Review

Prevention of postoperative peritoneal adhesions: a review of the literature

Beat Schnüriger, M.D., Galinos Barmparas, M.D., Bernardino C. Branco, M.D.,
Thomas Lustenberger, M.D., Kenji Inaba, M.D., F.R.C.S.C., F.A.C.S.,
Demetrios Demetriades, M.D., Ph.D., F.A.C.S.*

*Los Angeles County Medical Center, University of Southern California, Department of Surgery, Division of Acute Care
Surgery, Trauma, Emergency Surgery and Surgical Critical Care, LAC + USC Medical Center, Room 1105, 1200 North
State St, Los Angeles, CA, USA*

KEYWORDS:
Prevention;
Postoperative
peritoneal adhesions;
Review;
Bioabsorbable
barriers;
Risk factors

Abstract
   BACKGROUND: Postoperative adhesions are a significant health problem with major implications
on quality of life and health care expenses. The purpose of this review was to investigate the efficacy
of preventative techniques and adhesion barriers and identify those patients who are most likely to
benefit from these strategies.
   METHODS: The National Library of Medicine, Medline, Embase, and Cochrane databases were
used to identify articles related to postoperative adhesions.
   RESULTS: Ileal pouch–anal anastomosis, open colectomy, and open gynecologic procedures are
associated with the highest risk of adhesive small-bowel obstruction (class I evidence). Based on expert
opinion (class III evidence) intraoperative preventative principles, such as meticulous hemostasis,
avoiding excessive tissue dissection and ischemia, and reducing remaining surgical material have been
published. Laparoscopic techniques, with the exception of appendicitis, result in fewer adhesions than
open techniques (class I evidence). Available bioabsorbable barriers, such as hyaluronic acid/car-
boxymethylcellulose and icodextrin 4% solution, have been shown to reduce adhesions (class I
evidence).
   CONCLUSIONS: Postoperative adhesions are a significant health problem with major implications
on quality of life and health care. General intraoperative preventative techniques, laparoscopic tech-
niques, and the use of bioabsorbable mechanical barriers in the appropriate cases reduce the incidence
and severity of peritoneal adhesions.

Patients undergoing laparotomy for various reasons have a 90% risk of developing intraperitoneal adhesions,[1,2] and the incidence of re-admissions directly related to adhesions varies from 5% to 20%.[3–6] It is estimated that in the United States there are 117 hospitalizations for adhesion-related problems per 100,000 people and the total cost for hospital and surgeon expenditures is about $1.3 billion.[7] In some European countries the direct medical costs for adhesion-related problems were more than the surgical expenditure for gastric cancer and almost as much as for rectal cancer.[8,9]

In view of the magnitude of the health problems and financial burden related to adhesions, prevention or reduc-

tion of postoperative adhesions is an important priority. Numerous articles on the prevention of postoperative adhesions have been published but several controversies such as the effectiveness of available agents and their indication in general surgical patients still exist. Most of the available literature is based on gynecologic patients. For general surgical patients no recommendations or guidelines exist.

The purpose of this literature review was to assess the efficacy of various described adhesion prevention strategies after emergency and elective general surgery and to identify those patients who are most likely to benefit from these various prevention strategies.

Methods

The National Library of Medicine, Medline, Embase, and Cochrane databases were used to identify articles related to postoperative adhesions. English language citations published from January 1980 to May 2009 were assessed. The references in the identified articles also were reviewed. Case reports, letters to editors, and review articles were excluded.

To specifically identify preventative measures for the development of adhesive morbidity, we used the search terms "abdominal adhesion AND prevention" and "adhesive small bowel obstruction AND prevention." In addition, specific names of mechanical barriers were entered to identify all studies assessing their ability to prevent postoperative intestinal adhesions and obstruction. The titles and abstracts when available were scrutinized to select relevant controlled studies addressing the safety and efficacy of the use of these agents in abdominal surgery. A total of 39 studies and meta-analyses investigating different mechanical barriers were selected and further evaluated. Of those, 19 prospective randomized trials and 3 meta-analyses were identified and are discussed here in detail.[10–31]

Pathophysiology

Peritoneal tissue repair is a complex process that involves several different cell types, cytokines, coagulation factors, and proteases, all acting together to restore tissue integrity.[32] A complex interaction of biochemical events involved in inflammation, angiogenesis, and tissue repair control the adhesion formation process.[33]

It is widely accepted that the fibrinolytic system plays a central role in postoperative peritoneal healing. Immediately after surgical injury to the peritoneum there is bleeding and an increase in vascular permeability with extravasation of fibrinogen-rich fluid from the injured surfaces.[33–35] Almost simultaneously, an inflammatory response occurs, with migration of inflammatory cells, release of cytokines, and activation of the coagulation cascade.[32,35] The activation of the coagulation system results in thrombin formation, which is necessary for the conversion of fibrinogen to fibrin.[35] Fibrinolysis is a key factor in determining the amount of adhesion formation. Early fibrinolysis, within 5 days, encourages healing of the peritoneum without adhesion to the adjunct tissues.[36] However, if fibrinolysis does not occur within 5 to 7 days of the peritoneal injury, the temporary fibrin matrix persists and gradually becomes more organized as collagen-secreting fibroblasts and leads to adhesion formation.[32,37–39]

There are 2 major activators in the fibrinolytic system: tissue plasminogen activator and urokinase-like plasminogen activator. They are the main factors that convert plasminogen into active plasmin, a broad-range protease capable of degrading fibrin.[32,34] Plasminogen activator inhibitors inhibit fibrinolysis and encourage adhesion formation (Fig. 1).[34,40–42]

Inflammatory mediators also may play an important role in adhesion formation. There is experimental evidence that certain mediators, such as transforming growth factor-β and interleukins, decrease the fibrinolytic capacity of the peritoneum and increase the formation of adhesions.[43–46]

Clinical relevance of adhesion-related complications

Abdominal adhesions pose a significant health problem with major adverse effects on quality of life, use of health care resources, and financial costs. The most common adhesion-related problem is small-bowel obstruction (SBO). Adhesions are the most frequent cause of SBO in the developed world and are responsible for 60% to 70% of SBO.[4,47] In addition, adhesions have been implicated as a major cause of secondary infertility.[48–50] Pelvic adhesions were found to be responsible in 15% to 40% of infertilities.[51,52] It has been suggested that these adhesions may interfere with the ovum pick-up mechanism and gamete transportation. Furthermore, some investigators reported that adhesions are responsible for many cases of chronic abdominal pain although this concept remains a controversial issue.[53–56] Finally, the presence of adhesions makes reoperation more difficult, adds an average of 24 minutes to the surgery, increases the risk of iatrogenic bowel injury, and makes future laparoscopic surgery more difficult or even not possible.[57,58]

