

# The Incidence and Risk Factors of Post-Laparotomy Adhesive Small Bowel Obstruction

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## Abstract

**Introduction** The purpose of this review was to assess the incidence and risk factors for adhesive small bowel obstruction (SBO) following laparotomy.

**Methods** The PubMed database was systematically reviewed to identify studies in the English literature delineating the incidence of adhesive SBO and reporting risk factors for the development of this morbidity.

**Results** A total of 446,331 abdominal operations were eligible for inclusion in this analysis. The overall incidence of SBO was 4.6%. The risk of SBO was highly influenced by the type of procedure, with ileal pouch–anal anastomosis being associated with the highest incidence of SBO (1,018 out of 5,268 cases or 19.3%), followed by open colectomy (11,491 out of 121,085 cases or 9.5%). Gynecological procedures were associated with an overall incidence of 11.1% (4,297 out of 38,751 cases) and ranged from 23.9% in open adnexal surgery, to 0.1% after cesarean section. The technique of the procedure (open vs. laparoscopic) also played a major role in the development of adhesive SBO. The incidence was 7.1% in open cholecystectomies vs. 0.2% in laparoscopic; 15.6% in open total abdominal hysterectomies vs. 0.0% in laparoscopic; and 23.9% in open adnexal operations vs. 0.0% in laparoscopic. There was no difference in SBO following laparoscopic or open appendectomies (1.4% vs. 1.3%). Separate closure of the peritoneum, spillage and retention of gallstones during cholecystectomy, and the use of starched gloves all increase the risk for adhesion formation. There is not enough evidence regarding the role of age, gender, and presence of cancer in adhesion formation.

**Conclusion** Adhesion-related morbidity comprises a significant burden on healthcare resources and prevention is of major importance, especially in high-risk patients. Preventive techniques and special barriers should be considered in high-risk cases.

**Keywords** Adhesive small bowel obstruction · Early small bowel obstruction · Late small bowel obstruction · Postoperative small bowel obstruction

## Introduction

In 2006, almost 1.4 million patients underwent a surgical procedure involving the digestive system in the USA, including colectomy, appendectomy, cholecystectomy, and lysis of peritoneal adhesions.<sup>1</sup> Additionally, almost 1.3 million women underwent cesarean section during the same year. The development of intra-abdominal adhesions following such procedures is considered an inevitable consequence. In a postmortem study conducted in the early 1970s, Weibel and Majno found that of all subjects who had previously undergone a minor, a major, or multiple operations, 51%, 72%, and 93%, respectively, had intra-abdominal adhesions.<sup>2</sup> Menzies and Ellis found that, of a series of 210 patients who had previously had one or more

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abdominal procedures, 93% had intra-abdominal adhesions at re-laparotomy.<sup>3</sup>

Prevention of the development of intra-abdominal adhesions has been the focus of several investigators, and various products have been tested. While the efficacy of such products remains under evaluation, the true incidence of adhesive-related morbidity and especially that of adhesive small bowel obstruction (SBO) has not been fully assessed. Additionally, since it is known that most adhesions remain silent, the factors that may make patients more prone to developing adhesion-related morbidity are not fully understood.

In the present review, we aim to comprehensively assess the incidence of adhesive SBO and report the available evidence identifying risk factors predisposing to this condition.

## Methods

The National Library of Medicine MEDLINE database was utilized to identify all articles related to the incidence and risk factors associated with adhesive SBO. English language citations published from January 1980 to May 2009 were included. The “related articles” option in the PubMed Entrez interface was utilized. The bibliography in the identified articles was also reviewed. Case reports, letters to editors, and review articles were excluded.

To identify risk factors related to the development of adhesive morbidity, we utilized the search terms “abdominal adhesions AND risk factors” and “adhesive small bowel obstruction AND risk factors”. In addition, specific risk factors that possibly predispose to adhesion development were queried to identify their association with intestinal obstruction. These risk factors included age, gender, immunosuppression, gallstone spillage, use of starch-containing surgical gloves, and closure of the peritoneum following laparotomy.

