# Adhesiolysis-Related Morbidity in Abdominal Surgery

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**Objectives:** To determine the incidence of bowel injury in operations requiring adhesiolysis and to assess the impact of adhesiolysis on the incidence of surgical complications, postoperative morbidity, and costs.

**Background:** Morbidity of adhesiolysis during abdominal surgery seems an important health care problem, but the direct impact of adhesiolysis on inadvertent organ damage, morbidity, and costs is unknown.

**Methods:** In a prospective cohort study, detailed data on adhesiolysis were gathered by direct observation during elective abdominal surgery. Comparison was made between surgical procedures with and without adhesiolysis on the incidence of inadvertent bowel defects. Secondary outcomes were the effect of adhesiolysis and bowel injury on surgical complications, other morbidity, and costs.

**Results:** A total of 755 (out of 844) surgeries in 715 patients were included. Adhesiolysis was required in 475 (62.9%) of operations. Median adhesiolysis time was 20 minutes (range: 1–177). Fifty patients (10.5%) undergoing adhesiolysis inadvertently incurred bowel defect, compared with 0 (0%) without adhesiolysis ($P < 0.001$). In univariate and multivariate analyses, adhesiolysis was associated with an increase of sepsis incidence [odds ratio (OR): 5.12; 95% confidence interval (CI): 1.06–24.71], intra-abdominal complications (OR: 3.46; 95% CI: 1.49–8.05) and wound infection (OR: 2.45; 95% CI: 1.01–5.94), longer hospital stay (2.06 ± 1.06 days), and higher hospital costs [$18,579 (15,204–21,954) vs $14,063 (12,471–15,655)]. Mortality after adhesiolysis complicated by a bowel defect was 4 out of 50 (8%), compared with 7 out of 425 (1.6%) after uncomplicated adhesiolysis (OR: 5.19; 95% CI: 1.47–18.41).

**Conclusions:** Adhesiolysis and inadvertent bowel injury have a large negative effect on the convalescence after abdominal surgery. The awareness of adhesion-related morbidity during reoperation and the prevention of postsurgical adhesion deserve priority in research and clinical practice.

**Keywords:** adhesiolysis, enterotomy, health care costs, postoperative complications, postoperative morbidity

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Peritoneal adhesions develop after more than 90% of operations in the abdominal cavity, procedures frequently performed by general, vascular, and gynecological surgeons and urologists.[1–3]

Intestinal obstruction, female infertility, and abdominal pain are well-known adhesion-related complications that negatively impact millions of lives worldwide.[1,2,4–7] Surprisingly, adhesion-related complications receive little attention in clinical practice.[8–11]

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Complications that occur after adhesiolysis during repeat surgery might even form a larger burden of morbidity.[8] In a retrospective cohort, the risk of inadvertent bowel defects was as high as 19%.[12] The risk of needing repeat abdominal surgery is relatively high and is expected to increase in the western world with the increase of life expectancy and developments in surgical technology.[13–17]

Little is known of the impact of adhesiolysis and related organ injury on morbidity and socioeconomic costs in comparison with other adhesion-related complications. Knowledge of the morbidity related to adhesiolysis is needed to properly inform patients before surgery to take adhesiolysis risks into account in the operative decision-making, and to improve diagnosis of postoperative complications. In addition, proper data on adhesiolysis time and the socioeconomic burden of adhesions are helpful for operative room management and health care insurance.

In this prospective study, we did a detailed assessment and analysis of adhesiolysis, (post)operative complications, and socioeconomic factors in a large cohort of elective abdominal operations (clinicaltrials.gov registration number: NCT01236625).

## METHODS

### Study Design and Patients

This was a prospective observational study as part of the LAPAD (LAParotomy or LAParoscopy and ADhesiolysis) study. The LAPAD study was designed to assess the incidence and impact of adhesiolysis on preoperative and postoperative complications, quality of life, and socioeconomic costs. All adult patients planned for elective abdominal surgery at the Department of Surgery of the Radboud University Nijmegen Medical Center between June 2008 and June 2010 were screened for inclusion. Patients planned for admission to the surgical day-care unit were excluded because the short hospital stay did not allow for adequate follow-up.

Inclusion criterion was an elective laparotomy or laparoscopy. Exclusion criteria were age under 18 years and mental disorder. Patients were included after giving oral and written informed consent.

Relevant patient, surgical, and medical data were prospectively assessed before, during, and after hospital stay and at the outpatient clinic until 6 months after discharge. At surgery, detailed information of adhesions, adhesiolysis, and inadvertent organ damage was collected through direct observation by a trained researcher (R.B., C.S., or Y.I.) who did not take part in the operation. Evaluation of adhesions was comprised of a description of the location, for example, ventral abdominal wall, operative area, and other parts of the abdomen, grading of adhesions at these 3 locations according to the Zühlke classification, and timing the duration of adhesiolysis by stopwatch.[18] Findings were recorded into the real-time database by the researcher present in the operating theater. Operative and treatment decisions were made according to department guidelines or at the discretion of the surgical staff. As a rule in our institution, adhesiolysis was done by sharp dissection and not by electrocautery or ultrasonic dissection. The study was approved by the local medical ethical committee and conducted according to the revised version of the Declaration of Helsinki (October 2008, Seoul).

## Variables

Primary outcomes were the incidence of adhesions, adhesiolysis time, the incidence of bowel defects, seromuscular injury, injuries to other organs and structures, and the incidence of major surgery-related complications.

