

Postoperative Complications and Hospital Costs Following Elective and Emergency Colon Cancer Surgery: A Clavien-Dindo Grade-Specific Cost Analysis

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Abstract

Purpose

Postoperative complications are major drivers of healthcare costs following colon cancer surgery. The aim of this study was to compare hospital costs between elective and emergency colon cancer resections according to complication severity.

Methods

This retrospective cohort study included 520 patients undergoing colon cancer resection, of whom 431 underwent elective and 89 emergency surgery. Postoperative complications were graded according to the Clavien-Dindo classification. Hospital costs were analysed using a patient-level micro-costing approach. Adjusted costs were estimated using generalized linear models with gamma distribution and log link, adjusting for tumour stage, ASA classification, surgical technique, age and sex.

Results

Postoperative complications occurred in 35% of elective and 56% of emergency patients. Emergency patients had higher ASA class, more advanced tumour stage and lower BMI (all $p < 0.05$). Hospital costs increased progressively with complication severity in both groups ($p < 0.001$). Among patients without complications, median costs were €9 809 following elective surgery and €12 079 following emergency surgery. Among patients with complications, costs were higher in emergency versus elective surgery (€19 655 vs. €14 820; $p = 0.004$). Adjusted excess costs increased stepwise with complication severity, with a stronger effect in emergency surgery. The highest costs were observed for grade IV complications. In adjusted analyses, complication severity remained strongly associated with increased costs, with cost ratios of 3.21 in elective, 4.84 in emergency surgery for grade IV vs no complications.

Conclusions

Complication severity was independently associated with substantial cost increases after colon resection. Emergency surgery was associated with higher costs across complication grades.

Introduction

Colorectal cancer is the third most common malignancy in Sweden with more than 7 000 new cases diagnosed annually, placing a substantial burden on healthcare systems and hospital resources. In Sweden, approximately 11% of colon cancer resections are performed in the emergency setting. Postoperative complication rates after colon cancer surgery have remained relatively stable over the

past two decades, affecting approximately 20% of elective cases, whereas rates are approximately doubled in emergency surgery (1).

Postoperative complications constitute major drivers of healthcare costs following colorectal cancer surgery, with costs increasing progressively with complication severity (2). This burden is further accentuated in emergency colon resections, where patients present with a more advanced disease and a significantly higher risk of postoperative complications, reoperations, and mortality compared with elective surgery (1). Pooling elective and emergency resections may obscure important differences in perioperative risk, postoperative resource utilization, and cost drivers between these fundamentally different clinical settings.

Despite this, most previous cost analyses have either pooled elective and emergency colon resections (3, 4), or included heterogeneous surgical populations across different surgical specialties (5, 6), limiting interpretation of procedure-specific cost drivers. Furthermore, variation in healthcare systems, reimbursement structures, and costing methodologies, including the use of reimbursement-based estimates or hospital charges rather than actual expenditures, limit comparability across studies. Although several studies have evaluated costs associated with specific postoperative complications, such as surgical site infections or anastomotic leakage, patients frequently experience multiple concurrent complications. Therefore, overall complication severity may better reflect the postoperative resource utilization than isolated adverse events. To our knowledge, no previous study has conducted an adjusted grade-specific cost analysis across the full Clavien-Dindo spectrum with separate analyses for elective and emergency surgery.

The aim of this study was therefore to conduct a detailed cost analysis of colon cancer surgery, with separate analyses of elective and emergency resections, and to quantify excess costs associated with postoperative complications stratified by Clavien-Dindo grade (7), using a generalized linear model.

Method

Study population and complications

We conducted a single-center retrospective health economic study of patients aged > 18 years who underwent surgery for colon cancer at Helsingborg General Hospital between 2016 and 2022. The Swedish Colorectal Cancer Registry (SCRCR) was used to identify eligible patients and to extract demographic and clinical data. The SCRCR is a prospective national quality registry for colorectal cancer with near-complete national coverage (1). The medical records of each patient, including the index admission and 30-day postoperative follow-up, were reviewed to validate registry data and obtain additional clinical information not available. Patients undergoing colon resections for benign disease or for rectal or appendiceal cancer were excluded. Both elective and emergency cancer resections were included and analysed separately. Emergency surgery was defined as unplanned colon resections

performed within 48 hours of acute hospital admission, whereas all other resections were defined as elective procedures.