## Incidence

Determining the true incidence of adhesion-related morbidity following a laparotomy is difficult. While it is known that the vast majority of patients undergoing an abdominal procedure will develop intra-abdominal adhesions, the short- and long-term risks for developing adhesion-related morbidity cannot be predicted. The complex natural history of the disease, in addition to the significant heterogeneity between the studied populations and the failure of a reliable follow-up, enhance the difficulty of assessing the true risk associated with the presence of intra-abdominal adhesions.

The incidence of adhesion-related readmissions and adhesive SBO is available in the literature from several

sources. One major source is the trilogy of the Surgical and Clinical Adhesions Research (SCAR) studies, which utilized the Scottish National Health Service medical record linkage database.<sup>4–9</sup> These large-scale studies had the endpoint “adhesion-related readmissions”. Retrospective reports with a non-standardized follow-up, having as endpoints “early or late SBO requiring surgical intervention” is another source. A third source is the reported incidence of adhesive SBO in control patients of randomized controlled trials assessing the efficacy of adhesion preventive methods. Finally, patients enrolled in randomized controlled trials which aim to assess the cost-efficacy and safety of laparoscopic vs. open abdominal surgical procedures, comprise another source of data.

## The Surgical and Clinical Adhesions Research Studies

One of the most comprehensive efforts to evaluate the burden of adhesion-related morbidity was undertaken by the SCAR group. The investigators of this group utilized the Scottish National Health Service Medical Record Linkage Database, which holds data on individual linked patients' records on every inpatient and day-case hospital admission from 1981 onwards in Scotland, excluding psychiatric or maternity admissions.

The first SCAR study<sup>4</sup> focused on assessing the frequency of complications from adhesions in the general population. Patients undergoing initial abdominal or pelvic surgery in 1986 were analyzed, excluding those who had undergone abdominal or pelvic surgery in the previous 5 years. All patients were followed up for readmissions for defined outcomes over a period of 10 years. Despite all efforts to eliminate overestimation of the burden of adhesion-related readmissions, it was found that over 5.7% of all readmissions were directly related to adhesions, with 66.7% of these patients requiring adhesiolysis (Table 1). Overall, 7.3% of patients who had undergone a mid- and hindgut procedure were readmitted for reasons directly related to adhesions. This proportion was lower among patients who had undergone for gut or other abdominal procedures (4.6%) or female reproductive tract procedures (4.4%). One in three patients was readmitted at least twice over the 10-year study period, and at least one in 18 outcome readmissions (for operative and non-operative) were directly related to adhesions.

Parker et al.<sup>5</sup> used subsequently the same data and methodology to look specifically at patients who had undergone lower abdominal surgery (mid- and hindgut). It was found that patients who had undergone an initial operation involving the rectum had the highest rate of readmissions directly related to adhesions (8.8%), followed by those who had undergone an operation involving the small bowel (7.6%) and the colon (7.1%). Similarly, Lower et al.<sup>6</sup> examined specifically patients who had undergone an

**Table 1** Summary of the Results from the First Study from the Surgical and Clinical Adhesions Research (SCAR) Group<sup>4</sup>

	Readmissions directly related to adhesions	Readmissions possibly related to adhesions	Readmissions directly or possibly related to adhesions
Operation/adhesions	808 (2.7%)	3,186 (10.7%)	3,994 (13.4%)
Non-operative management	401 (1.4%)	5,054 (17.0%)	5,455 (18.4%)
Total	1,209 (4.1%)	8,240 (27.7%)	9,449 (31.7%)

Incidence of adhesion-related readmissions after open abdominal or pelvic surgery ( $N=29,790$ )

The study population comprises of patients who had undergone open abdominal or pelvic surgery in the year 1986 and no other abdominal or pelvic surgery in the previous 5 years. Patients were followed up for 10 years

open gynecological operation and found that patients who had undergone an ovarian operation had the highest risk for readmission directly related to adhesions, at 7.1% (Table 2).