A detailed description of any adhesion present was obtained by direct observation. Adhesiolysis time was measured in minutes from the start of adhesiolysis until the operative area was cleared of adhesions.

Bowel defects were classified as inadvertent enterotomy or delayed diagnosed perforation. Inadvertent enterotomy was defined as any iatrogenic, unintended full thickness bowel defect detected during operation. Preexisting fistulas or defects created while dissecting the bowel loop that harbored the fistula were not scored as inadvertent enterotomy. Delayed diagnosed perforation was defined as a bowel defect with spill of gastrointestinal content that was diagnosed postoperatively by imaging, at reoperation, or at autopsy, and that could not be explained by anastomotic leakage, bowel ischemia, or any other obvious causes of leakage unrelated to adhesiolysis.

Seromuscular injury was defined as injury to the serosal and muscular layers of the bowel, without visualization of the bowel lumen or spillage of bowel content. Other intraoperative injuries were comprised of any injury to the spleen, liver, pancreas, urogenital structures, lung, vascular structures, or nerves.

Postoperative complications noted as major surgery-related complications were death, wound infection (categorized as superficial or deep), anastomotic leak, fistula and abscess, pneumonia, sepsis, hemorrhage, and urinary tract infection. Major surgery-related complications were defined according to the criteria of the International Classification of Diseases, Tenth Revision, the National Nosocomial Infections Surveillance System, the Center for Disease Control and Prevention, or according to the decision of the senior medical staff of the department.

Secondary outcomes were other morbidity and socioeconomic costs including total operative time, blood loss, recovery unit stay, hospital stay, unplanned or prolonged intensive care unit admission, intensive care unit stay, parental feeding, tube feeding, incidence of emergency reoperations, and incidence of readmission to the hospital within 30 days after discharge.

Cost analysis was performed in United States dollars (unit of analysis) and included only the direct hospital costs: operation costs, ward stay, intensive care unit stay, extra charges for parental and tube feeding, postoperative diagnostics, reoperation costs, and blood products. Cost calculations were performed using the guidelines for cost analysis of the Dutch College of Health Insurance Companies using a top-down approach.[19] Operation costs were calculated based on total anesthesia time using operating room costs of $1390 per hour, including personnel, material, and overhead costs. Total costs for the surgical ward and intensive care unit were $661 and $2289 per day, respectively, and included basic nutritional costs. More than basic parental and tube feedings were considered as extra nutritional costs. Diagnostic and reoperation costs were calculated using the 2004 price lists for medical procedures by the Dutch College of Health Insurance Companies. Medication costs and blood products costs were calculated according to the standardized price list of the Dutch College of Health Insurance Companies updated for June 2008.[20]

Baseline demographics included sex, age, body mass index, Alcohol Use Disorders Identification Test alcohol abuse index,[21] history of abdominal operations, number of laparotomies in history, number of laparoscopies in history, history of generalized peritonitis, American Society of Anesthesiologists classification, P-Possum score, Revised Cardiac Risk Index, diabetes mellitus, extent of surgery, surgical approach (open or laparoscopic), anatomical site of operation [upper gastro-intestinal, lower gastro-intestinal, hepatobiliary–pancreatic, abdominal wall, or other], and level of surgical experience (surgeon or resident).

## Statistical Methods

Univariate comparisons were performed using linear regression for continuous and logistic regression for dichotomous data. Effect size was expressed as mean difference with standard deviation for continuous data and odds ratios (ORs) for dichotomous data. Despite the large number of patients, differences in baseline factors between the groups were expected because adhesions are mostly due to prior surgery. To avoid potential bias by an unequal distribution of risk factors, we calculated an adjusted effect size using multivariate linear and logistic regression for continuous and dichotomous data, respectively. All factors with unequal distribution at baseline with $P < 0.010$ were included in the multivariate model, except a history of peritoneal surgery and generalized peritonitis, and peritoneal surgery and previous peritonitis were considered pathogenic for adhesion formation and were not expected to have further independent adverse effects on treatment outcomes. In composite outcomes, statistical results were presented for both the composite outcome and the individual components of the composite. Costs are presented as mean cost with a 95% confidence interval (CI). Statistical comparison of costs was performed by multivariate regression on the logistically transformed values of the costs to reduce the impact of outliers. All outcomes were assessed per operation and analyzed according to an intention-to-treat, unless otherwise stated.

In the subgroup of operations with adhesiolysis, we compared major surgery-related complications, other morbidities, and costs between adhesiolysis complicated by bowel defects and uncomplicated adhesiolysis.

In an additional analysis, we calculated the risk for enterotomy, seromuscular injury, and other organ injury by categorizing adhesiolysis time (none, 1–15, 16–30, 31–60, and >60 min).

There was only minimal missing data; thus, we excluded per analysis those cases with missing data. We used SPSS for Windows version 16.0 software (SPSS, Chicago, IL) for statistical analysis. Values of $P < 0.05$ were considered significant.

# RESULTS

## Cohort and Baseline Comparison

A total of 844 consecutive elective surgeries were screened for eligibility; 89 operations were excluded. Main reasons for exclusion were cancellation of the operation (N = 38), refusal to participate (n = 11), and mental incompetence of the patient (N = 8). A total of 755 operations carried out in 715 patients were included in the study (Fig. 1). Adhesiolysis time was missing in 4 operations (0.5%). There were no further missing data.