Risk factors for adhesion-related problems

The identification of high-risk patients may help in the development and use of adhesion-preventing strategies and advice them on the risk of adhesive SBO before an elective surgery. Review of the literature shows clearly that the most important risk factor for adhesive SBO is the type of surgery and extent of peritoneal damage. Surgeries of the colon and rectum are associated with a
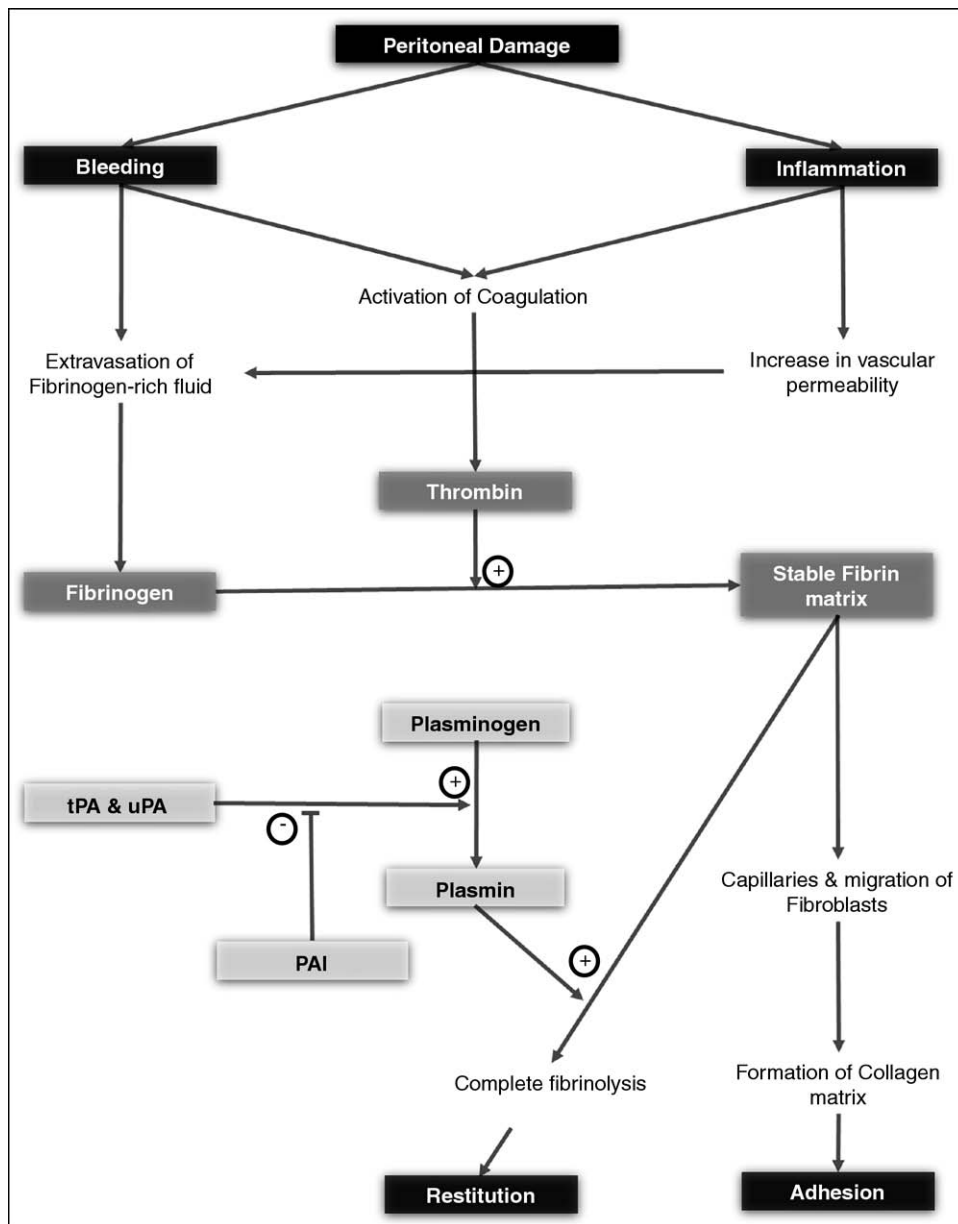
Figure 1   Pathophysiology of peritoneal adhesions. tPA = tissue plasminogen activator; uPA = urokinase-like plasminogen activator; PAI = plasminogen activator inhibitor.

higher risk of adhesion-related problems than surgeries to the small bowel, appendix, or gallbladder.[4] Total colectomy with ileal pouch–anal anastomosis is the procedure with the highest incidence for adhesion-related problems with an overall incidence of SBO of 19.3%. Other high-risk procedures include gynecologic surgeries (11.1%) and open colectomy (9.5%). Table 1 shows the incidence of adhesion-related re-admission after various abdominal surgical procedures. In general, open procedures, with the exception of appendectomy, have a higher risk for the development of adhesions than a laparoscopic intervention.[59]

Other possible risk factors include age younger than 60 years, previous laparotomy within 5 years, peritonitis, mul-tiple laparotomies, emergency surgery, omental resection, and penetrating abdominal trauma, especially gunshot wounds.[6,60–64]

Some studies examined possible risk factors for recurrence of SBO. There is evidence that with growing numbers of previous episodes of SBO requiring adhesiolysis, the risk for future re-admission for SBO increases.[65,66] The same studies identified nonsurgical management of the initial episode as a risk factor for recurrence. A multicenter pro-spective study of 286 patients with adhesive SBO and a 5-year follow-up period identified age younger than 40 years, the presence of matted adhesions, and surgical com-plications during the surgical management of the first epi-sode as independent risks for recurrence.[67]

Table 1 Incidence of adhesion-related re-admissions according to surgical procedure

Surgery	Total number of patients	Adhesion-related re-admission	References
Open appendectomy	266,695	3,663 (1.4%)	4,6,8,64,98–119
Laparoscopic appendectomy	4,445	57 (1.3%)	41,42,54,100,102,105–107,109–114,118,120
Open cholecystectomy	141	10 (7.1%)	121,122
Laparoscopic cholecystectomy	7,103	11 (.2%)	121–123
Open colectomy	121,085	11,491 (9.5%)	4–6,64,124–128
Laparoscopic colectomy	930	40 (4.3%)	123,128,129
Ileal pouch–anal anastomosis	5,268	1,018 (19.3%)	17,115,130–142
Gynecologic procedures	38,751	4297 (11.1%)	
Open hysterectomy	20,377	3,182 (15.6%)	143–145
Laparoscopic hysterectomy	303	0 (.0%)	6,145
Open adnexal surgery	4621	1,105 (23.9%)	143–145
Laparoscopic adnexal surgery	470	0 (.0%)	144,145
Cesarean section	12,980	10 (.1%)	143–145
Overall incidence	446,331	20,635 (4.6%)	

Prevention

In view of the magnitude of the medical problems and financial burden related to adhesions, prevention or reduction of postoperative adhesions in an important priority. Some groups have recognized the importance of the problem and have attempted to educate physicians on this issue. Numerous articles on adhesion barriers have been published but several controversies such as the effectiveness of available agents and their indication in general surgical patients still exist. Most of the available literature is based on gynecologic patients. For general surgical patients no recommendations or guidelines exist.

Any prevention strategy should be safe, effective, practical, and cost effective. A combination of prevention strategies might be more effective but our knowledge on this topic is fairly limited. The prevention strategies can be grouped into 4 categories: general principles, surgical techniques, mechanical barriers, and chemical agents.

General principles

Intraoperative techniques such as avoiding unnecessary peritoneal dissection, avoiding spillage of intestinal contents or gallstones, and the use of starch-free gloves are basic principles that should be applied to all patients.