Postoperative complications were classified according to the Clavien-Dindo classification (7). In patients with multiple complications, the complication with the highest Clavien-Dindo grade was used. Patients with Clavien–Dindo grades 0–I were categorized as having no complications, as minor deviations from the normal postoperative course are difficult to reliably identify retrospectively and are unlikely to substantially influence hospital costs or clinical outcomes.

Cost analysis

Subsequently, we performed an analysis of the hospital costs associated with different types of complications according to the Clavien-Dindo classification. Total in-hospital costs were obtained and analysed in collaboration with a health economist. Costs reflected actual hospital expenditures derived from the institutional cost accounting system rather than reimbursement data or hospital charges.

The costs were categorized into the following components: operating room, anaesthesia, postoperative unit care, intensive care unit (ICU), laboratory and radiologic services, medications and medical supplies, staff salaries, and other costs. The category of "other costs" included premises-related expenses and emergency department utilization.

A patient-level micro-costing approach was used (8). Costs were calculated for the entire hospital care episode for each patient, including the index admission and subsequent readmissions deemed clinically related to the postoperative course. All cost components were assigned on a per-patient basis using the hospital's cost accounting system. Only direct healthcare costs were included in the analysis, while indirect costs, such as productivity losses, were excluded.

Excess costs associated with increasing Clavien-Dindo grades were calculated, using patients without postoperative complications as the reference group.

Statistical analysis

Given the skewed distribution of cost data, non-parametric methods were applied for descriptive analyses, and results were presented as medians with interquartile ranges (Q1-Q3). Categorical variables were presented as numbers and percentages and comparisons of proportions were made using the Chi-square test. Comparisons of continuous variables were made using the Mann-Whitney U test.

To estimate adjusted costs and excess costs, a generalized linear model (GLM) (9) with gamma distribution and log link was used, adjusting for tumour stage, ASA class, surgical technique, sex and age. Gamma distribution with log link was selected due to the right-skewed and non-negative nature of healthcare cost data. The results were presented as estimated marginal means with 95% confidence intervals, as gamma generalized linear models estimate arithmetic mean costs despite skewed cost

distributions. Confidence intervals for excess costs were derived from pairwise comparisons of estimated marginal means using the Wald method, using the no-complication group as the reference category. Separate models were constructed for elective and emergency surgery. In analyses according to complication type, cardiac, non-SSI and surgical complications were included simultaneously as separate covariates in the same multivariable model to estimate the independent cost associated with each complication category.

All costs were inflated to January 2024 SEK and converted to Euros using purchasing power parity (1 Euro = 11.43 SEK).

Statistical analysis was performed using the Statistical Package for Social Sciences (IBM SPSS, version 31.0) and a p-value < 0.05 was considered statistically significant.

The study was approved by the Swedish Ethical Review Authority (2019–04329).

Results

Participants and complications

A total of 520 patients were included, of whom 431 underwent elective resections and 89 underwent emergency resections. Postoperative complications occurred in 151 elective patients (35%) and 50 emergency patients (56%) (Table 1).

Compared with elective surgery, emergency patients had a higher ASA classification ($p=0.008$), more advanced tumour stage ($p<0.001$) and lower BMI ($p=0.018$). There were no significant differences in age, sex, reoperation rate, or 30-day readmission between groups. Emergency surgery was associated with a longer hospital stay ($p<0.001$), a higher proportion of open procedures ($p<0.001$) and increased need for ICU treatment ($p=0.001$) (Table 1).