The incidences of adhesions and adhesiolysis were 497 out of 755 (65.8%) and 475 out of 755 (62.9%), respectively. Most common etiologies for the presence of adhesions were previous intra-abdominal surgery and peritonitis (Table 1); mean adhesiolysis time was 20 minutes (range: 1–177). Adhesions to the incision scar of a previous operation were found in 399 (80.3%) of operations with adhesions, whereas in 416 operations (83.7%), adhesions were present in the operative area and in 329 operations (63.6%), adhesions were found in other parts of the abdomen. Median Zühlke score was 2 (range: 1–5) at all 3 locations. Severe adhesions (Zühlke score: 3 or 4) were found under a previous scar in 233 operations (46.9%) with adhesions, at the operative area in 235 operations (47.3%), and in other parts of the abdomen in 160 operations (32.2%). Patients who had adhesions and no prior surgery or general peritonitis in their

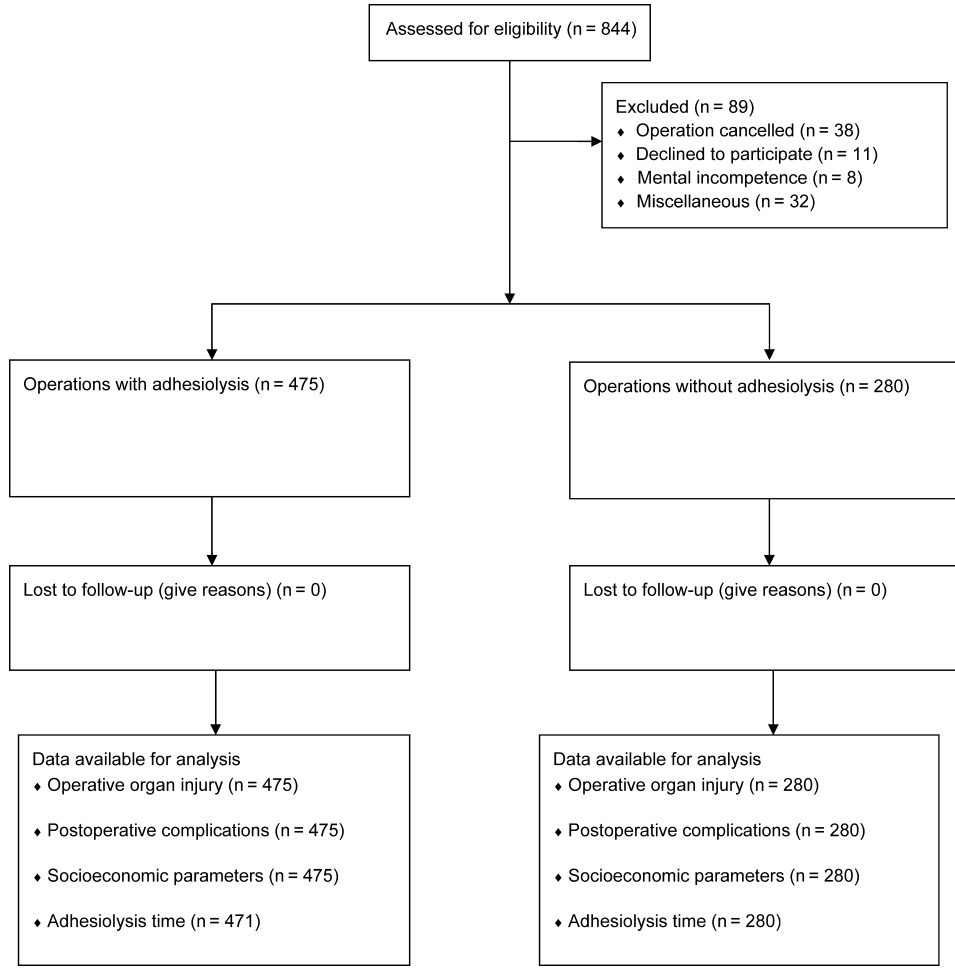


**FIGURE 1.** Flow diagram of the included operations.

history usually only had a few low-grade adhesions with a median adhesiolysis time of 5 minutes (range: 1–93). Those adhesions were mostly located adjacent to a local inflammatory process or tumor.

Table 1 shows the baseline data for the 2 groups. There were significant differences in the anatomical location of the operation ($P < 0.001$), operative severity ($P < 0.001$), surgical approach ($P = 0.01$), and body mass index ($P = 0.003$).

## Impact of Adhesiolysis on Peroperative Complications

The incidence of full thickness bowel defects was 10.5% in the adhesiolysis group and 0% in the nonadhesiolysis group ($P < 0.001$). During 43 operations, there was a median of 1 (range: 1–9) inadvertent enterotomy. Bowel resection and anastomosis were required in 24 operations (55.8%) with 1 or more enterotomies, and in the remaining operations, enterotomies were repaired by primary suturing. Injury to the seromuscular layer occurred in 131 procedures (27.6%) with adhesiolysis compared with 11 (3.9%) without adhesiolysis ($P < 0.001$). As a rule, seromuscular injuries were repaired by suturing.

Delayed diagnosed perforation occurred after 10 surgeries. A delayed diagnosed perforation occurred after 8 out of 142 seromuscular injuries (5.6%) and 3 out of 43 enterotomies (7.0%). The 3 patients with a delayed diagnosed perforation after an enterotomy also had seromuscular injuries. In 2 patients with delayed diagnosed perforation (20.0%), no seromuscular injury or enterotomy occurred during initial operation.