Starched gloves are a preventable significant risk factor for postoperative adhesions. Several experimental studies have shown that the use of starch-powdered gloves during laparotomy is associated with an increased risk of extensive adhesions.[68,69] Examining the association between starched gloves and adhesions in the clinical setting is difficult. Cooke and Hamilton[70] found that in most patients with an abdominal surgery who had undergone laparotomy within the previous 2 years, starch granulomas could be detected in peritoneal nodules and adhesions and were responsible for the development of SBO. The investigators suggested that although starch usually is absorbed within 2 years, associated band adhesions may persist.

The role of gallstone spillage in adhesion formation is not clear. Experimental evidence implicates gallstone spillage into the peritoneal cavity in the formation of adhesions.[71–73] Infected gallstones were associated with more extensive adhesions.[71,72,74] Some investigators suggested that noninfected gallstones do not increase the risk of adhesion formation.[74–76] The role of gallstone spillage in adhesion formation in the clinical situation is not as clear as shown in experimental studies. In more than 7% of laparoscopic cholecystectomies there is accidental perforation of the gallbladder and spillage of gallstones and about one third of these patients will be discharged with retained intraperitoneal stones.[77] The available literature on the significance of this complication is limited in quantity and quality. Memon et al[78] reported no adhesive SBO over a 7-year period in 106 patients who had gallstone spillage during cholecystectomy. Similar results were reported by other smaller series.[79,80] In view of the limitations of the available clinical studies and the incriminating findings of experimental studies, every effort should be made to avoid accidental gallstone spillage and retrieve any spilled gallstones.

Surgical techniques

The surgical approach (open vs laparoscopic surgery) plays an important role in the development of adhesive SBO. In most abdominal procedures the laparoscopic approach is associated with a significantly lower incidence of adhesive SBO or adhesion-related re-admission. In a collective review of the literature the incidence of adhesion-related re-admissions was 7.1% in open versus .2% in laparoscopic cholecystectomies, 9.5% in open versus 4.3% in laparoscopic colectomy, 15.6% in open versus 0% in laparoscopic total abdominal hysterectomy, and 23.9% in open versus 0% in laparoscopic adnexal surgery. Only in appendectomies there was no difference between the 2 techniques (Table 1).

The role of surgical handling of the peritoneum during the surgery in adhesion formation is not clear. Many experimental studies have shown that nonclosure of the peritoneum was associated with decreased adhesion formation.[81–84] However, some studies reported no difference[85,86] or even decreased adhesion formation[87] with closure.

In the clinical setting there are no reliable data regarding the management of the peritoneum after a midline incision. However, there is some class I evidence in obstetrics supporting the theory that suturing the peritoneum increases the risk of adhesions. Komoto et al[88] randomized 124 women undergoing a cesarean section into 2 groups, closure or no 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 frequent adhesiolysis. Similar results were reported by Malvasi et al[89] in a prospective randomized study of women undergoing cesarean sections. At repeat surgery, women with peritoneal closure had a significantly higher incidence of adhesions than those without closure (57% vs 20.6%; $P < .05$). Microscopy showed increased mesothelial hyperplasia, fibrosis, and neoangiogenesis in the group with peritoneal closure. In view of these findings it is prudent to avoid peritoneal closure during laparotomies.

Mechanical barriers

In theory, inert materials that prevent contact between the damaged serosal surfaces for the first few critical days allow separate healing of the injured surfaces and may help in the prevention of adhesion formation. Various bioabsorbable films or gels, solid membranes, or fluid barrier agents have been tested experimentally and in clinical trials. Table 2 summarizes materials for adhesion prevention that the Food and Drug Administration has approved. A significant amount of research has been conducted in gynecologic surgery because a second follow-up laparoscopy after the initial surgery is common, thus allowing the evaluation of the efficacy of the therapeutic agents in reducing adhesions. The most extensively studied bioabsorbable films are Seprafilm (Genzyme Corporation, Cambridge, MA) and Interceed (Johnson & Johnson, New Brunswick, NJ).

Hyaluronic acid/carboxymethylcellulose

Hyaluronic acid/carboxymethylcellulose (Seprafilm) is the most extensively tested adhesion prevention agent in general surgery. It is absorbed within 7 days and excreted from the body within 28 days.[35] Its safety with regard to systemic or specific complications, such as abdominal abscess, wound sepsis, anastomotic leak, and prolonged ileus, has been established in many studies, including a safety study of 1,791 patients with abdominal or pelvic surgery.[90] There are concerns about a higher incidence of anastomotic

Table 2 Food and Drug Administration–approved mechanical barriers for the prevention of mechanical adhesions

Agent	Mechanism of action	Trade name	Reduction of adhesions	Advantages	Disadvantages	References
Hyaluronic acid/ carboxymethyl cellulose (film)	Physical barrier that separates traumatized tissue surfaces, absorbed within 7 days	Seprafilm	Effective in gynecologic and elective colorectal surgery (class I evidence)	Safe and effective in reducing the incidence of adhesions and early SBO	Prevention of late SBO remains uncertain Safety in contaminated condition remains uncertain	10–18
Oxidized regenerated cellulose	Physical barrier that forms a gelatinous protective coat to separate injured surfaces, absorbed within 14 days	Interceed	Effective in gynecologic patients (class I evidence)	Safe and effective in reducing the incidence and extent of adhesions after gynecologic surgeries	Not studied in general surgical patients	19–29
Icodextrin 4%	Temporary separation of peritoneal surfaces by hydroflotation as a result of maintaining a fluid reservoir for up to 3–4 days	Adept	Effective in gynecologic patients (class I evidence)	Safe and effective in reducing the incidence of adhesions, can be administered laparoscopically	Prevention of late SBO remains uncertain Adept is contraindicated in cases involving bowel resection or repair, appendectomy, and in surgical cases with frank abdominopelvic infection	30

Class I evidence was from a randomized controlled study.

leaks in cases in which the film is placed directly around the anastomosis.[90] Numerous prospective randomized controlled trials showed efficacy in reducing the incidence and extent of postoperative adhesions. Becker et al,[10] in a prospective, randomized, multicenter, double-blind study of 175 evaluable patients with colectomy and ileoanal pouch procedure, compared Seprafilm with controls. The incidence, extent, and severity of adhesions were assessed laparoscopically by a blinded observer at second surgery 8 to 12 weeks after the initial surgery for ileostomy closure. The Seprafilm group had significantly fewer and less severe adhesions (odds ratio [OR], .06; 95% confidence interval [CI], .02–.16).

Tang et al[11] in a prospective, single-center study randomized 70 patients undergoing an elective rectal resection who needed an ileostomy into a Seprafilm and a control group. The outcomes included severity of adhesions and stomal complications at ileostomy closure at 3 weeks after the initial surgery. The study reported a significant reduction of the mean adhesion scores in the treatment group (5.81 ± .5 vs 7.82 ± .6; $P < .05$). Also, there was a tendency to easier closure and a lower incidence of perioperative complications.

Vrijland et al,[12] in a prospective multicenter study, randomized 71 patients undergoing Hartmann's resection into a Seprafilm and a control group. The outcomes included the incidence and severity of adhesions and complications and were evaluated at a second planned surgery by a blinded evaluator. Although the incidence of adhesions did not differ significantly between the study groups (OR, .34; 95% CI, .06–1.98), the Seprafilm group showed a significant reduction of the severity of adhesions.