Cost analysis

Hospital costs increased with higher Clavien-Dindo grade in both elective and emergency surgery. Among patients without postoperative complications, the median total hospital cost was €9 809 (€8 613- €11 512) following elective surgery and €12 079 (€10 739- €13 546) following emergency surgery, $p<0.001$. Among patients with postoperative complications, median total hospital costs were significantly higher after emergency resection at €19 655 (€13 918- €27 134) compared with elective resection at €14 820 (€12 097- €18 862), $p=0.004$.

As shown in Tables 2 and 3, total hospital costs increased with higher Clavien-Dindo grade across all predefined healthcare categories. Total hospital costs increased stepwise with complication severity in both elective and emergency surgery ($p<0.001$).

The highest costs were observed among patients with Clavien-Dindo grade IV complications, with median total costs of €26 307 (€22 684–€47 893) following elective surgery and €45 374 (€25 812–€107 051) following emergency surgery. In both groups, total costs associated with Clavien-Dindo grade V complications were lower than those observed for grade III and IV complications, respectively.

Adjusted costs and excess costs according to complication severity and type

After adjustment for tumour stage, ASA classification, surgical technique, sex and age, increasing complication severity remained significantly associated with higher costs in the generalized linear model analysis. Adjusted mean costs increased with higher Clavien-Dindo grade in both elective and emergency surgery. In elective surgery, Clavien-Dindo grade IV complications were associated with more than a threefold increase in costs (cost ratio 3.21), whereas emergency patients demonstrated an almost fivefold increase in costs (cost ratio 4.84) compared with patients without complications (Table 4).

Adjusted excess costs increased progressively with higher Clavien-Dindo grade in both elective and emergency surgery (Figures 1a and 1b). The largest excess costs were observed among patients with Clavien-Dindo grade IV complications, with a more pronounced increase in emergency surgery. This association was less consistent for grade V complications.

Figures 2a and 2b illustrate adjusted excess costs according to complication type. In elective surgery, all complication categories were associated with increased costs, with the greatest excess costs observed for surgical complications. In emergency surgery, surgical complications remained strongly associated with increased costs, whereas cardiac and non-SSI complications were not independently associated with significantly increased costs.

Discussion

This retrospective single-center study used patient-level hospital cost data and adjusted generalized linear models to evaluate complication-associated costs across the full Clavien–Dindo spectrum following elective and emergency colon cancer surgery. We demonstrated a clear association between increasing postoperative complication severity and higher hospital costs. Emergency surgery was associated with higher and more variable costs, reflecting greater clinical complexity. Surgical complications were the main drivers of excess costs in both elective and emergency surgery, whereas cardiac and non-surgical site infection complications showed less consistent associations with increased costs.

Postoperative complications are major drivers of hospital costs following colon cancer surgery. However, previous studies have applied heterogeneous methodological approaches, often focusing on selected complication types or surgical techniques rather than overall complication burden or severity. A systematic review (10), showed that anastomotic leakage and surgical site infections are among the complications associated with the highest financial burden, highlighting the economic impact of

clinically relevant adverse events. However, analyses of isolated complications have limited clinical relevance, as patients frequently experience multiple concurrent complications and resource use is better captured by overall morbidity burden than by single events.

In this study, complications were classified using the Clavien-Dindo classification, a standardized and widely accepted framework that enables assessment of complication severity across the full clinical spectrum (7). Although only a limited number of cost analyses in colorectal cancer surgery have applied this classification, previous evidence has demonstrated higher costs with increasing Clavien-Dindo grade (2, 4), consistent with our findings. This supports a clear gradient in resource use across severity levels. The lower costs associated with Clavien-Dindo grade V complications, likely reflect a shorter time window for resource accumulation rather than a lower resource intensity of care.

In analyses stratified by complication type, surgical complications were associated with the highest excess costs in both elective and emergency surgery. In emergency surgery, cardiac and non-SSI complications were not independently associated with significantly increased costs in the adjusted model. However, overlap between complication categories should be acknowledged, as patients may experience multiple concurrent events, which limits attribution to individual complication types.