An additional significant finding from these studies was that the greatest percentage of readmissions (22.1%) occurred in the first year after the index operation and continued to rise steadily over the 10-year follow-up for all outcome measures.<sup>4–6</sup>

The SCAR-2 study<sup>7</sup> aimed to examine the real-time burden of adhesion-related readmissions following colorectal surgery and to assess the impact of previous surgery on adhesion-related outcomes. The findings of this study demonstrated that the rates of adhesion-related readmissions (directly and possibly related) were 12.4%, 19.5%, 25.7%, and 29.7% at 1, 2, 3, and 4 years after the index surgery, respectively (Table 3). Lower et al.<sup>8</sup> used subsequently the same methodology to examine these outcomes in female patients undergoing open or laparoscopic gynecological procedures. The results from this examination demonstrated that with the exception of laparoscopic sterilization, which is considered a low-risk gynecological procedure for adhesion development, open and laparoscopic gynecological procedures are associated with comparable risks for adhesion-related readmissions (Table 4).

The SCAR-3 study<sup>9</sup> focused on aspects such as the nature of the surgery, age, comorbid conditions, and history of previous surgery. The findings of this study will be discussed in the following sections (Table 5).

Despite the serious limitations of registry-based studies, the SCAR studies comprise the first and most comprehen-

sive to date efforts to quantify the problem of adhesion-related readmissions. A major benefit of utilizing this database was the demography of Scotland, which, geographically, is self-contained and has a stable population of about 5.1 million, with less than 1% annual migration.<sup>10</sup>

### Risk Factors

Identification of patients who are at high risk of developing adhesions is important in prevention strategies. True risk factors that predispose patients to develop adhesion-related morbidity, however, and especially adhesive SBO, have not been clearly identified. Several have been proposed, but level I evidence is lacking in most instances.

### Type of Surgery

The type of surgery may be the most important factor that determines the incidence of adhesion-related morbidity, especially adhesive SBO. As mentioned, the SCAR studies have demonstrated a higher incidence of adhesion-related admissions for patients undergoing a mid- and hindgut surgery. Additionally, the SCAR-3 study demonstrated that patients undergoing an index surgery involving the ileum had the highest risk (7.7%), followed by those having abdominal wall and colorectal surgery (Table 5).

In our collective review of the literature, we analyzed 62 published studies in the English literature with 448,718 patients who underwent an abdominal operation. Overall,

**Table 2** Incidence of Adhesion-Related Readmissions After Open Surgery to the Reproductive System<sup>6</sup>

	Readmissions directly related to adhesions	Readmissions possibly related to adhesions	Readmissions directly or possibly related to adhesions
Operation/adhesions	245 (2.9%)	1,278 (15.1%)	1,523 (18.0%)
Non-operative management	–	1,201 (14.1%)	1,201 (14.1%)
Total	245 (2.9%)	2,479 (29.2%)	2,724 (31.1%)

Results from the Scottish National Health Service Medical Record Linkage Database ( $N=8,489$ )

Study population: Women with open surgery to the reproductive system

**Table 3** Summary of the Results from the Second Study of the Surgical and Clinical Adhesions Research (SCAR) Group<sup>7</sup>

Years following operation	Readmissions directly related to adhesions (%)	Readmissions possibly related to adhesions (%)	Total readmissions (%)
1	2.1	6.1	8.2
2	3.2	9.4	12.6
3	4.1	11.3	15.4
4	4.5	12.5	17.0

The results represent the directly and possibly adhesion-related readmissions for the subgroup of patients who had not undergone abdominopelvic procedure in the previous 5 years ( $N=2,067$ )

Study population: Patients with open colorectal surgery in 1996–1997 and no abdominal surgery in the previous 5 years

20,635 patients (4.6%) required adhesion-related readmission, mostly due to adhesive SBO (Table 6). The incidence varied widely according to procedure. The highest incidence was reported in patients with open adnexal surgery (23.9%), followed by patients with ileal pouch–anal anastomosis (19.3%), open total abdominal hysterectomy (15.6%), and open colectomy (9.5%).