Cohen et al,[13] in a prospective multicenter trial, randomized 120 patients with colectomy and ileal pouch surgeries into a Seprafilm and a control group. The outcomes included incidence and severity of adhesions and were assessed laparoscopically by a blinded observer at a second surgery 8 to 12 weeks later for ileostomy closure. Treatment with Seprafilm significantly reduced the incidence and severity of adhesions (OR, .23; 95% CI, .08–.62).

Kusunoki et al,[14] in a prospective randomized study of 62 patients who underwent surgery for rectal carcinoma, compared Seprafilm with no treatment. The outcomes included severity of adhesions at the subsequent surgery for ileostomy closure. Seprafilm significantly reduced the adhesions in both the midline incision area and the peristomal area. This was associated with shorter surgical time, reduced blood loss, and smaller incisions for ileostomy closure.

Kumar et al[15] in a recent Cochrane collective review of 6 randomized trials with nongynecologic surgical patients found that Seprafilm significantly reduced the incidence of adhesions (OR, .15; 95% CI, .05–.43; $P < .001$) and the extent of adhesion (mean difference, −25.9%; 95% CI, −40.56 to −11.26; $P < .001$).

The experience with Seprafilm in gynecologic surgeries is fairly limited. Diamond,[16] in a prospective, randomized, blinded multicenter study of 127 women undergoing myomectomy, compared Seprafilm with no treatment. The incidence, severity, and extent of adhesions were assessed laparoscopically at a mean of 23 days after the initial procedure. The incidence, measured as the mean number of sites adherent to the uterine surface, was significantly less in treated patients than in untreated patients (mean ± standard error of the mean, 4.98 ± .52 vs 7.88 ± .48 sites; $P < .05$), severity and extent of adhesions (mean ± standard error of the mean, 13.2 ± 1.67 vs 18.7 ± 1.66 cm^2; $P < .05$) were significantly less in the treated group.

Although there is satisfactory class I evidence that Seprafilm significantly reduces the incidence and severity of postoperative adhesions, there is fairly limited work on the effect of this adhesion reduction on the incidence of SBO. Clinical trials evaluating this specific outcome are difficult to perform because of the need for long-term follow-up evaluation of a large number of patients. Fazio et al,[17] in a prospective, randomized, multicenter, single-blind study of 1,791 patients with intestinal resection compared Seprafilm with no treatment intervention. The mean follow-up time for SBO was 3.5 years. There was no difference between the Seprafilm and control group in the overall incidence of SBO (12% vs 12%). However, the incidence of SBO requiring surgical intervention was significantly lower in the Seprafilm group (1.8% vs 3.4%; $P < .05$). This was an absolute reduction of 1.6% and a relative reduction of 47%. Stepwise multivariate analysis showed that the use of Seprafilm was the only independent factor for reducing SBO requiring reoperation. In both groups, 50% of the first episodes of SBO occurred within 6 months of the initial surgery, with nearly 30% occurring within the first 30 days.

Kudo et al[18] in a nonrandomized study of 51 patients who underwent transabdominal aortic aneurysm surgery, analyzed the incidence of early SBO in patients who had Seprafilm applied and in control patients with no treatment. The incidence of early SBO was 0% in the Seprafilm group and 20% in the control group ($P < .05$). Early SBO was defined according to Pickleman and Lee[91]: patients who have symptoms of SBO within 30 days after the surgery, symptoms that last for 7 days or more, or symptoms of any duration that occurred 7 to 30 days after the surgery. These symptoms included distension, obstipation, abdominal pain, vomiting, and altered bowel sounds, as well as radiologic findings with dilated small bowel and air fluid levels.

Oxidized regenerated cellulose

Oxidized regenerated cellulose (Interceed) is a mechanical barrier that forms a gelatinous protective coat and breaks down and is absorbed within 2 weeks. This product has been studied in numerous prospective randomized studies in open or laparoscopic gynecologic surgeries. It has been shown to be safe and effective in reducing adhesions.

Azziz,[19] in a prospective randomized study of 134 women undergoing adhesiolysis by laparotomy (268 pelvic sidewalls), applied Interceed on one sidewall and left the opposite side uncovered. The incidence and severity of adhesions were evaluated at a second-look laparoscopy 10 days to 14 weeks after surgery. Interceed significantly reduced the incidence and extent of adhesions.

Larsson et al[20] of the Nordic Adhesion Prevention Study group in a multicenter, prospective, randomized, blinded study of 66 women undergoing adhesiolysis of 132 ovaries used Interceed around the adnexa on one side and left the other side uncovered. The incidence and severity of adhesions were assessed at a second-look laparoscopy 4 to 10 weeks after the initial surgery. The study showed that Interceed significantly reduced the incidence, extent, and severity of adhesions.

Other smaller, prospective, randomized studies using the same methodology showed similar efficacy of Interceed application in laparoscopic or open surgery.[21–27] A meta-analysis of 7 randomized studies showed that Interceed decreased the incidence of adhesions by 24.2% ± 3.3% ($P < .001$) when compared with untreated sites.[28] A more recent meta-analysis also concluded that Interceed reduced the incidence and severity of adhesions after open or laparoscopic gynecologic surgery.[29]

Expanded polytetrafluoroethylene

Expanded polytetrafluoroethylene (Gore-Tex, Preclude; W.L. Gore & Associates, 's Hertogenbosch, The Netherlands): It is an inert, nonabsorbable permanent membrane that needs to be removed a few days after application. It has been studied mainly in gynecologic surgeries with favorable results.[92] Its usefulness is limited because of the need to be removed surgically at a later stage.

Bioabsorbable gels

Various agents have been developed and tested, but most have been abandoned or withdrawn because of safety issues or a lack of efficacy. SprayGel (Confluent Surgical, Inc, Waltham, MA) is one of the more extensively tested gels. It is a sprayable hydrogel that adheres to the tissues for a period of 5 to 7 days. After several days it is hydrolyzed into water-soluble molecules and is absorbed. The safety of SprayGel has been shown in a few gynecologic and colorectal studies.[93–96] Although early preliminary clinical trials showed its effectiveness, a larger-scale study was stopped owing to a lack of efficacy.[31]

Fluid agents

Fluid agents have the theoretical advantage of covering more potential sites of adhesion formation than mechanical barriers. However, the experience is still limited and much more work is needed to show their efficacy.

The most widely studied and the only Food and Drug Administration–approved adhesion-prevention fluid agent in laparoscopic surgery is Adept (Baxter Healthcare, Deerfield, IL). Adept (icodextrin 4% solution) is used as an irrigant fluid throughout surgery and at the end of surgery 1,000 mL is instilled and left in the peritoneal cavity. The fluid remains in the peritoneal cavity for several days and separates the damaged surfaces during the critical period of adhesion formation. A large multicenter, prospective, randomized, double-blind study by Brown et al[30] compared Adept (N = 203) with lactated Ringer's solution (N = 199), in women undergoing laparoscopic gynecologic surgery for adhesiolysis. The study patients returned for a second laparoscopy within 4 to 8 weeks. Adept was significantly more likely to reduce adhesions and improve fertility scores than lactated Ringer's solution. There was a higher incidence of labial swelling in the treatment group (6% vs .4%; $P = .002$).