Injury to other organs was 8.6% in the adhesiolysis group compared with 2.5% in the nonadhesiolysis group ($P = 0.001$). Most common injuries in the adhesiolysis group were to the liver (n = 14), vascular structures (n = 11), urogenital structures (n = 8), spleen (n = 4), and bile ducts (n = 3). Injuries in the nonadhesiolysis group were comprised of vascular structures (n = 4), spleen (n = 2), and bile duct (n = 1).

After adjustment for anatomical location, operative severity, surgical approach, and body mass index, the difference in incidence of seromuscular injury and other organ injuries remained significant (Fig. 3A). Multivariate analysis could not be conducted for bowel defects as none occurred in the nonadhesiolysis group.

The 43 inadvertent enterotomies occurred exclusively in patients who underwent open surgery. One patient (2.9%) who underwent laparoscopy had a delayed diagnosed perforation compared with 9 (2.0%) who underwent open surgery ($P = 0.75$).

The incidence of enterotomy was 0.0% in virgin abdomens, 2.5% after 1, 8.7% after 2, and 15.5% after 3 or more prior abdominal operations. A high Zühlke score correlated with an increased incidence of enterotomy. Incidence of enterotomy was 0% in grade 1, 0.7% in grade 2, 8.9% in grade 3, and 36.4% in operations with grade 4 adhesions in the operative area. Enterotomies were found in

**TABLE 1.** Baseline Comparison Between Operations With and Without Adhesiolysis

| | Adhesiolysis Group (n = 475) | NonAdhesiolysis Group (n = 280) | *P* |
|---|---|---|---|
| *Demographics* | | | |
| Sex | | | |
| Male | 264 (55.6%) | 116 (59.3%) | |
| Female | 211 (44.4%) | 114 (40.7%) | 0.32 |
| Age* | 58.1 ± 13.8 | 59.4 ± 14.1 | 0.23 |
| Body mass index* | 26.0 ± 4.8 | 25.1 ± 3.8 | 0.003 |
| Smoking status | | | |
| Nonsmoker | 163 (34.3%) | 104 (37.3%) | |
| Ex-smoker | 210 (44.2%) | 130 (46.6%) | 0.20 |
| Smoker | 102 (21.5%) | 45 (16.1%) | |
| Alcohol abuse | | | |
| Low risk | 450 (94.9%) | 261 (93.5%) | |
| Moderate risk | 18 (3.8%) | 12 (4.3%) | 0.60 |
| High risk | 6 (1.3%) | 6 (2.2%) | |
| Peritoneal surgery in history | | | |
| Yes | 412 (86.7%) | 90 (32.1%) | |
| No | 63 (13.3%) | 190 (67.9%) | <0.001 |
| Laparotomies in history† | 2 (0–56) | 0 (0–3) | <0.001 |
| Laparoscopies in history† | 0 (0–2) | 0 (0–1) | <0.001 |
| Generalized peritonitis in history | | | |
| Yes | 66 (13.9%) | 1 (0.4%) | |
| No | 409 (86.1%) | 279 (99.6%) | <0.001 |
| *Preoperative risk assessment* | | | |
| American Society of Anesthesiologists classification | | | |
| I | 77 (16.2%) | 46 (16.4%) | |
| II | 284 (59.8%) | 172 (61.4%) | |
| III | 113 (23.8%) | 62 (22.1%) | 0.83 |
| IV | 1 (0.2%) | 0 (0.0%) | |
| P-Possum score* | 6.2 ± 9.8 | 6.0 ± 8.7 | 0.79 |
| Revised Cardiac Risk Index | | | |
| 2 | 396 (83.4%) | 222 (79.3%) | |
| 3 | 66 (13.9%) | 45 (16.1%) | 0.25 |
| 4 | 13 (2.7%) | 13 (4.6%) | |
| Diabetes Mellitus in history | | | |
| Yes | 43 (9.1%) | 29 (10.4%) | |
| No | 432 (90.9%) | 251 (89.6%) | 0.56 |
| Operative severity | | | |
| Minor | 0 (0.0%) | 2 (0.7%) | |
| Moderate | 22 (4.6%) | 14 (5.0%) | |
| Large | 311 (65.5%) | 134 (47.9%) | <0.001 |
| Major | 142 (29.9%) | 130 (46.4%) | |
| *Characteristics of planned operation* | | | |
| Open surgery/laparoscopy | | | |
| Open surgery | 440 (92.6%) | 244 (87.1%) | |
| Laparoscopy | 35 (7.4%) | 36 (12.9%) | 0.01 |
| Anatomical site of primary intervention | | | |
| Upper gastrointestinal tract | 25 (5.3%) | 58 (20.7%) | |
| Lower gastrointestinal tract | 219 (46.1%) | 122 (43.6%) | |
| Hepato-biliary–pancreatic | 82 (17.3%) | 61 (21.8%) | |
| Abdominal wall | 115 (24.2%) | 9 (3.2%) | <0.001 |
| Other | 34 (7.2%) | 30 (10.7%) | |
| Surgical experience | | | |
| Surgeon | 330 (69.5%) | 194 (69.3%) | |
| Resident | 145 (30.5%) | 86 (30.7%) | 0.96 |

*Mean ± standard deviation; †Median (range).

