly dependent on patient selection[22]. Few reports have clarified the implications of complications for an individual patient or for resource utilization[23].

The aim of this study was to determine the nature and frequency of complications after gastroenterological operations, and to identify factors predictive of postoperative morbidity. The primary endpoint was to assess the impact of postoperative complications on resource utilization in

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Table 1 Definition of complications[27]

Cardiorespiratory
Respiratory failure (mechanical ventilation > 24 h)
Cardiac failure, cardiac index < 2 litres per min per m^2 (treated first by fluid resuscitation and if no response by inotropic or vasoconstrictive medication)
Pulmonary oedema (radiological diagnosis)
Pleural fluid (radiographic diagnosis)
Acute myocardial infarction (electrocardiographic diagnosis)
Acute renal failure (need for haemofiltration)
Stroke with neurological symptoms
Pulmonary embolism, distal ischaemia (digital angiography and clinical diagnosis)
Deep venous thrombosis (phlebography)
Other cardiorespiratory
Surgical
Unexpected blood loss > 0·5 litres during operation
Bowel perforation
Wound dehiscence
Postoperative bleeding (overt blood loss requiring > 2 units transfusion with normal clotting profile)
Delayed oral intake (intravenous fluids > 1 week owing to postoperative ileus)
Anastomosis leakage
Other surgical
Infective
Sepsis (pyrexia > 38°C and septic focus or positive blood culture)
Postoperative peritonitis (clinical diagnosis)
Abdominal abscess (ultrasonography, computed tomography or operative diagnosis)
Necrotizing fasciitis
Wound infection (positive wound swab culture)
Pneumonia (radiological diagnosis)
Chest infection (e.g. mediastinitis, empyema)
Urinary tract infection
Disseminated intravascular coagulation
Other infectious complication

terms of length of hospital stay, need for intensive care and costs.

Patients and methods

This was a prospective follow-up study with no interventions. The ethics committee of Kuopio University Hospital (KUH) approved the study and informed consent was obtained from each patient or the near relatives. KUH serves as a tertiary referral centre to a population of 870 000 inhabitants in eastern Finland. The study population consisted of patients aged 16 years or more, admitted during a 12-month period between 1996 and 1997, and having a laparotomy for a gastroenterological disease. Those who had an appendicectomy, a transrectal procedure or inguinal herniotomy were excluded. If the patient had more than one operation, the first procedure was taken into account. All patients were treated according to the routine practice of the attending anaesthesiologists and surgeons.

Data were collected prospectively for preoperative diseases, American Society of Anesthesiologists (ASA) status[24], Shoemaker's criteria[25], Physiological and Operative Severity Score for the enUmeration of Mortality and morbidity (POSSUM)[26], and type of surgical procedure. An operation was classified as urgent if the patient was considered to need an operation within 24 h after hospital admission. Follow-up lasted for 6 months after discharge. Complications were predefined (*Table 1*, *Fig. 1*)[27]. The impact of complications (*Fig. 2*) was assessed by an anaesthesiologist (M.L.) and a gastrointestinal surgeon (P.M.). The change from the preoperative health status was taken into account. Because factors other than purely medical variables may influence discharge from hospital, each patient was assessed individually. As a guideline, the usual length of hospitalization was taken as 7 days for exploratory laparotomy, 5 days for ventral hernia operation, 11 days for a procedure involving the oesophagus, stomach and duodenum, 10 days for an intestinal procedure, 12 days for a rectal procedure, 7 days for stoma formation, 7 days for open cholecystectomy, 12 days for pancreatic resection and 7 days for other procedures.

Cost accounting

The communities in the KUH catchment area finance the hospital. KUH receives a government subsidy for education