Intergel solution (Lifecore Biomedical, Inc, Chaska, MN), which contains .5% ferric hyaluronate, is another solution used for adhesion prevention. In preliminary studies it has been shown to reduce the number, severity, and extent of adhesions in peritoneal surgery.[95] However, the use of Intergel in abdominal surgery in which the gastrointestinal tract was opened led to an unacceptably high rate of postoperative complications.[97]

Conclusions

Postoperative adhesions are a significant health problem with major implications on quality of life and health care expenses. General intraoperative preventative techniques, such as starch-free gloves, avoiding unnecessary peritoneal dissection, avoiding spillage of intestinal contents or gallstones, and reducing remaining surgical material, may reduce the risk of adhesions and should be applied in every patient. Laparoscopic techniques are preferable to open techniques whenever possible. In high-risk procedures the use of bioabsorbable mechanical barriers should be considered.

Acknowledgments

References

1. Menzies D, Ellis H. Intestinal obstruction from adhesions—how big is the problem? Ann R Coll Surg Engl 1990;72:60–3.

2. Weibel MA, Majno G. Peritoneal adhesions and their relation to abdominal surgery. A postmortem study. Am J Surg 1973;126: 345–53.

3. Parker MC, Wilson MS, Menzies D, et al. Colorectal surgery: the risk and burden of adhesion-related complications. Colorectal Dis 2004; 6:506–11.

4. Parker MC, Ellis H, Moran BJ, et al. Postoperative adhesions: ten-year follow-up of 12,584 patients undergoing lower abdominal surgery. Dis Colon Rectum 2001;44:822–30.

5. Ellis H, Moran BJ, Thompson JN, et al. Adhesion-related hospital readmissions after abdominal and pelvic surgery: a retrospective cohort study. Lancet 1999;353:1476–80.

6. Parker MC, Wilson MS, Menzies D, et al. The SCAR-3 study: 5-year adhesion-related readmission risk following lower abdominal surgical procedures. Colorectal Dis 2005;7:551–8.

7. Ray NF, Denton WG, Thamer M, et al. Abdominal adhesiolysis: inpatient care and expenditures in the United States in 1994. J Am Coll Surg 1998;186:1–9.

8. Tingstedt B, Johansson J, Nehez L, et al. Late abdominal complaints after appendectomy—readmissions during long-term follow-up. Dig Surg 2004;21:23–7.

9. Kossi J, Salminen P, Rantala A, et al. Population-based study of the surgical workload and economic impact of bowel obstruction caused by postoperative adhesions. Br J Surg 2003;90:1441–4.

10. Becker JM, Dayton MT, Fazio VW, et al. Prevention of postoperative abdominal adhesions by a sodium hyaluronate-based bioresorbable membrane: a prospective, randomized, double-blind multicenter study. J Am Coll Surg 1996;183:297–306.

11. Tang CL, Seow-Choen F, Fook-Chong S, et al. Bioresorbable adhesion barrier facilitates early closure of the defunctioning ileostomy after rectal excision: a prospective, randomized trial. Dis Colon Rectum 2003;46:1200–7.

12. Vrijland WW, Tseng LN, Eijkman HJ, et al. Fewer intraperitoneal adhesions with use of hyaluronic acid-carboxymethylcellulose membrane: a randomized clinical trial. Ann Surg 2002;235:193–9.

13. Cohen Z, Senagore AJ, Dayton MT, et al. Prevention of postoperative abdominal adhesions by a novel, glycerol/sodium hyaluronate/carboxymethylcellulose-based bioresorbable membrane: a prospective, randomized, evaluator-blinded multicenter study. Dis Colon Rectum 2005;48:1130–9.

14. Kusunoki M, Ikeuchi H, Yanagi H, et al. Bioresorbable hyaluronate-carboxymethylcellulose membrane (Seprafilm) in surgery for rectal carcinoma: a prospective randomized clinical trial. Surg Today 2005; 35:940–5.

15. Kumar S, Wong PF, Leaper DJ. Intra-peritoneal prophylactic agents for preventing adhesions and adhesive intestinal obstruction after non-gynaecological abdominal surgery. Cochrane Database Syst Rev 2009;1:CD005080.

16. Diamond MP. Reduction of adhesions after uterine myomectomy by Seprafilm membrane (HAL-F): a blinded, prospective, randomized, multicenter clinical study. Seprafilm Adhesion Study Group. Fertil Steril 1996;66:904–10.

17. Fazio VW, Cohen Z, Fleshman JW, et al. Reduction in adhesive small-bowel obstruction by Seprafilm adhesion barrier after intestinal resection. Dis Colon Rectum 2006;49:1–11.

18. Kudo FA, Nishibe T, Miyazaki K, et al. Use of bioresorbable membrane to prevent postoperative small bowel obstruction in transabdominal aortic aneurysm surgery. Surg Today 2004;34:648–51.

19. Azziz R. Microsurgery alone or with INTERCEED absorbable adhesion barrier for pelvic sidewall adhesion re-formation. The INTERCEED (TC7) Adhesion Barrier Study Group. II. Surg Gynecol Obstet 1993;177:135–9.

20. The efficacy of Interceed (TC7)* for prevention of reformation of postoperative adhesions on ovaries, fallopian tubes, and fimbriae in microsurgical operations for fertility: a multicenter study. Nordic Adhesion Prevention Study Group. Fertil Steril 1995;63:709–14.

21. Franklin RR. Reduction of ovarian adhesions by the use of Interceed. Ovarian Adhesion Study Group. Obstet Gynecol 1995;86:335–40.

22. Greenblatt EM, Casper RF. Adhesion formation after laparoscopic ovarian cautery for polycystic ovarian syndrome: lack of correlation with pregnancy rate. Fertil Steril 1993;60:766–70.

23. Keckstein J, Ulrich U, Sasse V, et al. Reduction of postoperative adhesion formation after laparoscopic ovarian cystectomy. Hum Reprod 1996;11:579–82.

24. Mais V, Ajossa S, Marongiu D, et al. Reduction of adhesion reformation after laparoscopic endometriosis surgery: a randomized trial with an oxidized regenerated cellulose absorbable barrier. Obstet Gynecol 1995;86:512–5.

25. Mais V, Ajossa S, Piras B, et al. Prevention of de-novo adhesion formation after laparoscopic myomectomy: a randomized trial to evaluate the effectiveness of an oxidized regenerated cellulose absorbable barrier. Hum Reprod 1995;10:3133–5.

26. Saravelos H, Li TC. Post-operative adhesions after laparoscopic electrosurgical treatment for polycystic ovarian syndrome with the application of Interceed to one ovary: a prospective randomized controlled study. Hum Reprod 1996;11:992–7.

27. Wallwiener D, Meyer A, Bastert G. Adhesion formation of the parietal and visceral peritoneum: an explanation for the controversy on the use of autologous and alloplastic barriers? Fertil Steril 1998; 69:132–7.

28. Wiseman DM, Trout JR, Franklin RR, et al. Metaanalysis of the safety and efficacy of an adhesion barrier (Interceed TC7) in laparotomy. J Reprod Med 1999;44:325–31.

29. Ahmad G, Duffy JM, Farquhar C, et al. Barrier agents for adhesion prevention after gynaecological surgery. Cochrane Database Syst Rev 2008;16:CD000475.

30. Brown CB, Luciano AA, Martin D, et al. Adept (icodextrin 4% solution) reduces adhesions after laparoscopic surgery for adhesiolysis: a double-blind, randomized, controlled study. Fertil Steril 2007; 88:1413–26.