2 operations (0.6%) without adhesions to a previous scar, 0% with grade 1, 2.2% with grade 2, 12.0% with grade 3, and 26.9% with grade 4 adhesions to a previous scar. The correlation between adhesion grade and enterotomies was less strong for adhesions in other parts of the abdomen with an incidence of 0.5% without adhesions, 2.9% with grade 1, 7.4% with grade 2, 19.5% with grade 3, and 18.9% with grade 4 adhesions. The incidence of enterotomy, seromuscular injury, and other organ injury significantly increased with longer adhesiolysis time (Figs. 2A–C).

## Impact of Adhesiolysis on Surgical Complications

In the adhesiolysis group, 111 (23.4%) of surgeries had 1 or more major surgery-related complications compared with 50 (17.6%) in the nonadhesiolysis group [adjusted $P = 0.05$; (Fig. 3A)].

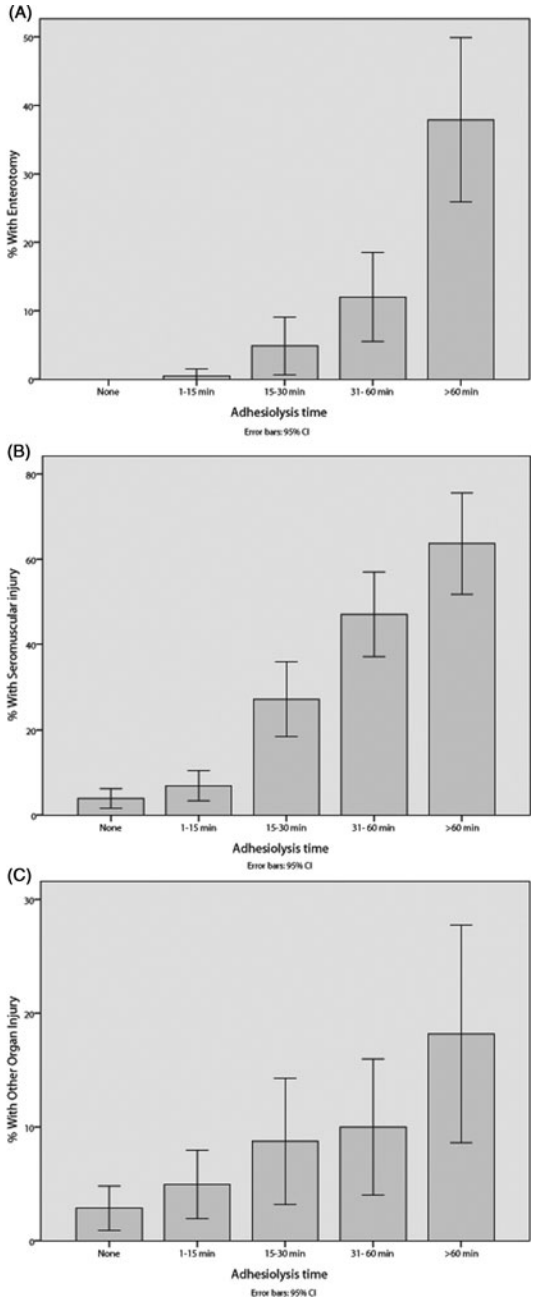


**FIGURE 2.** Risk of inadvertent organ injury with 95% CI stratified by adhesiolysis time: A, Enterotomy. B, Seromuscular injury. C, Other organ injury.

There was a significantly higher risk for sepsis, incisional wound infection, and abdominal complications in the adhesiolysis group (univariate analysis and after correction), although there were no significant differences in the incidence of death, urinary tract infection, pneumonia, or hemorrhage (Fig. 3A). The adjusted OR for sepsis was 5.12 (95% CI: 1.06–24.7), for wound infection 2.45 (95% CI: 1.01–5.94), and for abdominal complications 3.46 (95% CI: 1.49–8.05). Other variables included in multivariate analysis were not significant. Wound infections were found in 6 out of 67 operations (9.0%) performed with a history of peritonitis, compared with 32 out of 688 operations (4.7%) without peritonitis in their history—this difference was not significant ($P = 0.137$).

## Impact of Adhesiolysis on Other Morbidity and Costs

Adhesiolysis was associated with a statistically significantly longer operative time, recovery time, and hospital stay. There was 29% more operative blood loss in the adhesiolysis group and more need of postoperative parental feeding. There tended to be more additional surgeries in the adhesiolysis group, although the difference was not significant ($P = 0.060$). Unplanned admissions to the intensive care unit and intensive care unit stays were comparable between the groups (Table 2).

The inpatient costs were higher in the adhesiolysis group for all domains, resulting in a total of $18,579 (15,204–21,954) per operation for direct hospital costs compared with a total of $14,063 (12,471–15,655) in the nonadhesiolysis group ($P < 0.001$; Table 3).

Readmission rate within 30 days after discharge was also significantly higher in the adhesiolysis group ($P = 0.002$). In the adhesiolysis group, 48 out of 69 readmissions (70.0%) were for a complication possibly related to previous surgery (abscess in 15, wound infection in 9, small bowel obstruction in 8, sepsis in 6, pneumonia in 5, and urinary tract infection in 5). In the nonadhesiolysis group, 12 out of 20 readmissions (60.0%) possibly were for a surgery-related complication (5 times for abscess, 2 times each for pneumonia, wound dehiscence, and leakage of the cervical anastomosis after esophageal resection, and once for urinary tract infection).

## Impact of a Bowel Defect on Surgical Complications, Morbidity, and Costs

A major surgery-related complication occurred more than twice as often after adhesiolysis complicated by a bowel defect (Fig. 3B).