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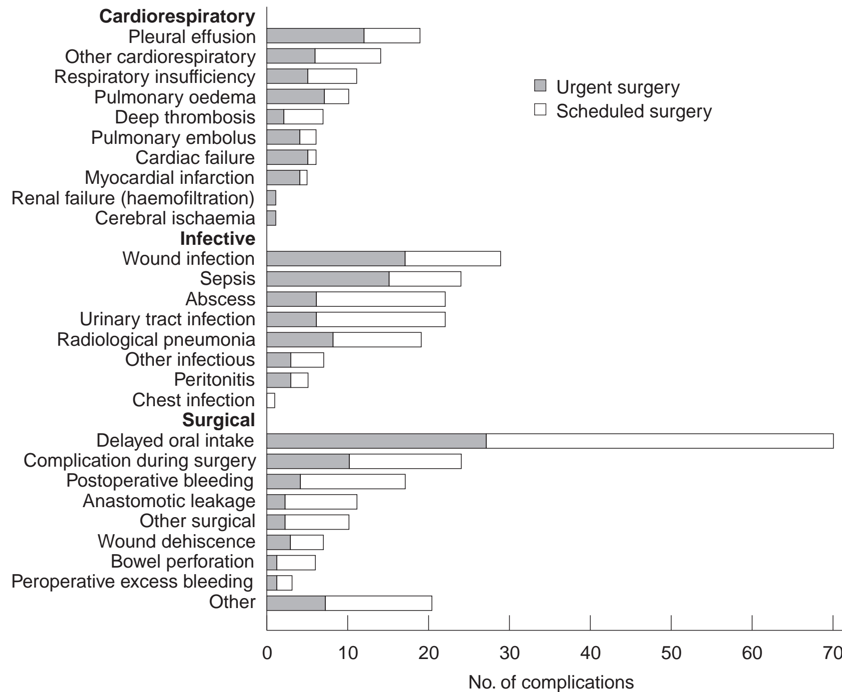

Fig. 1 Occurrence of cardiorespiratory (n = 64), infective (n = 107), surgical (n = 123) and other complications[27] in 503 patients. Patients could have complications in more than one category

and research. The calculation of costs was based on the internal hospital cost accounting system, under which each department within the hospital sells services to other departments on a non-profit basis. The prices of these services are determined by the total costs of a service per patient. The costs were calculated by totalling the costs of anaesthesia, surgery, intensive care unit (ICU), operating room, all laboratory tests, clinical radiology, drugs, nutrition and costs of hospital patient-days accumulated per patient during the same hospital stay. This method can be regarded as a modified bottom-up method. The costs were obtained from the hospital's computerized database. ICU costs were obtained from a clinical information management system (Clinisoft CIMS®; Datex-Ohmeda, Helsinki, Finland) and calculated as follows: cost per therapeutic intervention scoring system (TISS) score = annual ICU expenditure/total accumulation of TISS scores; costs per patient = patient TISS score accumulation × cost of one TISS score. In 1996–1997 the cost of one TISS point was €33[28].

Statistical analysis

Statistical analysis was performed using the Statistical Package for Social Sciences version 7.5 program (SPSS, Chicago, Illinois, USA). Data are expressed as median (range) unless otherwise stated. Differences between groups were calculated by χ^2 test, Student's unpaired t test or Mann–Whitney U test as appropriate. No correction for multiple comparisons was performed. Logistic regression analysis was carried out to study the independent contribution of variables on the development of complications. Youden's index[29] (sensitivity + specificity − 1) was chosen for the best cut-off value. Statistical significance was defined as $P < 0{\cdot}05$.

Results

Demographics

The study population consisted of 503 patients (236 men and 267 women) who underwent 566 operations. Six hundred and ninety-eight patients fulfilled the inclusion criteria and 195 were excluded owing to patient refusal or failure to obtain consent. These patients did not differ from the study patients with respect to age, sex, ASA status, length of hospital stay or hospital mortality rate. Descriptive data according to the site of operation are presented in *Table 2*. Fifty-six patients were classified as having ASA status I, 179 as ASA II, 232 as ASA III, 32 as ASA

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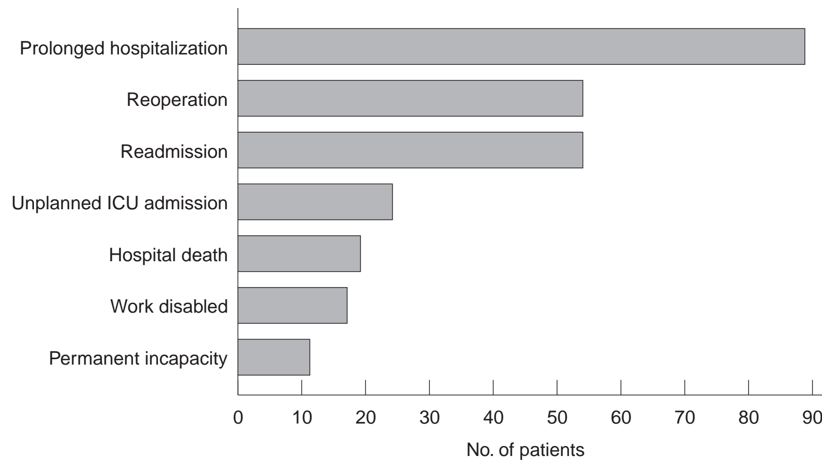