31. Bhardwaj R, Parker MC. Impact of adhesions in colorectal surgery. Colorectal Dis 2007;9(Suppl 2):45–53.

32. Holmdahl L, Ivarsson ML. The role of cytokines, coagulation, and fibrinolysis in peritoneal tissue repair. Eur J Surg 1999;165:1012–9.

33. Reed KL, Fruin AB, Bishop-Bartolomei KK, et al. Neurokinin-1 receptor and substance P messenger RNA levels increase during intraabdominal adhesion formation. J Surg Res 2002;108:165–72.

34. Cheong YC, Laird SM, Li TC, et al. Peritoneal healing and adhesion formation/reformation. Hum Reprod Update 2001;7:556–66.

35. Reijnen MM, Bleichrodt RP, van Goor H. Pathophysiology of intra-abdominal adhesion and abscess formation, and the effect of hyaluronan. Br J Surg 2003;90:533–41.

36. Sulaiman H, Dawson L, Laurent GJ, et al. Role of plasminogen activators in peritoneal adhesion formation. Biochem Soc Trans 2002;30:126–31.

37. Rout UK, Diamond MP. Role of plasminogen activators during healing after uterine serosal lesioning in the rat. Fertil Steril 2003; 79:138–45.

38. Dijkstra FR, Nieuwenhuijzen M, Reijnen MM, et al. Recent clinical developments in pathophysiology, epidemiology, diagnosis and treatment of intra-abdominal adhesions. Scand J Gastroenterol Suppl 2000;232:52–9.

39. Holmdahl L. Making and covering of surgical footprints. Lancet 1999;353:1456–7.

40. Holmdahl L, Eriksson E, al-Jabreen M, et al. Fibrinolysis in human peritoneum during operation. Surgery 1996;119:701–5.

41. Ivarsson ML, Bergstrom M, Eriksson E, et al. Tissue markers as predictors of postoperative adhesions. Br J Surg 1998;85:1549–54.

42. Moore KL, Bang NU, Broadie TA, et al. Peritoneal fibrinolysis: evidence for the efficiency of the tissue-type plasminogen activator. J Lab Clin Med 1983;101:921–9.

43. Williams RS, Rossi AM, Chegini N, et al. Effect of transforming growth factor beta on postoperative adhesion formation and intact peritoneum. J Surg Res 1992;52:65–70.

44. Holmdahl L, Kotseos K, Bergstrom M, et al. Overproduction of transforming growth factor-beta1 (TGF-beta1) is associated with ad-

hesion formation and peritoneal fibrinolytic impairment. Surgery 2001;129:626–32.

45. Tsukada K, Katoh H, Shiojima M, et al. Concentrations of cytokines in peritoneal fluid after abdominal surgery. Eur J Surg 1993;159: 475–9.

46. Whawell SA, Thompson JN. Cytokine-induced release of plasminogen activator inhibitor-1 by human mesothelial cells. Eur J Surg 1995;161:315–8.

47. Ellis H. The magnitude of adhesion related problems. Ann Chir Gynaecol 1998;87:9–11.

48. Tulandi T, Collins JA, Burrows E, et al. Treatment-dependent and treatment-independent pregnancy among women with periadnexal adhesions. Am J Obstet Gynecol 1990;162:354–7.

49. Marana R, Rizzi M, Muzii L, et al. Correlation between the American Fertility Society classifications of adnexal adhesions and distal tubal occlusion, salpingoscopy, and reproductive outcome in tubal surgery. Fertil Steril 1995;64:924–9.

50. Marana R, Catalano GF, Muzii L, et al. The prognostic role of salpingoscopy in laparoscopic tubal surgery. Hum Reprod 1999;14: 2991–5.

51. Milingos S, Kallipolitis G, Loutradis D, et al. Adhesions: laparoscopic surgery versus laparotomy. Ann N Y Acad Sci 2000;900: 272–85.

52. Vrijland WW, Jeekel J, van Geldorp HJ, et al. Abdominal adhesions: intestinal obstruction, pain, and infertility. Surg Endosc 2003;17: 1017–22.

53. Klingensmith ME, Soybel DI, Brooks DC. Laparoscopy for chronic abdominal pain. Surg Endosc 1996;10:1085–7.

54. Hallfeldt KK, Kantelhardt T, Waldner H, et al. [Laparoscopic adhesiolysis in therapy of chronic abdominal pain]. Zentralbl Chir 1995; 120:387–91.

55. Kolmorgen K, Schulz AM. [Results of laparoscopic lysis of adhesions in patients with chronic pelvic pain]. Zentralbl Gynakol 1991; 113:291–5.

56. Swank DJ, Swank-Bordewijk SC, Hop WC, et al. Laparoscopic adhesiolysis in patients with chronic abdominal pain: a blinded randomised controlled multi-centre trial. Lancet 2003;361:1247–51.

57. Coleman MG, McLain AD, Moran BJ. Impact of previous surgery on time taken for incision and division of adhesions during laparotomy. Dis Colon Rectum 2000;43:1297–9.

58. Van Der Krabben AA, Dijkstra FR, Nieuwenhuijzen M, et al. Morbidity and mortality of inadvertent enterotomy during adhesiotomy. Br J Surg 2000;87:467–71.

59. Gutt CN, Oniu T, Schemmer P, et al. Fewer adhesions induced by laparoscopic surgery? Surg Endosc 2004;18:898–906.

60. Luijendijk RW, de Lange DC, Wauters CC, et al. Foreign material in postoperative adhesions. Ann Surg 1996;223:242–8.

61. Frykberg ER, Phillips JW. Obstruction of the small bowel in the early postoperative period. South Med J 1989;82:169–73.

62. Menzies D. Postoperative adhesions: their treatment and relevance in clinical practice. Ann R Coll Surg Engl 1993;75:147–53.

63. Tortella BJ, Lavery RF, Chandrakantan A, et al. Incidence and risk factors for early small bowel obstruction after celiotomy for penetrating abdominal trauma. Am Surg 1995;61:956–8.

64. Stewart RM, Page CP, Brender J, et al. The incidence and risk of early postoperative small bowel obstruction. A cohort study. Am J Surg 1987;154:643–7.

65. Barkan H, Webster S, Ozeran S. Factors predicting the recurrence of adhesive small-bowel obstruction. Am J Surg 1995;170:361–5.

66. Fevang BT, Fevang J, Lie SA, et al. Long-term prognosis after operation for adhesive small bowel obstruction. Ann Surg 2004;240: 193–201.

67. Duron JJ, Silva NJ, du Montcel ST, et al. Adhesive postoperative small bowel obstruction: incidence and risk factors of recurrence after surgical treatment: a multicenter prospective study. Ann Surg 2006; 244:750–7.

68. Holmadhl L, al-Jabreen M, Xia G, et al. The impact of starch-powdered gloves on the formation of adhesions in rats. Eur J Surg 1994;160:257–61.

69. van den Tol MP, Haverlag R, van Rossen ME, et al. Glove powder promotes adhesion formation and facilitates tumour cell adhesion and growth. Br J Surg 2001;88:1258–63.

70. Cooke SA, Hamilton DG. The significance of starch powder contamination in the aetiology of peritoneal adhesions. Br J Surg 1977;64: 410–2.