The in-hospital mortality rate increased fivefold from 1.6% to 8.0% in the case of a bowel defect (Fig. 3B). The bowel defect group had significantly more additional surgical interventions ($P < 0.001$; Table 2). Hospital stay was a mean of $10.2 \pm 2.4$ days longer in the bowel defect group ($P = 0.036$). Total costs were almost threefold higher in patients with a bowel defect [$43,784 (16,629–70,938)] compared with those without a defect [$15,614 (13,642–17,586); Table 3].

# DISCUSSION

In this study, adhesiolysis-induced morbidity was high: a median of 20 minutes increase of operative time, a 1 in 10 risk of inadvertent bowel defects, a sevenfold increase in seromuscular injury, and a threefold to fourfold increase in other organ injury. Adhesiolysis, particularly with the resulting bowel defects, led to more postoperative sepsis, intra-abdominal complications including surgical site infections, a longer hospital stay, more readmissions, and increased costs.

Adhesiolysis at repeat surgery has received less attention than bowel obstruction and infertility in reports assessing the clinical and socioeconomical burden of postoperative adhesions. Underestimation of the related morbidity and the passiveness of many physicians, who consider adhesiolysis an annoying but unavoidable part of redo surgery, account for the paucity of reports on the consequences of adhesiolysis. The available literature is limited to small series in specific surgical areas or retrospective series in which previous surgeries or rehospitalization are taken as the measure of adhesiolysis.[2,12,22,23] We designed a large prospective study to provide accurate incidences of adhesiolysis-related morbidity and socioeconomical costs. This study provided for continuous observation of the surgical procedures

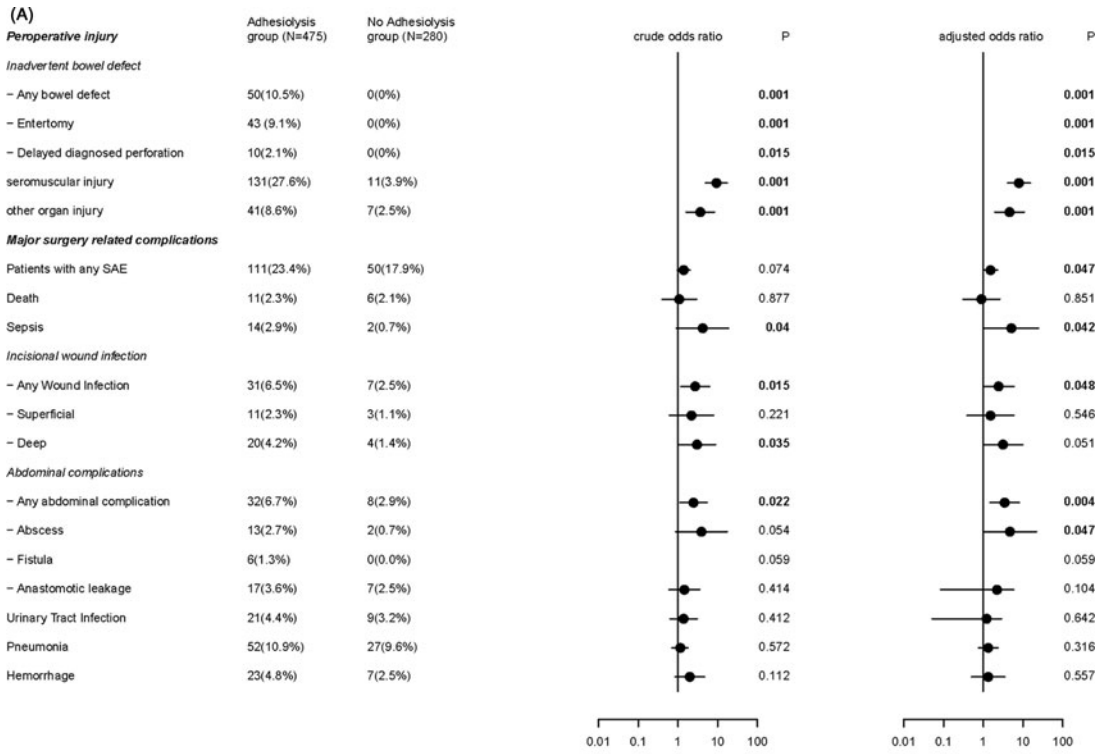


**FIGURE 3.** A, Crude and adjusted ORs with 95% CI for (post)operative complications compared between surgery with and without adhesiolysis. B, ORs with 95% CI of postoperative complications after surgery with adhesiolysis compared between surgery with or without inadvertent bowel defect.

**TABLE 2.** Morbidity Outcomes Compared Between Operations With and Without Adhesiolysis and Compared Between Surgery With or Without Inadvertent Bowel Defect in the Subgroup of Operations With Adhesiolysis

