Optimizing the Prevention and Management of Postsurgical Adhesions

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Statement of Need
Adhesions are the most common complication of abdominal surgery, developing postoperatively in 50% to 100% of all such interventions. They can lead to serious medical complications, substantial morbidity, high monetary costs, large surgical workloads, dangerous and difficult reoperations, and an increasing number of medicolegal claims. An official definition of the condition has not been established, and an unequivocally effective prevention method has not been identified. A standardized classification for adhesion assessment and scoring also is lacking, as are guidelines for diagnosis and management. To close these gaps, clinician education is necessary.

Goal
The goal of this educational activity is to provide surgeons with up-to-date, clinically useful information concerning the prevention and management of postoperative adhesions.

Learning Objectives
At the conclusion of this activity, participants will be better prepared to:
- Review the pathophysiology and complications of postoperative adhesions formation.
- Summarize current strategies used to prevent postoperative adhesion formation.
- Describe the various types of barrier materials used to prevent postoperative adhesion formation.

Estimated Time for Completion
60 minutes

Course Format
Monograph (print and online)

Intended Audience
The intended audience for this educational activity includes general surgeons, vascular surgeons, colon and rectal surgeons, critical care surgeons, surgical oncologists, trauma surgeons, and thoracic surgeons.

Accreditation Statement
This activity has been planned and implemented in accordance with the Essential Areas and policies of the Accreditation Council for Continuing Medical Education (ACCME) through the joint sponsorship of the Medical College of Wisconsin and Applied Clinical Education. The Medical College of Wisconsin is accredited by the ACCME to provide continuing medical education for physicians.

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Method of Participation
There are no fees for participating in or receiving credit for this activity. To receive CME credit, participants should read the preamble and the monograph and complete the post-test and evaluation. A score of at least 70% is required to complete this activity successfully.

Conflict of Interest Statement
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Financial Disclosures
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Disclosure of Unlabeled Use
This educational activity may contain discussion of products that are not FDA-approved for use in the prevention and management of surgical adhesions.

Introduction
Peritoneal adhesions describe aberrant fibrous bands connecting tissue surfaces, typically omentum, bowel loops, and the abdominal wall. The bands form on the surfaces of injured tissue and frequently on the peritoneum.1-3 Surgical trauma to the peritoneum and other vulnerable tissue is a common cause of adhesions, with adhesions occurring in between 50% and 100% of patients undergoing major abdominal surgery, and between 55% and 100% of women undergoing pelvic surgery.4-6 Gynecologic surgery is a particularly common cause of postsurgical adhesions, with an estimated 90% of adnexal surgeries resulting in ovarian adhesions and 65% of cesarean deliveries being associated with adhesions.7,8

The economic costs of postsurgical adhesions are substantial. A study published in 2011 of inpatient costs arising from surgical intervention (adhesiolysis) for abdominal and gynecologic adhesions found total expenditures of $2.25 billion (in 2005 dollars), including $1.35 billion for primary and $902 million for secondary adhesiolysis. Data from this study, derived from the 2005 Healthcare Cost and Utilization Project’s Nationwide Inpatient Sample (the largest inpatient database in the United States), also found that although primary adhesiolysis accounted for more than 50% of the total inpatient...
costs, it represented only 23% of procedures. Furthermore, of approximately 350,000 adhesiolysis-related hospitalizations, 125,000 were for procedures involving the female reproductive tract.9

Postsurgical adhesions are associated with numerous complications and risks, including small bowel obstruction (SBO), pain, infertility, and mortality, as well as a high risk for repeat surgery, and subsequent risk for inadvertent enterotomy.10-14 The risk for death from undiagnosed bowel obstruction resulting from postsurgical adhesions has been estimated at 10%, whereas the mortality risk directly related to inadvertent enterotomy occurring in adhesiolysis procedures is approximately 13%.11,15

The high likelihood of hospitalization is both an indicator of the depth of the problem inherent with postsurgical adhesions and a significant driver of health care utilization costs associated with this condition. The SCAR (Surgical and Clinical Adhesions Research) studies offer the best epidemiologic data on the risk for readmission for adhesion-related complications after abdominal or pelvic surgery.16 The initial SCAR data, published in 1999, involved follow-up over a period of more than 10 years with nearly 30,000 patients in the Scottish National Health Service who had undergone open surgery in 1986. To avoid the confounding influence of previous surgeries, this group included only patients who, apart from the index surgery, had not undergone surgery over the previous 5 years. The authors found that of this patient population, 34.7% had been readmitted to the hospital for reasons directly or possibly related to adhesions. Within that group of rehospitalized patients, 53.8% had been rehospitalized once, 41.4% had been rehospitalized between 2 and 5 times, and 4.8% had been rehospitalized 6 or more times.16