Fig. 2 Impact of complications on the 503 study patients. Work disabled accounts for patients with prolonged sick leave or inability to work as a consequence of complications. ICU, intensive care unit

Table 2 Proportion of urgent operations, patient age and length of operation according to the site of operation

Site or operation	No. of patients*	No. of urgent operations*	Age (years)†	Length of operation (min)‡
Exploratory laparotomy	58	38 (66)	59(18)	73 (13–382)
Ventral hernia	45	16 (36)	61(13)	91 (18–263)
Oesophagus, stomach and duodenum	40	8 (20)	59(14)	132 (21–394)
Intestine	83	32 (39)	62(16)	150 (45–370)
Rectum	48	4 (8)	64(15)	187 (80–405)
Stoma formation	39	15 (38)	57(17)	122 (39–272)
Biliary tract	158	88 (56)	61(15)	104 (20–336)
Pancreas (resection)	14	0 (0)	60(16)	302 (60–504)
Other	18	4 (22)	54(12)	165 (55–497)
All	503	205 (41)	61(16)	119 (13–504)

*Values in parentheses are percentages; values are †mean(s.d.) or ‡median (range)

IV and four patients as ASA V. No Shoemaker's criteria were present in 279 patients, 135 had one criterion and 89 had two or more criteria. The median POSSUM score was 21 (10–47). There were 272 patients with a chronic cardiovascular disease (coronary heart disease, heart failure, rhythm disturbance, hypertension or cerebrovascular disease). Sixty-seven patients had a chronic respiratory disease.

Morbidity and mortality

A total of 235 patients had at least one complication. One-quarter of patients had a surgical complication, either functional or mechanical, one-fifth suffered from infective complications and 13 per cent had a cardiorespiratory complication (*Fig. 1*). Surgical and infective complications were most common after rectal operations (*Table 3*). The total number of complications was 376; 166 patients had one complication, 41 had two and 30 had three or more complications.

In 173 patients complications led to increased resource consumption or hospital death (*Fig. 2*). Thirteen patients died in hospital during the same hospitalization, 19 patients within 30 days and 46 within 6 months of the first operation.

Factors associated with complications

Factors associated with complications are shown in *Table 4*. Fourteen of the 17 patients who had pre-existing cardiovascular disease and who underwent rectal operation developed complications. The presence of chronic respiratory disease did not increase the occurrence of complica-

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Table 3 Occurrence of complications according to the site of operation

Site or operation	No. of patients	No. of patients with complications*			
		Any	Cardiorespiratory	Infective	Surgical
Exploratory laparotomy	58	31 (53)	10	11	11
Ventral hernia	45	15 (33)	1	6	9
Oesophagus, stomach and duodenum	40	18 (45)	10	6	12
Intestine	83	44 (53)	12	20	24
Rectum	48	30 (62)†	3	17	18
Stoma formation	39	19 (49)	3	8	15
Biliary tract	158	62 (39)‡	21	30	25
Pancreas (resection)	14	8 (57)	1	4	5
Other	18	8 (44)	3	5	4
All	503	235 (47)	64	107	123

Values in parentheses are percentages. *Patients could have complications in more than one category. The frequency of complications was †higher or ‡lower than that in all remaining patients ($P < 0{\cdot}05$, χ^2 test)

Table 4 Preoperative and operation-related factors among patients with and without postoperative complications

	No complication (n = 268)	Complication (n = 235)	P
Age (years)*	58(16)	64(15)	0·018§
Coronary heart disease	46	67	0·002¶
Heart failure	11	21	0·027¶
Diabetes	24	39	0·010¶
Duration of operation (min)†	104 (13–394)	139 (15–504)	0·005**
Duration of intraoperative hypotension (min)†‡	5 (0–220)	10 (0–270)	0·004**
Blood loss during surgery (ml)†	200 (0–7000)	300 (0–32 000)	0·001**