The method of operation (open vs. laparoscopic) also plays an important role in the development of adhesive SBO. Collective review of the literature shows an incidence of 7.1% in open cholecystectomy vs. 0.2% in laparoscopic cholecystectomy, 15.6% in open total abdominal hysterectomy (TAH) vs. 0.0% in laparoscopic TAH, and 23.9% in open vs. 0.0% in laparoscopic adnexal operations. In the case of appendectomies, it seems that there is no difference between the open and laparoscopic techniques (1.4% vs. 1.3%; Table 6).

Due to the high incidence of SBO associated with colectomies, it would be expected that the beneficial effect of laparoscopy would be apparent. Despite the fact, however, that laparoscopy has been shown to be associated with a decreased adhesion formation,<sup>11</sup> this has not been shown to be associated with a lower incidence of SBO in colorectal surgery. A recent Cochrane meta-analysis assessing the

**Table 4** Adhesion-Related Readmissions within 4 Years After Open or Laparoscopic Gynecological Surgery<sup>8</sup>

Method of operation	Readmissions directly related to adhesions (%)	Readmissions possibly related to adhesions (%)	Total readmissions (%)
Laparoscopic ( $N=15,197$ )	1.5	16.1	17.6
Open ( $N=8,849$ )	2.0	14.5	16.5

Results from the Scottish National Health Service Medical Record Linkage Database ( $N=24,046$ )

**Table 5** Summary of the Results from the Third Study of the Surgical and Clinical Adhesions Research (SCAR) Group<sup>9</sup>

Site of surgery	Admissions directly related to adhesions within 5years of operation (%)
Duodenum ( $N=685$ )	1.8
Ileum ( $N=912$ )	7.7
Colon ( $N=3176$ )	5.0
Rectum ( $N=1,690$ )	5.2
Abdominal wall ( $N=2,180$ )	5.4
Appendix ( $N=4,113$ )	0.9

Readmissions directly related to lower abdominal surgery (excluding gynecological procedures) according to site and type of operation ( $N=12,756$ )

Study population: Patients with open lower abdominal surgery (excluding gynecological operations) during the period 1996–1997

long-term results of colorectal cancer resection failed to show a benefit with regards to reoperation for adhesions in patients undergoing a laparoscopic procedure when compared with those undergoing an open procedure.<sup>12</sup> In addition, the conventional vs. Laparoscopic-Assisted Surgery In Colorectal Cancer trial, which is attempting to evaluate the incidence of adhesion-related complications, particularly SBO, after laparoscopic and open colorectal surgery has failed to date to show any significant difference between the two approaches.<sup>13</sup>

In our collective review of the literature, however, we found that the incidence of SBO is twofold higher in open when compared with laparoscopic procedures (Table 6). It should be noted, however, that the studies reporting the incidence of SBO after the various types of surgery are highly heterogeneous. The follow-up is insufficient in most instances, while comorbid conditions are rarely accounted for. Selection bias puts into question the reported incidence.

#### Gender

Only a few studies examining the role of gender in the development of adhesion-related complications were identified, and the reported results were significantly conflicting. Riber et al.<sup>14</sup> examined the role of gender in patients undergoing open appendectomy and found that female patients had an almost fourfold higher overall risk for SBO requiring surgical intervention. Contrarily, Andresson<sup>15</sup> found that female patients were at a slightly lower risk for developing this complication [adjusted hazard ratio 0.8 (0.8–0.9)] in a similar population. The SCAR-3 study<sup>9</sup> did not report the results of the effect of gender on readmissions directly related to adhesions due to the significant skewness of the data towards women. Therefore, conclusions with regards to the role of gender cannot be withdrawn.