Surgical complications are well-established drivers of cost following colon cancer surgery. Superficial surgical site infections are associated with lower excess costs compared with deep infections, whereas anastomotic leakage is associated with particularly high costs (10). A stepwise increase in costs has been observed with increasing severity of surgical site infection (3), a pattern that closely parallels the Clavien-Dindo classification, in which higher grades reflect progressively greater resource utilization. Consistently, a small subgroup of patients with severe complications accounts for a disproportionate share of total hospital costs. In the present study, Clavien-Dindo grade III complications were more costly than the index surgical procedure, while grade II complications accounted for more than half of the cost of the index operation. High-grade complications, particularly Clavien-Dindo IV events, are likely driven by intensive care admission, organ support, reinterventions and prolonged hospital stay, often in the context of multiple concurrent complications (11).

When stratified by surgical setting, important differences were observed between elective and emergency surgery (12). Previous cost analyses have predominantly focused on elective patients (5, 6, 13, 14), whereas some studies have included both elective and emergency resections in their analyses (3, 4). Given the substantial differences in baseline physiology, disease stage, and perioperative risk, elective and emergency patients are not comparable with respect to resource utilization. Nevertheless, emergency surgery was associated with both higher and more variable hospital costs, likely driven by increased requirements for urgent operative management, intensive care, and prolonged postoperative recovery (15). In contrast, elective surgery allows for preoperative optimization and structured perioperative pathways, which may reduce both complication rates and variability in resource utilization.

Together, these findings reinforce postoperative complications as a major and potentially modifiable driver of hospital costs. Interventions aimed at reducing complication rates and accelerating recovery,

including enhanced recovery pathways, minimally invasive surgical techniques, and early recognition of postoperative deterioration, may therefore provide both clinical and economic benefits. Furthermore, given that a substantial proportion of colon cancer resections are still performed urgently, strategies aimed at reducing emergency presentations or converting emergency cases into elective pathways may further reduce both morbidity and healthcare expenditures (16) .

A major strength of this study was the use of a patient level micro-costing approach, with direct hospital costs estimated in close collaboration with a health economist. Resource utilization was assessed at the individual patient level, with multiple cost components assigned directly to each patient using the institutional cost-accounting system. In addition, generalized linear models enabled adjusted cost estimates while accounting for potential confounding factors and the skewed distribution of healthcare cost data. Importantly, complications were systematically identified through detailed review of individual medical records in combination with registry data, allowing a more complete ascertainment of postoperative events than registry-based data alone.

Another strength was the separate analysis of elective and emergency surgery. To our knowledge, few previous studies have directly compared complication-associated costs between these surgical settings, providing new insight into the economic burden associated with emergency colon cancer surgery. Finally, postoperative complications were classified according to the Clavien-Dindo classification across the full clinical spectrum. This enabled a clinically meaningful evaluation of postoperative morbidity and its economic impact.

Several limitations should be acknowledged. First, the single-center retrospective design may limit generalizability. Second, although the micro-costing approach increases precision, cost structures and accounting systems may differ between healthcare systems, potentially limiting external validity. Third, retrospective assessment of complications may increase the risk of underreporting minor postoperative events, particularly lower grade complications. Fourth, higher Clavien-Dindo grades were relatively rare, which may reduce statistical precision. Finally, only direct costs were included, and the total societal economic burden associated with postoperative complications is therefore likely underestimated.

Conclusion

Postoperative complications after colon cancer surgery are associated with a clear stepwise increase in hospital costs across the Clavien-Dindo spectrum, with severe complications accounting for a disproportionate share of total resource utilization. Emergency surgery is associated with higher complication rates and increased costs compared with elective surgery.

A small group of patients with severe complications appears to drive a large proportion of total hospital costs, underscoring complications as a modifiable cost driver. Efforts to reduce emergency presentations and optimize perioperative pathways may therefore have both clinical and economic benefits.

Declarations

Research ethics and patient consent: The study was approved by the Swedish Ethical Review Authority (2019-04329). According to the ethical approval, informed consent was waived.