Values are *mean(s.d.) or †median (range). ‡Systolic arterial blood pressure less than 100 mmHg. § Student's unpaired t test, ¶χ^2 test, **Mann-Whitney U test

tions. One hundred and forty-one patients (47 per cent) undergoing elective surgery and 94 (46 per cent) of those who had an emergency operation had complications. The difference between these groups was not significant. Patients with complications had a greater number of Shoemaker's criteria and higher POSSUM scores than those with uncomplicated postoperative recovery (1 (0–6) *versus* 0 (0–3) and 24 (10–47) *versus* 19 (10–44) respectively; $P < 0{\cdot}001$). In a logistic regression analysis containing the variables listed in *Table 4*, as well as chronic respiratory disease, number of Shoemaker's criteria and rectal surgery as independent variables, only the number of Shoemaker's criteria ($P < 0{\cdot}001$) and the length of operation ($P < 0{\cdot}01$) were significant predictors for complications. The sensitivity and specificity of ASA status, Shoemaker's criteria and POSSUM in identifying patients who developed postoperative complications are presented in *Table 5*.

Resource allocation

The length of hospital stay after operation was 8 (0–74) days. The length of stay of patients with complications was longer than that for those without complications (11 (1–74) *versus* 6 (0–21) days; $P < 0{\cdot}001$). The 235 patients (47 per cent) who had a complicated recovery accounted for 3332 hospital patient-days, or 67 per cent of all patient-days of the study patients. The 119 patients (24 per cent) whose hospital stay lasted 13 days or longer consumed half of all hospital patient-days. Of these, 105 patients had complications. Costs per patient among patients with complications were higher than costs among those without complications (€6551 (1527–83 869) *versus* €3638 (896–14 849); $P < 0{\cdot}001$) after both scheduled and urgent surgery (*Fig. 3*). The urgency of operation did not affect costs in different complication categories (*Fig. 4*). The influence of complications on length of stay and costs according to the site of operation is presented in *Table 6*.

Thirty-eight patients were admitted to the ICU. Eleven of these patients were already being treated in the ICU before the first operation and 27 were admitted to the ICU after the first operation or later during their postoperative hospital stay. Three of these 27 patients had a scheduled ICU admission after surgery and had no complications. Six of the 24 patients who had an emergency admission to the

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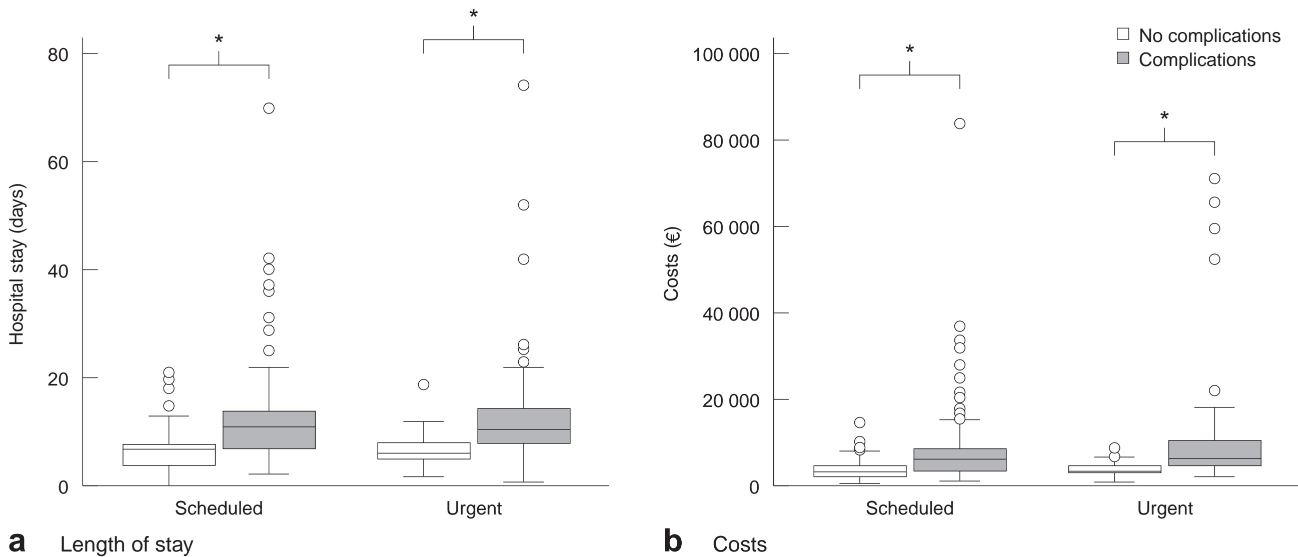