**Table 6** Overall Incidence of Adhesion-Related Readmissions According to the Type of Surgery

Surgery	Total number of patients	Adhesion-related readmissions	References
Open appendectomy	266,695	3,663 (1.4%)	5,9,14,15,22,23,45–65
Laparoscopic appendectomy	4,445	57 (1.3%)	16,22,45,46,48–60,62,63,66
Open cholecystectomy	141	10 (7.1%)	67,68
Laparoscopic cholecystectomy	7,103	11 (0.2%)	66–68
Open colectomy	121,085	11,491 (9.5%)	4,5,7,9,23,69–73
Laparoscopic colectomy	930	40 (4.3%)	66,72,74
Ileal pouch–anal anastomosis	5,268	1,018 (19.3%)	75–89
Laparotomy for trauma	1,913	48 (2.5%)	23–25,90,91
Gynecological procedures	38,751	4,297 (11.1%)	
Open TAH	20,377	3,182 (15.6%)	6,8,92
Laparoscopic TAH	303	0 (0.0%)	6,92
Open adnexal surgery	4,621	1,105 (23.9%)	6,8,92
Laparoscopic adnexal surgery	470	0 (0.0%)	6,92
Cesarean section	12,980	10 (0.1%)	6,8,92
Overall incidence	446,331	20,635 (4.6%)	

## Age

The role of age as a risk factor predisposing to adhesion-related morbidity has been examined in very few studies. The SCAR-3 study<sup>9</sup> found that patients <60 years old undergoing a colorectal surgery had a higher overall risk for readmission directly related to adhesions compared with their ≥60-year-old counterparts, even after censoring the data for mortality. This difference applied both, to patients who had or had not undergone an abdominopelvic procedure in the previous 5 years. Additionally, it was found that patients ≥16 years old undergoing an appendectomy were at higher risk for readmission directly related to adhesions over the following 5 years, when compared with young patients <16 years old. Contrarily, Andersson found that of all patients undergoing appendectomy, those in the age group 20–39 years had the lowest risk for SBO requiring surgery, while patients >70 years old had a twofold higher risk, compared with patients <20 years old.<sup>15</sup>

Age <40 years was identified as an independent risk factor for recurrence of adhesive SBO in a multicenter prospective study conducted in France with a median follow-up of 41 months (range, 1–75 months).<sup>16</sup>

## Immunosuppression and Comorbidities

Whether the difference in the risk for adhesion-related morbidity between the various age groups is attributed to immunosuppression associated with age, cannot be easily determined. Several studies suggest that immunosuppressed patients undergoing transplantation may have a decreased risk for adhesion formation due to the suppression of the

inflammatory response. In a retrospective review of 4,001 patients undergoing orthotopic liver transplantation, only 19 (0.5%) had postoperative SBO directly related to peritoneal adhesions.<sup>17</sup> Similarly, pancreas transplant recipients<sup>18</sup> demonstrate comparative low incidence of adhesive SBO.

Wasserberg et al.<sup>19</sup> in an experimental study in which groups of rats underwent small bowel transplantation and were subsequently randomized for tacrolimus immunosuppression versus no immunosuppression, it was found that postsurgical adhesion formation was significantly reduced in the immunosuppressed group of rats.<sup>19</sup>

Very few studies have evaluated this factor in the general surgery population and most of them have only looked at cancer patients. The SCAR-3 study demonstrated that patients with colorectal cancer had a significantly lower risk for adhesion-related readmissions.<sup>9</sup> The authors, however, attributed this difference to the type of surgery performed in this group, which was mostly right hemicolectomy and which was associated with a lower overall incidence of adhesion-related readmissions. Most of the other studies have demonstrated that patients with cancer are at higher risk for adhesive SBO. Park et al.<sup>20</sup> in a randomized controlled trial evaluating the efficacy of Seprafilm<sup>®</sup> reported an incidence of 7% for early in-hospital SBO and 4.6% for readmissions for SBO in the control group of cancer patients undergoing radical resection of their sigmoid or rectal cancer. However, there was no comparative group with no cancer patients in this study. Shin et al.<sup>21</sup> found that poor general condition, defined as American Society of Anesthesiologists (ASA) grade ≥3 and local remnant tumor were factors independently associated with early adhesive SBO in patients undergoing pelvic

surgery for colorectal cancer. Recently, Leung et al. reported that for patients undergoing an appendectomy, the risk for SBO is more than sevenfold higher in those with pathology of cancer or chronic appendicitis.<sup>22</sup> It is of note though, that other parameters, such as radiotherapy or chemotherapy, have not been accounted for.