71. Agalar F, Sayek I, Agalar C, et al. Factors that may increase morbidity in a model of intra-abdominal contamination caused by gallstones lost in the peritoneal cavity. Eur J Surg 1997;163:909–14.

72. Johnston S, O'Malley K, McEntee G, et al. The need to retrieve the dropped stone during laparoscopic cholecystectomy. Am J Surg 1994;167:608–10.

73. Sax HC, Adams JT. The fate of the spilled gallstone. Arch Surg 1993;128:469.

74. Soybir GR, Koksoy F, Polat C, et al. The effects of sterile or infected bile and dropped gallstones in abdominal adhesions and abscess formation. Surg Endosc 1997;11:711–3.

75. Welch N, Hinder RA, Fitzgibbons RJ Jr, et al. Gallstones in the peritoneal cavity. A clinical and experimental study. Surg Laparosc Endosc 1991;1:246–7.

76. Cline RW, Poulos E, Clifford EJ. An assessment of potential complications caused by intraperitoneal gallstones. Am Surg 1994;60: 303–5.

77. Woodfield JC, Rodgers M, Windsor JA. Peritoneal gallstones following laparoscopic cholecystectomy: incidence, complications, and management. Surg Endosc 2004;18:1200–7.

78. Memon MA, Deeik RK, Maffi TR, et al. The outcome of unretrieved gallstones in the peritoneal cavity during laparoscopic cholecystectomy. A prospective analysis. Surg Endosc 1999;13:848–57.

79. Hui TT, Giurgiu DI, Margulies DR, et al. Iatrogenic gallbladder perforation during laparoscopic cholecystectomy: etiology and sequelae. Am Surg 1999;65:944–8.

80. Manukyan MN, Demirkalem P, Gulluoglu BM, et al. Retained abdominal gallstones during laparoscopic cholecystectomy. Am J Surg 2005;189:450–2.

81. O'Leary DP, Coakley JB. The influence of suturing and sepsis on the development of postoperative peritoneal adhesions. Ann R Coll Surg Engl 1992;74:134–7.

82. Elkins TE, Stovall TG, Warren J, et al. A histologic evaluation of peritoneal injury and repair: implications for adhesion formation. Obstet Gynecol 1987;70:225–8.

83. Milewczyk M. [Experimental studies on the development of peritoneal adhesions in cases of suturing and non-suturing of the parietal peritoneum in rabbits]. Ginekol Pol 1989;60:1–6.

84. Parulkar BG, Supe AN, Vora IM, et al. Effects of experimental non-closure of peritoneum on development of suture line adhesions and wound strength in dogs. Indian J Gastroenterol 1986;5:251–3.

85. Viana Ade T, Daud FV, Bonizzia A, et al. Comparative study between parietal peritoneum suture and nonsuture in midline laparotomies in rats. Acta Cir Bras 2008;23:348–51.

86. Leon CJ, Gomez NA, Iniguez SA. Suturing of the peritoneum during abdominal wall closure after laparotomy. World J Surg 1994;18:292.

87. Whitfield RR, Stills HF Jr, Huls HR, et al. Effects of peritoneal closure and suture material on adhesion formation in a rabbit model. Am J Obstet Gynecol 2007;197:e641–5.

88. Komoto Y, Shimoya K, Shimizu T, et al. Prospective study of non-closure or closure of the peritoneum at cesarean delivery in 124 women: impact of prior peritoneal closure at primary cesarean on the interval time between first cesarean section and the next pregnancy and significant adhesion at second cesarean. J Obstet Gynaecol Res 2006;32:396–402.

89. Malvasi A, Tinelli A, Farine D, et al. Effects of visceral peritoneal closure on scar formation at cesarean delivery. Int J Gynecol Obstet 2009;105:131–5.

90. Beck DE, Cohen Z, Fleshman JW, et al. A prospective, randomized, multicenter, controlled study of the safety of Seprafilm adhesion barrier in abdominopelvic surgery of the intestine. Dis Colon Rectum 2003;46:1310–9.

91. Pickleman J, Lee RM. The management of patients with suspected early postoperative small bowel obstruction. Ann Surg 1989;210: 216–9.

92. Montz FJ, Monk BJ, Lacy SM. The Gore-Tex surgical membrane: effectiveness as a barrier to inhibit postradical pelvic surgery adhesions in a porcine model. Gynecol Oncol 1992;45:290–3.

93. Dunn R, Lyman MD, Edelman PG, et al. Evaluation of the SprayGel adhesion barrier in the rat cecum abrasion and rabbit uterine horn adhesion models. Fertil Steril 2001;75:411–6.

94. Mettler L, Audebert A, Lehmann-Willenbrock E, et al. A randomized, prospective, controlled, multicenter clinical trial of a sprayable, site-specific adhesion barrier system in patients undergoing myomectomy. Fertil Steril 2004;82:398–404.

95. Johns DA, Ferland R, Dunn R. Initial feasibility study of a sprayable hydrogel adhesion barrier system in patients undergoing laparoscopic ovarian surgery. J Am Assoc Gynecol Laparosc 2003;10:334–8.

96. Tjandra JJ, Chan MK. A sprayable hydrogel adhesion barrier facilitates closure of defunctioning loop ileostomy: a randomized trial. Dis Colon Rectum 2008;51:956–60.

97. Tang CL, Jayne DG, Seow-Choen F, et al. A randomized controlled trial of .5% ferric hyaluronate gel (Intergel) in the prevention of adhesions following abdominal surgery. Ann Surg 2006;243:449–55.

98. Andersson RE. Small bowel obstruction after appendicectomy. Br J Surg 2001;88:1387–91.

99. Khairy GA, Afzal MF, Murshid KR, et al. Post appendectomy small bowel obstruction. Saudi Med J 2005;26:1058–60.

100. Cox MR, McCall JL, Toouli J, et al. Prospective randomized comparison of open versus laparoscopic appendectomy in men. World J Surg 1996;20:263–6.

101. Hansen JB, Smithers BM, Schache D, et al. Laparoscopic versus open appendectomy: prospective randomized trial. World J Surg 1996;20: 17–21.

102. Macarulla E, Vallet J, Abad JM, et al. Laparoscopic versus open appendectomy: a prospective randomized trial. Surg Laparosc Endosc 1997;7:335–9.

103. Mutter D, Vix M, Bui A, et al. Laparoscopy not recommended for routine appendectomy in men: results of a prospective randomized study. Surgery 1996;120:71–4.

104. Williams MD, Collins JN, Wright TF, et al. Laparoscopic versus open appendectomy. South Med J 1996;89:668–74.

105. Kazemier G, de Zeeuw GR, Lange JF, et al. Laparoscopic vs open appendectomy. A randomized clinical trial. Surg Endosc 1997;11: 336–40.

106. Laine S, Rantala A, Gullichsen R, et al. Laparoscopic appendectomy—is it worthwhile? A prospective, randomized study in young women. Surg Endosc 1997;11:95–7.

107. Heikkinen TJ, Haukipuro K, Hulkko A. Cost-effective appendectomy. Open or laparoscopic? A prospective randomized study. Surg Endosc 1998;12:1204–8.

108. Hellberg A, Rudberg C, Kullman E, et al. Prospective randomized multicentre study of laparoscopic versus open appendicectomy. Br J Surg 1999;86:48–53.