Data from the SCAR-3 study, published in 2005, examined the disposition of patients seen within the Scottish National Health Service specifically for lower abdominal surgery (excluding appendectomy) during a 12-month period from 1996 to 1997. Apart from the location of the surgery (ie, noninclusion of pelvic surgery), the SCAR-3 study was more restricted in several other ways compared with previous SCAR studies. The follow-up period was 5 years instead of 10; counting of readmissions was limited to those patients who were rehospitalized only for reasons directly related to adhesions; and only the number of patients readmitted, as opposed to the number of total readmissions, was counted, although this, as the authors acknowledged, underestimates the rehospitalization burden. Again, patients experiencing surgery over the previous 5 years were excluded from these results.17 The authors observed a readmission rate of 5.2% over the 5-year study period in a patient population of 12,756. Within this group, much higher levels of readmission risk were seen among patients undergoing particular surgical procedures: ileal resection (7.0%), ileostomy (10.6%), panproctocolectomy (15.4%), and total colectomy (8.8%). Age older than age 60 years also was considered a significant risk factor for readmission versus age younger than 60 years (P<0.0001).17

An additional report on the SCAR data over the same 1996-1997 period, this time specific to children and adolescents under the age of 16 years, focused on rehospitalizations directly related to adhesions in the 5-year period following open abdominal surgery.18 Overall, excluding patients undergoing appendectomy, the adhesion-related readmission rate was 5.3%, whereas those patients experiencing ileostomy had a readmission rate of 25%, and those having ileal resection had an 8.3% rate of rehospitalization.18

Considering the enormous burden of both morbidity and mortality associated with postsurgical adhesions, it is important that surgeons of all specialties be well apprised of the nature of and risks associated with postsurgical adhesions. The purpose of this activity is to review the pathophysiology and complications related to postsurgical adhesions and to describe techniques and strategies for avoiding adhesions, as well as surgical materials available for adhesion prevention.

### Characteristics and Pathophysiology of Postsurgical Adhesions

Postsurgical peritoneal adhesions have been categorized into 2 types.2 Type 1 refers to de novo adhesions, formed at a site where no previous adhesions had occurred, with subcategories, type 1A, where no prior surgical intervention had occurred at the adhesion site, and type 1B, where a previous surgical intervention...
had occurred at the adhesion site. Type 2 refers to an instance of adhesion reformation, including subtype 2A, where no prior surgical intervention had occurred except for adhesiolysis, and 2B, where prior surgical intervention, in addition to adhesiolysis, had occurred. A complicating factor in the diagnosis and categorization of adhesions arises from the fact that despite the development of 20 different scoring systems for adhesions, no single universally accepted means of scoring has been established.19

The precipitating event in postsurgical adhesions is peritoneal injury resulting from the trauma caused by surgery and consequent retraction of tissue and organ(s), whereas peritoneal exposure to foreign contaminants (eg, gloves, powder, intraabdominal prosthetic meshes) also may contribute to the formation of adhesions.20,21 Bleeding and fluid exudate rich in fibrinogen follow peritoneal injury, creating a coagulative cascade that produces thrombin, which, in turn, promotes conversion of fibrinogen to fibrin.2 The production of fibrin promotes tissue regeneration; fibrin, a sticky substance, is deposited along serosal surfaces, causing adjacent peritoneal surfaces to fuse (Figure 1).22 Ideally, these fusions are broken down via fibrinolysis within several days of the injury, restoring the peritoneal surfaces to their previous condition. Successful fibrinolysis is conducive to the proliferation of mesothelial cells, which aid in the repair of the peritoneal injury.23 However, surgical intervention causing peritoneal injury disrupts the balance between coagulation and fibrinolysis, which would normally keep fibrin production in check, but which, under these circumstances, favors coagulation and produces an expanded extracellular matrix (ECM) that, instead of being a temporary structure, persists. Failure of lysis to occur within 5 to 7 days is predictive of sustenance of the fibrin matrix.24 This situation comes about as a consequence of the infiltration of the fibrin matrix by collagen-secreting fibroblasts, ultimately resulting in the formation of peritoneal adhesions.25 The maturation of adhesions sees a more complex structure develop, with vascularization, including arterioles, venules, and capillaries, as well as smooth muscle hyperplasia and hypertrophy resulting in adventitial and medial wall thickening.25 Innervation also occurs in adhesions from a fairly early stage—in a matter of months or less—and such innervation is characterized by both myelinated and demyelinated axons.25

The normal equilibrium between coagulation and fibrinolysis also is influenced by the activation of plasminogen, which is converted into plasmin. Plasmin plays an important role in fibrin degradation and, therefore, degradation of the ECM (Figure 2).2,26 The 2 primary activators in this process of converting plasminogen to plasmin are tissue plasminogen activator (tPA) and urokinaselike plasminogen activator (uPA), with uPA being responsible for 95% of plasmin generation.27,28 Plasminogen conversion is inhibited by glycoproteins collectively designated as plasminogen activator inhibitors (PAI)-1 and PAI-2, with PAI-1 being the primary inhibitor.27 PAI-1 binds to tPA and uPA, thereby inhibiting their activity and precluding fibrin degradation. In the case of adhesion formation, the homeostatic relationship between these processes is disrupted, reducing the activity of plasmin.26 It is additionally worth noting that our current understanding of postsurgical adhesion formation is based, in part, on the fact that the potential for fibrinolysis has been shown in animal and human trials to be reduced by peritoneal injury, with consequent disruption of the coagulative-fibrinolytic equilibrium.28