Fig. 3 Impact of the urgency of operation on **a** length of hospital stay and **b** costs among patients with complications or an uncomplicated recovery after scheduled (n = 298) and urgent (n = 205) surgery. Horizontal lines represent median values and boxes denote interquartile range; circles represent extreme cases. $^*P < 0.001$ (Mann–Whitney U test)

Table 5 Sensitivity and specificity of the American Society of Anesthesiologists physical status classification[24], number of Shoemaker's criteria[25] and the Physiological and Operative Severity Score for the enUmeration of Mortality and morbidity [26] in identifying patients who developed postoperative complications

	Cut-off	Sensitivity (%)	Specificity (%)
ASA status	⩾ 3	63	56
No. of Shoemaker's criteria	⩾ 1	55	65
POSSUM score	⩾ 19	74	48

ASA, American Society of Anesthesiologists; POSSUM, Physiological and Operative Severity Score for the enUmeration of Mortality and morbidity

ICU died during their stay in hospital. The ICU stay of 24 patients with a postoperative emergency ICU admission lasted for 2·2 (0·3–70) days and the median cost of the ICU stay was €2748 (762–178 136). The ICU costs represented one-third of all costs for these patients.

Discussion

The main findings of this study were that approximately one-half of patients undergoing gastroenterological surgery had postoperative complications, which resulted in a twofold increase in the length of hospital stay and costs of care.

Complications have been reported to occur in up to two-thirds of patients undergoing gastroenterological surgery, presumably because of wide definitions[13]. Cardiopulmonary complications occurred in one-fifth of patients in a study by Pedersen *et al.*[10]. Cardiovascular and respiratory complications occurred together in one-third of patients described by Lawrence *et al.*[8]. The results of the present study are in accordance with these findings. Of 64 patients with cardiorespiratory complications, 18 patients had both cardiovascular and respiratory problems. In a study by Hall and Brooks[13] the incidence of infectious complications (22 per cent) and wound infection (6 per cent) corresponded with those of the present study, while parenteral nutrition was required less frequently (6 per cent). Variable definitions and heterogeneity between patients make comparison between studies difficult. For practical reasons blinding of the study was not considered feasible and it remains unclear how blinding would have affected the results. In addition, the fact that no protocols for the management of complications were used may have caused bias because clinicians were aware of the study.

Complications were associated with easily recognizable clinical factors, such as increasing age, cardiovascular diseases and a prolonged operation, and occurred most often with rectal surgery as noted previously[4–6,10]. Shoemaker's criteria have been used mainly to select patients for therapeutic trials[25,27], and have not been designed specifically for risk prediction. Nevertheless, the ability of these rather pragmatic and readily available