Previous presentation: This paper has not been presented previously.

Conflict of interest: The authors declare no conflict of interest.

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Data availability statement: The data underlying this study were obtained from regional healthcare databases and are not publicly available due to patient confidentiality and Swedish data protection legislation. Access to de-identified data may be granted upon reasonable request, subject to approval by the relevant ethical review authority and the data-holding institution.

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Tables

Tables are available in the Supplementary Files section.

Figures

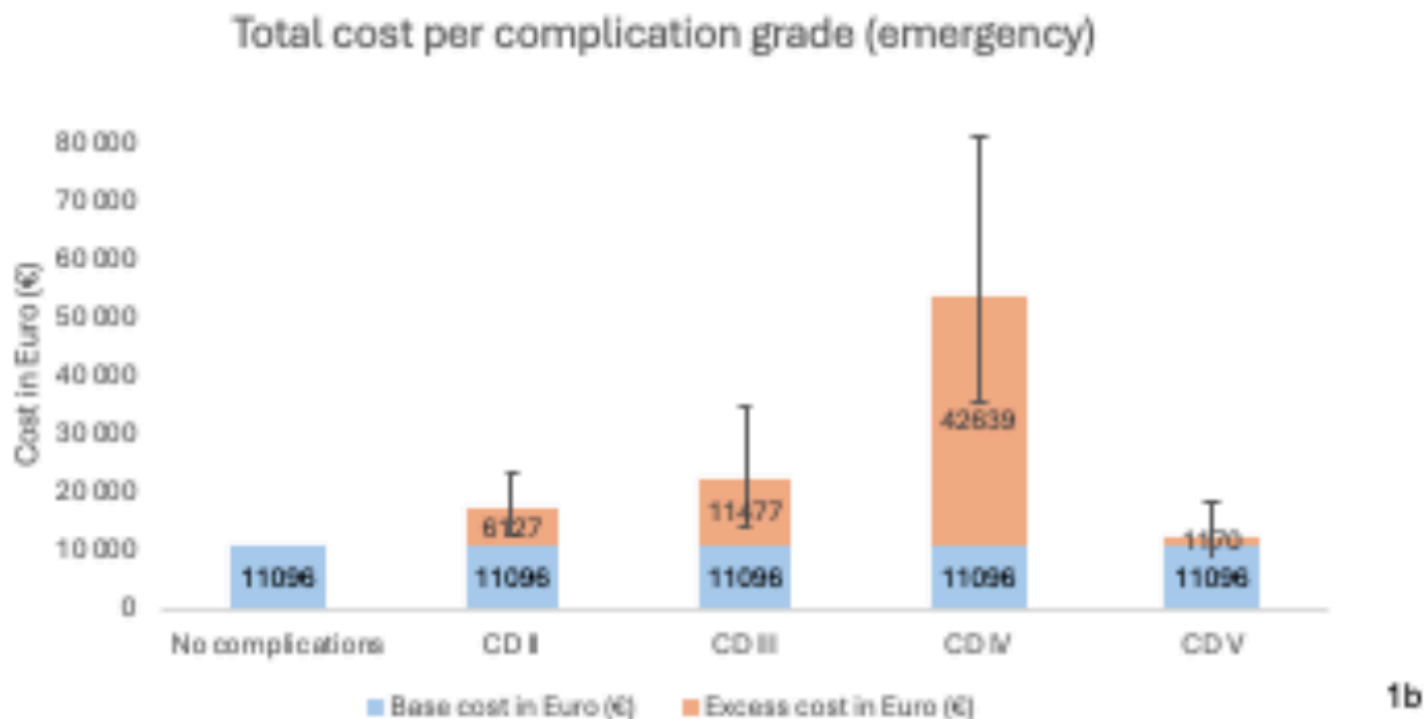
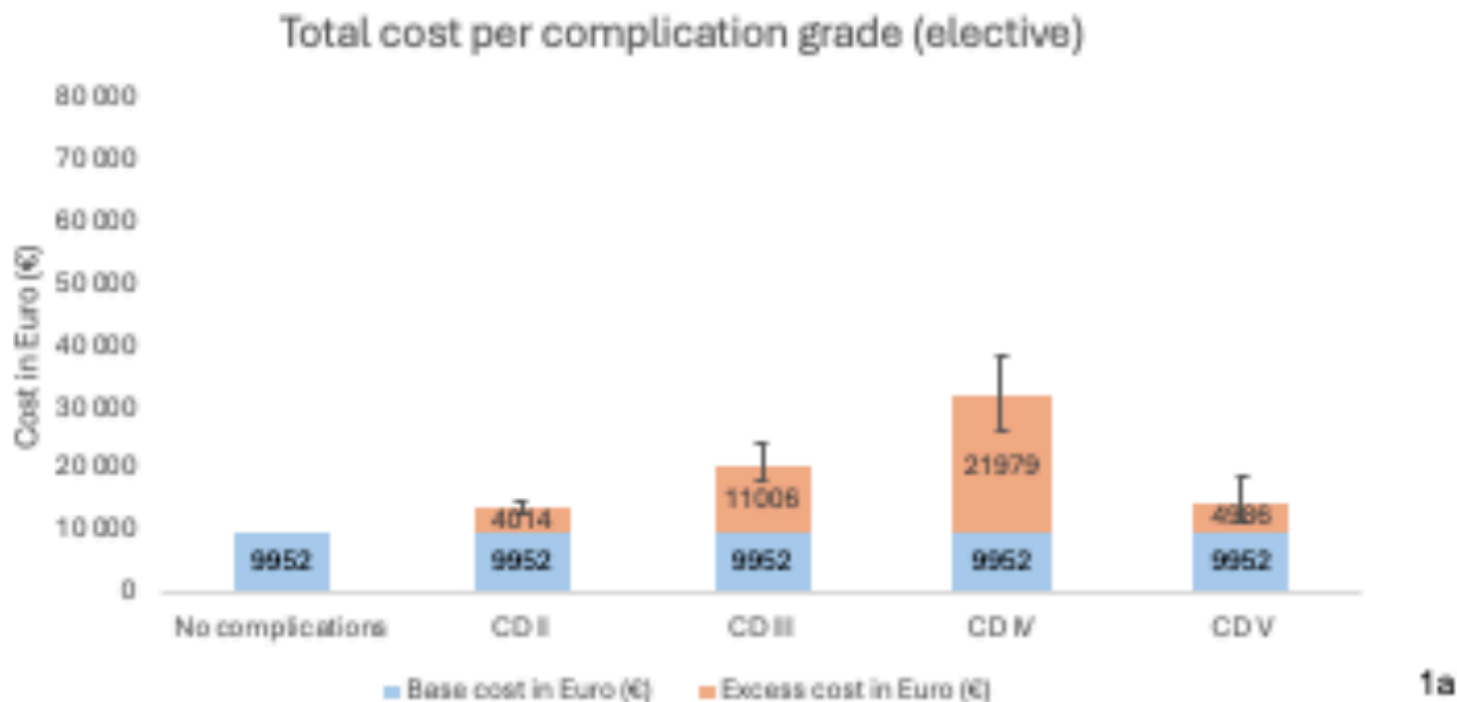