The role of other comorbid conditions has been evaluated by the SCAR-3 study.<sup>9</sup> Patients with diverticulitis (without peritonitis) or Crohn's disease, conditions associated with inflammatory reaction in the abdomen, were not at higher risk for readmissions directly related to adhesions. The presence of peritonitis in patients who underwent appendectomy had a slightly higher risk to be readmitted when compared with patients who did not have peritonitis. This difference was most prominent in patients who had undergone previous surgery.

### Abdominal Trauma

Table 7 summarizes the incidence of SBO associated with negative or non-therapeutic laparotomy for trauma. Penetrating injuries and injuries to the small bowel seem to increase the risk of early SBO requiring surgery.<sup>23</sup> Tortella et al.<sup>24</sup> in a prospective study of 298 patients undergoing celiotomy for penetrating trauma found that the incidence of SBO in these patients was high, reaching 7.3%. In the same study, gunshot wounds and injury of the small or large bowel were found to increase this risk. In a prospective observational study of trauma patients undergoing laparotomy, Weigelt et al. found that only five of the 248 patients developed SBO during their follow-up.<sup>25</sup> All five patients had intra-abdominal injuries and underwent extensive exploration of the abdominal cavity, with access to the retroperitoneum.

### Closure of the Peritoneum After Midline Laparotomy

The association between suturing of the peritoneum on abdominal closure and adhesion formation is highly debated due to the lack of clinical evidence. Several studies in the general surgery literature have suggested that non-closure of the peritoneum after midline laparotomy is associated with reduced operative time and decreased rate of wound-related postoperative complications.<sup>26–28</sup> Evalu-

ation of adhesion formation in these patients, however, was not feasible, and SBO was not reported as an outcome.

In obstetrics, however, several studies have evaluated this association. Komoto et al.<sup>29</sup> randomized 124 women undergoing cesarean section into two groups, closure vs. non-closure of the peritoneum. These patients were evaluated at a second cesarean section for adhesion formation. The study reported that patients who had their peritoneum sutured had a higher incidence of extensive adhesions and required more frequently adhesiolysis. This study, however, did not utilize a scoring system for the adhesions, and the exclusion criteria were not adequate. Recently, a meta-analysis from Cheong et al.<sup>30</sup> which utilized strict quality criteria for inclusion of the studies, concluded that according to current data in the literature, there is some evidence to suggest that non-closure of the peritoneum after cesarean section is associated with more adhesion formation compared with closure.

Malvasi et al.<sup>31</sup> in a prospective, randomized study of women undergoing cesarean sections found that at repeat operation, women with peritoneal closure had a significantly higher incidence of adhesions compared with those with non-closure (57.0% vs. 20.6%,  $p < 0.05$ ). Although no scoring system was utilized, these investigators found on microscopy increased mesothelial hyperplasia, fibrosis, and neoangiogenesis in the group with peritoneal closure, and they concluded that this practice may predispose to inflammatory reaction and adhesion formation.

Despite the conflicting results of the available literature, it seems that non-closure of the peritoneum might be beneficial in reducing the incidence of postoperative intra-abdominal adhesions.

### Use of Starch-Free Gloves

Since the introduction of starch gloves in the late 1940s, the association between starch granules and adhesion formation has been studied extensively. Starch is an absorbable material and does not remain in the peritoneal cavity indefinitely. The time for this absorption to occur, however, has not been clarified. Sheikh et al.<sup>32</sup> showed that most of the starch powder granules had been disappeared by the fourth week in rats undergoing a laparotomy. Cade and Ellis, however, found that, in rats undergoing laparotomy,