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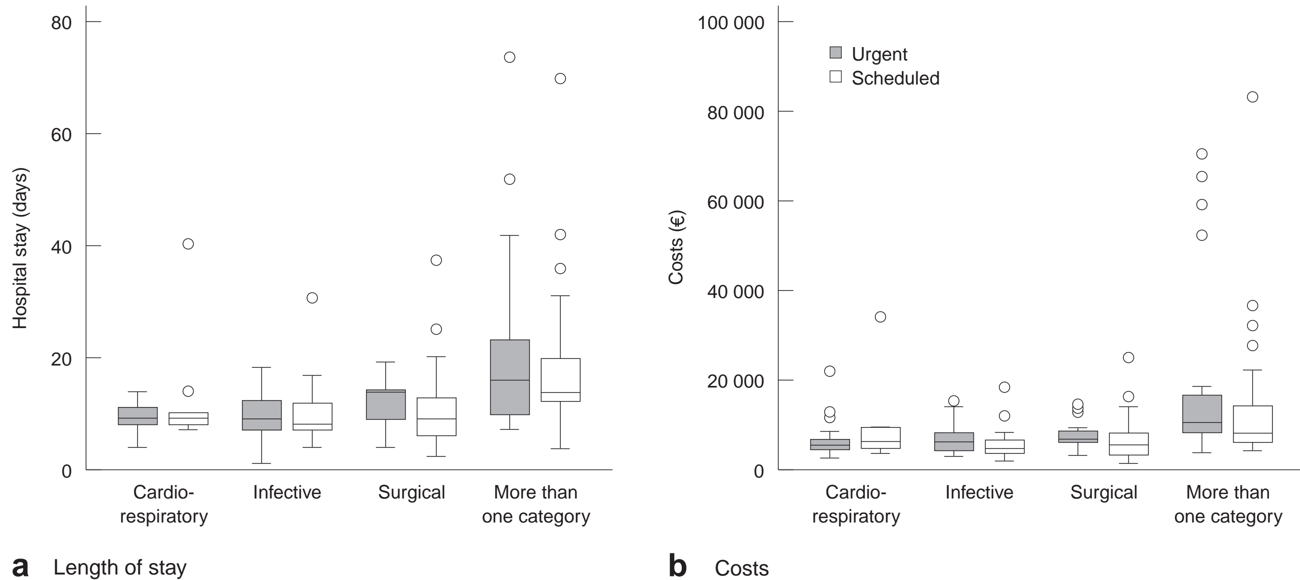

Fig. 4 **a** Length of hospital stay and **b** costs after scheduled and urgent surgery among patients with purely cardiorespiratory (n = 26), infective (n = 55) or surgical (n = 70) complications and among those with complications in more than one category (n = 65). Horizontal lines represent median values and boxes denote interquartile range; circles represent extreme cases (Mann–Whitney U test)

Table 6 Hospital stay after operation and costs for different operation types in patients with (n = 235) and without (n = 268) post-operative complications

		Hospital stay (days)			Total costs (€)		
Site or operation	No. of patients	No complication	Complication	P*	No complication	Complication	P*
Exploratory laparotomy	58	6 (2–19)	10 (1–25)	< 0·001	3698 (1603–14 849)	6214 (2563–22 431)	< 0·001
Ventral hernia	45	3 (1–8)	8 (4–20)	< 0·001	1743 (916–5375)	3069 (1696–16 582)	< 0·001
Oesophagus, stomach and duodenum	40	7 (1–11)	10 (4–70)	0·002	4405 (1792–6260)	9152 (1788–83 869)	< 0·001
Intestine	83	8 (0–21)	12 (1–42)	< 0·001	4233 (896–10 787)	6529 (2308–71 019)	< 0·001
Rectum	48	7 (5–15)	13 (7–36)	< 0·001	4330 (2537–10 752)	7049 (2638–27 721)	< 0·001
Stoma formation	39	6 (4–12)	13 (5–37)	< 0·001	3758 (2132–6594)	7987 (2859–25 003)	< 0·001
Biliary tract	158	6 (2–18)	9 (3–74)	< 0·001	3445 (1384–9401)	5428 (1527–65 404)	< 0·001
Pancreas (resection)	14	8 (6–12)	11 (2–19)	0·295	6678 (4337–8266)	9168 (4671–14 205)	0·156
Other	18	8 (3–10)	11 (7–20)	0·008	4393 (1542–8344)	8600 (3695–20 660)	0·008

Values are median (range). *Mann–Whitney U test

criteria to predict complications was confirmed in the present study. A further argument for the evaluation of these criteria is the lack of widely accepted instruments for predicting complications in gastroenterological surgery. In a study by Boyd *et al.*[27] the mortality rate was 14 per cent if a patient had two or more Shoemaker's criteria, compared with 11 per cent among this patient group in the present study. However, Shoemaker's criteria were not very sensitive in identifying high-risk patients. Complications were clearly associated with a higher POSSUM rating, but the low specificity limits its value in clinical practice. A modification of POSSUM, the Portsmouth POSSUM equation, may provide a more accurate prediction[30].