109. Ozmen MM, Zulfikaroglu B, Tanik A, et al. Laparoscopic versus open appendectomy: prospective randomized trial. Surg Laparosc Endosc Percutan Tech 1999;9:187–9.

110. Huang MT, Wei PL, Wu CC, et al. Needlescopic, laparoscopic, and open appendectomy: a comparative study. Surg Laparosc Endosc Percutan Tech 2001;11:306–12.

111. Pedersen AG, Petersen OB, Wara P, et al. Randomized clinical trial of laparoscopic versus open appendicectomy. Br J Surg 2001;88: 200–5.

112. Milewczyk M, Michalik M, Ciesielski M. A prospective, randomized, unicenter study comparing laparoscopic and open treatments of acute appendicitis. Surg Endosc 2003;17:1023–8.

113. Moberg AC, Berndsen F, Palmquist I, et al. Randomized clinical trial of laparoscopic versus open appendicectomy for confirmed appendicitis. Br J Surg 2005;92:298–304.

114. Lujan Mompean JA, Robles Campos R, Parrilla Paricio P, et al. Laparoscopic versus open appendicectomy: a prospective assessment. Br J Surg 1994;81:133–5.

115. Nyam DC, Brillant PT, Dozois RR, et al. Ileal pouch-anal canal anastomosis for familial adenomatous polyposis: early and late results. Ann Surg 1997;226:514–21.

116. Walker SJ, West CR, Colmer MR. Acute appendicitis: does removal of a normal appendix matter, what is the value of diagnostic accuracy and is surgical delay important? Ann R Coll Surg Engl 1995;77: 358–63.

117. Riber C, Soe K, Jorgensen T, et al. Intestinal obstruction after appendectomy. Scand J Gastroenterol 1997;32:1125–8.

118. Katkhouda N, Mason RJ, Towfigh S, et al. Laparoscopic versus open appendectomy: a prospective randomized double-blind study. Ann Surg 2005;242:439–50.

119. Cueto J, D'Allemagne B, Vazquez-Frias JA, et al. Morbidity of laparoscopic surgery for complicated appendicitis: an international study. Surg Endosc 2006;20:717–20.

120. Ortega AE, Hunter JG, Peters JH, et al. A prospective, randomized comparison of laparoscopic appendectomy with open appendectomy. Laparoscopic Appendectomy Study Group. Am J Surg 1995;169: 208–13.

121. Kiviluoto T, Siren J, Luukkonen P, et al. Randomised trial of laparoscopic versus open cholecystectomy for acute and gangrenous cholecystitis. Lancet 1998;351:321–5.

122. Lujan JA, Parrilla P, Robles R, et al. Laparoscopic cholecystectomy vs open cholecystectomy in the treatment of acute cholecystitis: a prospective study. Arch Surg 1998;133:173–5.

123. Duron JJ, Hay JM, Msika S, et al. Prevalence and mechanisms of small intestinal obstruction following laparoscopic abdominal surgery: a retrospective multicenter study. Association for Surgical Research. [French] Arch Surg 2000;135:208–12.

124. Mohri Y, Uchida K, Araki T, et al. Hyaluronic acid-carboxycellulose membrane (Seprafilm) reduces early postoperative small bowel obstruction in gastrointestinal surgery. Am Surg 2005;71: 861–3.

125. Parikh JA, Ko CY, Maggard MA, et al. What is the rate of small bowel obstruction after colectomy? Am Surg 2008;74: 1001–5.

126. Nieuwenhuijzen M, Reijnen MM, Kuijpers JH, et al. Small bowel obstruction after total or subtotal colectomy: a 10-year retrospective review. Br J Surg 1998;85:1242–5.

127. Beck DE, Opelka FG, Bailey HR, et al. Incidence of small-bowel obstruction and adhesiolysis after open colorectal and general surgery. Dis Colon Rectum 1999;42:241–8.

128. Duepree HJ, Senagore AJ, Delaney CP, et al. Does means of access affect the incidence of small bowel obstruction and ventral hernia after bowel resection? Laparoscopy versus laparotomy. J Am Coll Surg 2003;197:177–81.

129. Sonoda T, Pandey S, Trencheva K, et al. Longterm complications of hand-assisted versus laparoscopic colectomy. J Am Coll Surg 2009; 208:62–6.

130. MacLean AR, Cohen Z, MacRae HM, et al. Risk of small bowel obstruction after the ileal pouch-anal anastomosis. Ann Surg 2002; 235:200–6.

131. Poppen B, Svenberg T, Bark T, et al. Colectomy-proctomucosectomy with S-pouch: operative procedures, complications, and functional outcome in 69 consecutive patients. Dis Colon Rectum 1992;35: 40–7.

132. McMullen K, Hicks TC, Ray JE, et al. Complications associated with ileal pouch-anal anastomosis. World J Surg 1991;15:763–7.

133. Skarsgard ED, Atkinson KG, Bell GA, et al. Function and quality of life results after ileal pouch surgery for chronic ulcerative colitis and familial polyposis. Am J Surg 1989;157:467–71.

134. Becker JM, Stucchi AF. Proctocolectomy with ileoanal anastomosis. J Gastrointest Surg 2004;8:376–86.

135. Oresland T, Fasth S, Nordgren S, et al. The clinical and functional outcome after restorative proctocolectomy. A prospective study in 100 patients. Int J Colorectal Dis 1989;4:50–6.

136. Young CJ, Solomon MJ, Eyers AA, et al. Evolution of the pelvic pouch procedure at one institution: the first 100 cases. Aust N Z J Surg 1999;69:438–42.

137. Vasilevsky CA, Rothenberger DA, Goldberg SM. The S ileal pouch-anal anastomosis. World J Surg 1987;11:742–50.

138. Nicholls RJ, Holt SD, Lubowski DZ. Restorative proctocolectomy with ileal reservoir. Comparison of two-stage vs. three-stage procedures and analysis of factors that might affect outcome. Dis Colon Rectum 1989;32:323–6.

139. Fonkalsrud EW, Stelzner M, McDonald N. Experience with the endorectal ileal pullthrough with lateral reservoir for ulcerative colitis and polyposis. Arch Surg 1988;123:1053–8.

140. Marcello PW, Roberts PL, Schoetz DJ Jr, et al. Obstruction after ileal pouch-anal anastomosis: a preventable complication? Dis Colon Rectum 1993;36:1105–11.

141. Francois Y, Dozois RR, Kelly KA, et al. Small intestinal obstruction complicating ileal pouch-anal anastomosis. Ann Surg 1989;209:46–50.

142. Galandiuk S, Pemberton JH, Tsao J, et al. Delayed ileal pouch-anal anastomosis. Complications and functional results. Dis Colon Rectum 1991;34:755–8.

143. Lower AM, Hawthorn RJ, Clark D, et al. Adhesion-related readmissions following gynaecological laparoscopy or laparotomy in Scotland: an epidemiological study of 24 046 patients. Hum Reprod 2004;19:1877–85.

144. Al-Sunaidi M, Tulandi T. Adhesion-related bowel obstruction after hysterectomy for benign conditions. Obstet Gynecol 2006;108:1162–6.

145. Lower AM, Hawthorn RJ, Ellis H, et al. The impact of adhesions on hospital readmissions over ten years after 8849 open gynaecological operations: an assessment from the Surgical and Clinical Adhesions Research Study. Br J Obstet Gynaecol 2000;107:855–62.