| | Adhesiolysis Group (n = 475) | Nonadhesiolysis Group (n = 280) | Crude OR (95% CI) | *P* | Adjusted OR (95% CI) | *P* | Enterotomy/ DDP (n = 50) | No Enterotomy/DDP (N = 425) | OR (95% CI) | *P* |
|---|---|---|---|---|---|---|---|---|---|---|
| Operation time (min) | 195 ± 98* | 179 ± 89* | **16.2 ± 7.1**† | **0.020** | **22.5 ± 6.0**† | **<0.001** | 221 ± 101* | 192 ± 97* | 29.5 ± 14.56† | 0.05 |
| Blood loss (mL) | 934 ± 1630* | 725 ± 905* | **209 ± 106**† | **0.024** | **305 ± 101**† | **0.003** | 1119 ± 1438* | 912 ± 1652* | 207 ± 244† | 0.35 |
| Recovery unit stay (hours) | 7.9 ± 10.9* | 6.4 ± 9.0* | **1.49 ± 0.77**† | **0.043** | **2.21 ± 0.74**† | **0.003** | 7.2 ± 8.8* | 8.0 ± 11.2* | –0.8 ± 1.6† | 0.54 |
| Hospital stay (days) | 11.5 ± 16.5* | 9.4 ± 8.5* | **2.06 ± 1.06**† | **0.024** | **3.14 ± 1.08**† | **0.004** | 20.6 ± 33.1* | 10.4 ± 12.8* | **10.2 ± 2.4**† | **0.04** |
| Unplanned/prolonged intensive care unit admission | 77 (16.2%) | 51 (18.2%) | 0.87 (0.59–1.28) | 0.478 | 1.09 (0.70–1.70) | 0.70 | 14 (28.0%) | 63 (14.8%) | **2.24 (1.14–4.38)** | **0.02** |
| Intensive care unit stay (days) | 1.9 ± 11.6* | 1.0 ± 3.4* | 0.94 ± 0.71† | 0.101 | 1.22 ± 0.73† | 0.10 | 9.3 ± 31.8* | 1.08 ± 5.2* | 8.25 ± 1.70† | 0.07 |
| Parenteral feeding | 77 (16.2%) | 25 (8.9%) | 1.97 (1.22–3.18) | **0.005** | **2.00 (1.19–3.34)** | **<0.001** | 20 (40.0%) | 57 (13.4%) | **4.30 (2.29–8.09)** | **<0.001** |
| Parental feeding (days) | 3.0 ± 11.2* | 1.4 ± 5.9* | 1.58 ± 0.72† | **0.012** | **1.95 ± 0.74**† | **0.009** | 11.7 ± 26.2* | 2.0 ± 7.2* | **9.73 ± 1.62**† | **0.01** |
| Tube feeding | 95 (20.0%) | 92 (32.9%) | 0.511 (0.37–0.72) | **<0.001** | **0.99 (0.65–1.49)** | >0.999 | 10 (20.0%) | 85 (20.0%) | 1.00 (0.48–2.08) | >0.999 |
| Unplanned tube feeding | 67 (14.5%) | 44 (15.7%) | 0.88 (0.58–1.33) | 0.546 | 1.09 (0.70–1.70) | 0.21 | 10 (20.0%) | 57 (13.4%) | 1.61 (0.77–3.41) | 0.21 |
| Tube feeding (days) | 3.3 ± 11.8* | 3.55 ± 6.3* | –0.24 ± 0.76† | 0.718 | 0.47 ± 0.76† | 0.54 | 6.14 ± 23.7* | 3.0 ± 9.5* | 3.17 ± 1.76† | 0.35 |
| Reoperations | | | | | | | | | | |
| Any | 74 (15.6%) | 28 (10.0%) | **1.66 (1.05–2.64)** | **0.030** | 1.62 (0.98–2.67) | 0.06 | 16 (32.0%) | 58 (13.6%) | **2.98 (1.55–5.74)** | **0.001** |
| Relaparotomy | 57 (12.0%) | 19 (6.8%) | **1.87 (1.09–3.22)** | **0.021** | 1.68 (0.94–3.02) | 0.08 | 13 (26.0%) | 44 (10.4%) | **3.04 (1.50–6.16)** | **0.001** |
| Central venous line | 11 (2.3%) | 7 (2.5%) | 0.93 (0.35–2.41) | 0.873 | 1.13 (0.41–3.12) | 0.81 | 1 (2.0%) | 10 (2.4%) | 0.85 (0.11–6.76) | 0.88 |
| Other | 16 (3.4%) | 6 (2.1%) | 1.59 (0.62–4.11) | 0.333 | **2.03 (0.67–6.15)** | 0.21 | 5 (10.0%) | 11 (2.6%) | **4.18 (1.39–12.58)** | **0.006** |
| Readmissions within 30 days of discharge | 69 (14.5%) | 20 (7.1%) | 2.21 (1.31–3.72) | **0.002** | **2.37 (1.36–4.13)** | **0.002** | 13 (26.0%) | 56 (13.2%) | **2.32 (1.16–4.62)** | **0.02** |

Bold values indicate significant differences.
*Mean ± standard deviation; †Unadjusted coefficient ± standard deviation.

**TABLE 3.** Socioeconomical Cost Analysis Compared Between Operations With and Without Adhesiolysis and Compared Between Surgery With or Without Inadvertent Bowel Defect in the Subgroup of Operations With Adhesiolysis