Postoperative complications caused a major increase in resource utilization, most commonly owing to prolonged hospitalization. Previous studies have shown an approximately twofold increase in the length of stay or costs due to complications after abdominal[9] or cardiac[23] surgery, and in high-risk surgical patients in general[19]. Lawrence *et al.*[9] reported that hospital stay was longer after pulmonary than cardiac complications among patients undergoing abdominal surgery. The costs depend on various clinical practices

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and comparison between studies is difficult[31]. After colorectal surgery the excess cost has been estimated to be €2131 and after cholecystectomy €1139 per infection[31,32]. In the present study the variation in cost and length of stay within various types of surgery was great. Death, however, may be the most costly ultimate outcome[23]. There were no major differences in the length of stay or costs between the type of complications and therefore any complication may be relevant. If the complication rate could have been halved by an intervention in all patients with two or more Shoemaker's criteria ($n = 89$), 446 patient-days and €260 858 could have been saved.

In a previous study of patients undergoing digestive or hepatobiliary surgery, 6 per cent of patients were admitted in the perioperative period to the ICU[13]. In the present study 8 per cent of patients were treated in the ICU during some phase of their disease, although only a small proportion (2 per cent) received preoperative fluid therapy in the ICU or in the recovery room. Preoperative optimization of oxygen delivery in properly selected patients undergoing major surgery reduces the number of postoperative complications[19,33], improves survival and reduces costs[16].

In conclusion, while half of patients recover without complications and can be managed normally, the remainder develop complications that double resource consumption and costs. There is evidence that the outcome after high-risk surgery may be improved by quite simple treatment interventions. Simple criteria for identification and proper tracking of high-risk patients are desirable. Further studies aimed at improving the outcome for high-risk patients by treatment interventions are needed.

References

1 Pedersen T, Eliasen K, Henriksen E. A prospective study of mortality associated with anaesthesia and surgery: risk indicators of mortality in hospital. *Acta Anaesthesiol Scand* 1990; **34:** 176–82.

2 Prause G, Ratzenhofer-Comenda B, Pierer G, Smolle-Juttner F, Glanzer H, Smolle JG. Can ASA grade or Goldman's cardiac index predict peri-operative mortality? A study of 16 227 patients. *Anaesthesia* 1997; **52:** 203–6.

3 Wolters U, Wolf T, Stützer H, Schröder T, Pichlmaier H. Risk factors, complications, and outcome in surgery: a multivariate analysis. *Eur J Surg* 1997; **163:** 563–8.

4 Pedersen T, Eliasen K, Henriksen E. A prospective study of risk factors and cardiopulmonary complications associated with anaesthesia and surgery: risk indicators of cardiopulmonary morbidity. *Acta Anaesthesiol Scand* 1990; **34:** 144–55.

5 Howell SJ, Sear YM, Yeates D, Goldacre M, Sear JW, Foex P. Risk factors for cardiovascular death after elective surgery under general anaesthesia. *Br J Anaesth* 1998; **80:** 14–19.

6 Pedersen T. Complications and death following anaesthesia. A prospective study with special reference to the influence of patient-, anaesthesia-, and surgery-related risk factors. *Dan Med Bull* 1994; **41:** 319–31.

7 Bennett-Guerrero E, Welsby I, Dunn TJ, Young LR, Wahl TA, Diers TL *et al.* The use of a postoperative morbidity survey to evaluate patients with prolonged hospitalization after routine, moderate-risk, elective surgery. *Anesth Analg* 1999; **89:** 514–19.

8 Lawrence VA, Dhanda R, Hilsenbeck SG, Page CP. Risk of pulmonary complications after elective abdominal surgery. *Chest* 1996; **110:** 744–50.

9 Lawrence VA, Hilsenbeck SG, Mulrow CD, Dhanda R, Sapp J, Page CP. Incidence and hospital stay for cardiac and pulmonary complications after abdominal surgery. *J Gen Intern Med* 1995; **10:** 671–8.

10 Pedersen T, Viby-Mogensen J, Ringsted C. Anaesthetic practice and postoperative pulmonary complications. *Acta Anaesthesiol Scand* 1992; **36:** 812–18.

11 Menke H, Klein A, John KD, Junginger T. Predictive value of ASA classification for the assessment of the perioperative risk. *Int Surg* 1993; **78:** 266–70.

12 Sagar PM, Hartley MN, Mancey-Jones B, Sedman PC, May J, Macfie J. Comparative audit of colorectal resection with the POSSUM scoring system. *Br J Surg* 1994; **8:** 1492–4.