Figure 1

a-b. Total hospital costs stratified according to postoperative complication severity in elective (A) and emergency (B) colon cancer surgery. The blue bars represent the estimated baseline cost for patients without postoperative complications, while the orange bars represent the adjusted excess costs associated with increasing Clavien-Dindo (CD) grades. Error bars indicate 95% confidence intervals for the excess cost estimates.

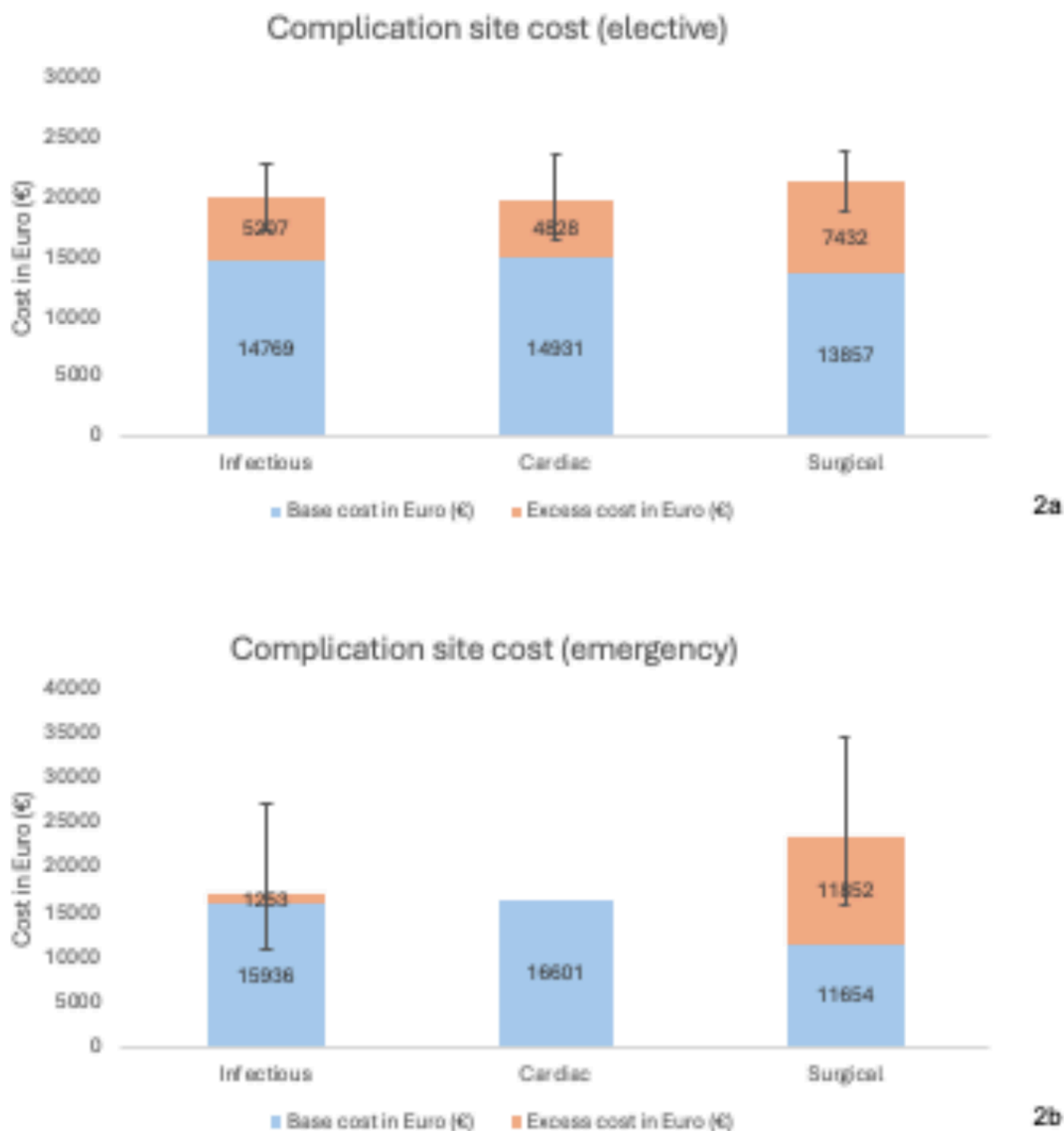


Figure 2

a–b. Total hospital costs according to postoperative complication category in elective (a) and emergency (b) colon cancer surgery. Bars represent total mean costs divided into baseline costs for patients without complications (blue) and excess costs attributable to postoperative complications within each complication category (orange). Error bars indicate 95% confidence intervals for excess costs.

Supplementary Files

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- [Table1.docx](#)
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