**Table 7** The Incidence of Small Bowel Obstruction (SBO) After Negative or Non-Therapeutic Laparotomy for Trauma

Study	Number of patients	SBO	Mean follow-up
Tortella et al. <sup>24</sup>	154	5 (2.3%)	6 months
Weigelt et al. <sup>25</sup>	186	5 (2.7%)	57 months
Renz et al. <sup>90</sup>	254	6 (2.4%)	36 months
Morrison et al. <sup>91</sup>	80	0 (0.0%)	36 months
Total	674	16 (2.4%)	

starch granules could be detected even after 15 months, but only with PAS staining of the peritoneal tissue.<sup>33</sup> Examining the association of starch-powdered gloves with the development of adhesions in the clinical setting is hardly feasible. Cooke et al.<sup>34</sup> excised peritoneal nodules and band adhesions for pathological examination from patients undergoing re-laparotomy for several reasons. It was found that, in the vast majority of patients who had undergone the first laparotomy within the previous 2 years, starch granulomas could be detected and they were responsible for the development of intestinal obstruction. In most patients who had undergone the first laparotomy more than 2 years before the second laparotomy, starch granules could not be detected, but the associated band adhesions persisted. Luijendijk et al.<sup>35</sup>, in a similar study, found that, when granulomas were present, the median interval between present and most recent laparotomy was significantly shorter than when no granulomas were found. Additionally, in patients with adhesions who had had the previous operation less than 6 months previously, granulomas were present in 71%. In contrast, only 13% of the patients operated upon longer than 6 months previously had granulomas.

#### Gallstone Spillage During Cholecystectomy

Iatrogenic perforation of the gallbladder during laparoscopic cholecystectomy is common. In a review of the literature, Woodfield et al.<sup>36</sup> estimated that, in a total of 7.3% of patients undergoing laparoscopic cholecystectomy, gallstones will be spilt in the peritoneal cavity and approximately 33% of these patients will be discharged having retained gallstones.

The presence of gallstones in the peritoneal cavity has been associated with serious complications, including several types of intra-abdominal abscesses, postoperative fever, and development of enterocutaneous fistulae.<sup>37</sup> Despite the availability of animal data suggesting an association between retained gallstones and adhesion formation, such clinical consequences are rarely reported.<sup>38,39</sup> Examining this phenomenon in patients can be hardly achieved. Gallstone ileus due to stone erosion into the small bowel is a known entity, but the development of adhesions due to the presence of gallstones is far from understood. Adhesion formation after gallstone spillage may be highly related to the inflammatory response that the gallstones provoke as foreign bodies. In one of the largest series examining the complications associated with gallstone spillage during laparoscopic cholecystectomy, only one out of 547 patients developed ileus.<sup>40</sup> It is unclear however, if this ileus was due to adhesion formation. In a prospective study over a 7-year period of 106 patients who had gallstone spillage, none developed complications directly related to adhesions.<sup>41</sup> Similarly,

Manukian et al.<sup>42</sup> reported on 21 such patients who were followed up for a period of 121 months. None of these patients had any complication related to adhesion formation. Hui et al.<sup>43</sup> also found that retained gallstones did not have any significant effect on patients after a median follow-up of 44 months, while Assaff et al.<sup>44</sup> found that spillage of gallstones did not affect the overall in-hospital course of patients.

In summary, with the exception of small number of case reports, the overall association of gallstone spillage with formation of intra-abdominal adhesions in humans has not been clearly determined. Due to the available animal data and the rare, but serious other complications associated with retained gallstones, every effort should be made to remove any spilt stones in the peritoneal cavity during laparoscopic cholecystectomy.

#### Conclusion

Adhesion-related morbidity comprises a significant burden on healthcare resources, and prevention is of major importance, especially in high-risk patients. The most important risk factor is the type of surgery, with open surgical interventions in the lower abdomen carrying the highest risk. Laparoscopic procedures appear to be associated with lower incidence of adhesive SBO when compared with open procedures. This, however, does not apply to appendectomy. Closure of the peritoneum, use of gloves containing starch granules, and gallstone spillage during cholecystectomy all increase the risk for adhesion formation. Further understanding of the risk factors for developing adhesion-related morbidity is important for the development of preventive strategies.

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