13 Hall JC, Brooks B. Australian national diagnosis related groups and abdominal surgery. *Aust N Z J Surg* 1994; **64:** 604–6.

14 Wolters U, Wolf T, Stützer H, Schröder T. ASA classification and perioperative variables as predictors of postoperative outcome. *Br J Anaesth* 1996; **77:** 217–22.

15 Older P, Hall A, Hader R. Cardiopulmonary exercise testing as a screening test for perioperative management of major surgery in the elderly. *Chest* 1999; **116:** 355–62.

16 Guest JF, Boyd O, Hart WM, Grounds RM, Bennett ED. A cost analysis of a treatment policy of a deliberate perioperative increase in oxygen delivery in high risk surgical patients. *Intensive Care Med* 1997; **23:** 85–90.

17 Poldermans D, Boersma E, Bax JJ, Thomson IR, van de Ven LL, Blankensteijn JD *et al.* The effect of bisoprolol on perioperative mortality and myocardial infarction in high-risk patients undergoing vascular surgery. Dutch Echocardiographic Cardiac Risk Evaluation Applying Stress Echocardiography Study Group. *N Engl J Med* 1999; **341:** 1789–94.

18 Greif R, Akca O, Horn EP, Kurz A, Sessler DI. Supplemental perioperative oxygen to reduce the incidence of surgical-wound infections. Outcomes Research Group. *N Engl J Med* 2000; **342:** 161–7.

19 Wilson J, Woods I, Fawcett J, Whall R, Dibb W, Morris C *et al.* Reducing the risk of major elective surgery: randomised controlled trial of preoperative optimisation of oxygen delivery. *BMJ* 1999; **318:** 1099–103.

20 Hall JC, Tarala RA, Tapper J, Hall JL. Prevention of respiratory complications after abdominal surgery: a randomized clinical trial. *BMJ* 1996; **312:** 148–52.

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21 Kollef MH, Allen BT. Determinants of outcome for patients in the medical intensive care unit requiring abdominal surgery: a prospective single-center study. *Chest* 1994; **106:** 1822–8.
22 Smetana GW. Preoperative pulmonary evaluation. *N Engl J Med* 1999; **340:** 937–44.
23 Ferraris VA, Ferraris SP, Singh A. Operative outcome and hospital cost. *J Thorac Cardiovasc Surg* 1998; **155:** 593–602.
24 Dripps RD, Lamont A, Eckenhoff JE. The role of anesthesia in surgical mortality. *JAMA* 1961; **178:** 261–6.
25 Shoemaker WC, Appel PL, Kram HB, Waxman K, Lee TS. Prospective trial of supranormal values of survivors as therapeutic goals in high-risk surgical patients. *Chest* 1988; **94:** 1176–86.
26 Copeland GP, Jones D, Walters M. POSSUM: a scoring system for surgical audit. *Br J Surg* 1991; **78:** 356–60.
27 Boyd O, Grounds RM, Bennett ED. A randomized clinical trial of the effect of deliberate perioperative increase of oxygen delivery on mortality in high-risk surgical patients. *JAMA* 1993; **270:** 2699–707.
28 Takala J, Ruokonen E. Costs and resource utilization in intensive care. In: Vincent JL, ed. *Yearbook of Intensive Care and Emergency Medicine*. Berlin: Springer, 1997: 885–95.
29 Feinstein AR. Youden's J. In: Feinstein AR, ed. *Clinical Epidemiology: The Architecture of Clinical Research*. Philadelphia, Pennsylvania: WB Saunders, 1985: 440–1.
30 Tekkis PP, Kocher HM, Bentley AJE, Cullen PT, South LM, Trotter GA *et al.* Operative mortality rates among surgeons. Comparison of POSSUM and p-POSSUM scoring systems in gastrointestinal surgery. *Dis Colon Rectum* 2000; **43:** 1528–32.
31 Davey PG, Nathwani D. What is the value of preventing postoperative infections? *New Horiz* 1998; **6**(Suppl 2): s64–71.
32 Lynch W, Malek M, Davey PG, Byrne DJ, Napier A. Costing wound infection in a Scottish hospital. *Pharmacoeconomics* 1992; **2:** 163–70.
33 Jones HJ, Coggins R, Lafuente J, de Cossart L. Value of a surgical high-dependency unit. *Br J Surg* 1999; **86:** 1578–82.

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