| | Adhesiolysis Group (n = 475) Mean (95% CI) | NonAdhesiolysis Group (n = 280) Mean (95% CI) | *P* | Enterotomy/DDP (n = 50) Mean (95% CI) | No Enterotomy/DDP (N = 425) Mean (95% CI) | *P* |
|---|---|---|---|---|---|---|
| Operation cost | 5204 (4986–5421) | 4871 (4611–5131) | <**0.001** | 5840 (5143–6536) | 5129 (4900–5358) | **0.03** |
| Ward stay | 6090 (5556–6624) | 5438 (4894–5982) | 0.12 | 7261 (5719–8804) | 5952 (5383–6522) | **0.04** |
| Intensive care unit stay | 4551 (2092–7009) | 2349 (1405–3293) | 0.11 | 21,828 (648–43,007) | 2518 (1350–3686) | **0.006** |
| Extra charges for parenteral/tube feeding | 945 (653–1237) | 529 (331–727) | 0.93 | 3411 (1290–5532) | 654 (453–856) | <**0.001** |
| Medication | 901 (451–1352) | 382 (303–462) | **0.01** | 3217 (0–7196) | 629 (427–832) | <**0.001** |
| Diagnostics (radiology, pathology, and microbiology) | 475 (368–581) | 400 (324–476) | 0.51 | 1098 (350–1846) | 401 (321–481) | 0.13 |
| Reoperations | 177 (128–225) | 94 (51–136) | **0.01** | 434 (181–746) | 143 (100–186) | <**0.001** |
| Blood products | 274 (171–376) | 99 (56–141) | <**0.001** | 811 (0–1637) | 211 (148–273) | **0.04** |
| Total costs | 18,579 (15,204–21,954) | 14,063 (12,471–15,655) | <**0.001** | 43,784 (16,629–70,938) | 15,614 (13,642–17,586) | <**0.001** |

in the operating theater by a trained researcher who did not take part in the surgery. This enabled the collection of reliable data that most probably could not have been retrieved from other sources such as operative reports.[24–26]

The long total adhesiolysis time reflected the high complexity of these operations: when the adhesiolysis was longer than 1 hour, 40% of the operations resulted in bowel defects. Previous studies have used adhesion scores and entry times as the parameter for complexity.[18,23] However, an adhesion score is subjective and loses merit when adhesions are present in different parts of the abdominal cavity. Entry time is only a useful parameter when opening a previous abdominal incision and reflects a minor part of total adhesiolysis time and adhesiolysis-related complications.[12,23] We also had difficulty in distinguishing between adhesiolysis required just to enter the abdomen and adhesiolysis required to free the operative area in cases with massive adhesion formation to the ventral and lateral abdominal walls.

The incidence of inadvertent enterotomy in this study was lower than the 19% previously reported by our group.[12] The increased awareness of the impact of adhesiolysis and the modification in our department's protocol for cutting adhesions may have contributed to the decrease in bowel defects. Another explanation could be the strict definition of iatrogenic bowel defects, which no longer included enterotomies in the proximity of a preexisting bowel fistula. The presence of an observer might also have raised the surgeon's vigilance to avoid injury. We noted, however, that the operating teams rapidly became accustomed to having an observer in the operating theater.

The need for adhesiolysis in 60% of the surgical procedures and the low number of laparoscopies could limit the generalizability of the study results. However, these percentages have been consistent in our academic department during the past decade, and they compare with those in a large multicenter series of patients who underwent elective colorectal surgery for a benign disease.[27,28] The percentage also results from the exclusion of short-stay surgery, which is predominantly minimally invasive surgery in virgin abdomens and emergency abdominal surgeries.

Our article is the first showing adhesiolysis as a risk factor for postoperative surgical complications, longer hospital stays, more readmissions, and increased costs. Inadvertent bowel defects increased even more morbidity and costs and they also caused significant mortality, which agrees with the results from our retrospectively collected data.[12,22] Incisional wound infection was the most prominent complication reflecting the longer adhesiolysis-related operating times and increased blood loss, events that are used to estimate the risk of surgical site infection.[29] The high morbidity, long hospital stay, and high costs of a surgical site infection are well known from other reports.[30,31] The portion of patients with surgical site infection after previous surgery could not be identified from the patients' medical charts. A history of peritonitis could be reliably obtained and was not a significant risk factor for surgical site infection.

The economical burden of adhesive bowel obstruction in the United States is at least 2 billion dollars annually.[32] The cost of adhesive small bowel obstruction per patient is estimated at $9700 for operatively treated patients and at $4000 for conservatively treated patients.[33,34] The cost data from this prospective study permitted an accurate calculation of the in-hospital costs related to adhesiolysis. These costs were $4500. Taking into account that adhesiolysis was required in 60% of the patients and that only about 2% to 4% of the patients acquire an adhesive small bowel obstruction after abdominal surgery, the economical burden of adhesiolysis is likely to exceed that of adhesive small bowel obstruction.[2,35] These cost calculations can be used for reimbursement purposes and to reevaluate decisions concerning the use of barriers to prevent adhesion formation in elective abdominal surgery. Current cost-effectiveness analyses have focused on prevention of adhesive small bowel obstruction and, in many countries, have not lead to the routine use of antiadhesive barriers.[33] With the projected increase in more repeat abdominal surgeries because of a longer life expectancy and newer technologies, prevention of adhesiolysis-related morbidity might be even more cost-effective.

The huge burden of adhesiolysis-related morbidity in elective abdominal surgery has consequences for the daily practice of physicians with regard to counseling patients. Less than 10% of surgeons inform their patients about the risk of adhesions.[9] The high risk of adhesiolysis complicating the immediate postoperative course warrants routine informed consent.[11] In an analysis of medicolegal claims for complications after adhesiolysis, inadvertent bowel injury accounted for a considerable portion of both submitted and granted complaints.[36,37]

This study has demonstrated the substantial clinical and socioeconomical burden of adhesiolysis, particularly when a bowel defect occurs. All physicians treating patients with disorders of the abdominal cavity that might require surgery should be aware of the adverse effects of adhesiolysis. Our data can be of help when counseling patients before surgery, when physicians and health care providers make decisions on implementing antiadhesive strategies, and for the reimbursement policy of insurance companies.

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