Complications of Postsurgical Adhesions

As might be expected from such a physically intrusive dysfunction as postsurgical adhesions, occurring in such vulnerable regions of the anatomy, complications can be very severe indeed and, moreover, may result in deleterious outcomes that only emerge many years later. In the case of the first SCAR study, which included follow-up of patients over a 10-year period, the authors observed that the incidence of disorders related to adhesions did not diminish.
with time during the entirety of the study; this, despite the fact that some of the study participants had died over the course of follow-up. Indeed, the authors concluded that morbidity risk associated with adhesions can be ongoing over a period of decades.16 In a long-term study of patients undergoing abdominal surgery in the United Kingdom, 21% experienced an intestinal obstruction less than 1 month after surgery, the same percentage experienced an intestinal obstruction between 1 and 5 years after surgery, and the same percentage again experienced an intestinal obstruction more than 10 years after surgery.29

SBO is, perhaps, the most significant cause of morbidity arising from postsurgical adhesions. In this context, SBO results from entrapment of the organ by fibrous adhesion bands, and is far more likely to occur in open procedures, while being relatively less common in laparoscopic procedures.1 Intraabdominal adhesions represent the single most important contributing cause of SBO, constituting between approximately 69% and 74% of SBO incidence.6,30 Colectomy, although performed less frequently than intraabdominal surgery, is associated with a particularly high risk for SBO, likely in part to the large surface area of peritoneal tissue at risk for damage during such procedures. A study from Cleveland Clinic evaluated outcomes of restorative proctocolectomy with ileal pouch-anal anastomosis (IPAA) in 1,005 patients over an 11-year period.31 It should be noted that a substantial number of these patients had undergone previous surgery procedures, including colectomy; hysterectomy, and cesarean delivery.32 In the study, 262 cases of adhesion-related SBOs were observed. Of these 262 patients, 92 had undergone previous abdominal surgery. Of these, 47 had previous gynecologic operations. Hysterectomy was the most common gynecologic procedure to result in an adhesion-related SBO (35 of 2,140 operations, for an incidence of 1.6%), and adnexal surgery was the next most common (8 of 924 operations, for an incidence of 0.87%), whereas myomectomy and cesarean delivery were less frequent contributors to risk for SBO.33 These results are consistent with those from a 2006 study from the same institution that found abdominal hysterectomy to be the most common cause of adhesion-related SBOs, with a rate of 13.6 SBOs per 1,000 abdominal hysterectomies.34 Thus, gynecologic procedures, although relatively infrequent causes of adhesion-related SBOs in purely numerical terms, contribute an outsized influence on the risk for SBO in women.

As may be seen more broadly with postsurgical adhesions, the risk for recurrence represents a large proportion of the total burden of adhesion-related SBOs. This problem was the subject of a French study that examined the incidence of recurrent SBO subsequent to surgery for postsurgical SBO caused by adhesions over a 5-year period (1997 to 2002) in 286 patients (186 women).34 At the end of the study, 15.9% of patients had experienced SBO recurrence, although it is worth noting that at the end of the first year, recurrence had only affected 5.5% of patients, offering additional evidence for the long-term nature of the risks involved with adhesions.34

Another highly significant complication of postsurgical adhesions is secondary female infertility, with adhesions accounting for an estimated 15% to 20% of all such cases.35 Infertility, in this context, appears to be caused by a deforming of adnexal anatomy reducing the passage of the ovum to the fallopian tubes, and also by impeding the passage of gametes and fertilized eggs through the fallopian tubes.1 Chronic pain also is a frequent occurrence in postsurgical adhesions, and is particularly common in women with adhesions. Indeed, adhesions are believed to be responsible for half of all cases of pelvic pain in women.36 And the relationship of adhesions to infertility—that is, restricted movement in the area of the reproductive organs—also is believed to be a cause of pelvic pain in women. As noted above, nerve fibers are present in adhesions; in fact, innervation has been seen to be present regardless of adhesion size or location, offering an explanation for how pain can be transmitted in adhesions.25,37

In addition to direct complications, postsurgical adhesions create a variety of problems as a result of medical procedures and interventions that are prevented from occurring, or are limited, as a consequence of the presence of adhesions. For example, adhesions may prevent peritoneal dialysis in patients with chronic renal failure, whereas they can make laparoscopic surgery challenging and, in some cases, impossible.24 Their presence also may rule out the use of intraperitoneal chemotherapy for patients who require it.38 The burden of adhesions may be seen further in the inherent difficulties of operative surgical intervention, often requiring intensive adhesiolysis that can create additional complications and extend the length of surgery.11 Moreover, inadvertent enterotomy is a frequent occurrence in adhesiolysis, being seen in approximately 19% of reoperative surgeries.11 Taken together, adhesions exert an enormous overall burden on surgery procedures such that it is difficult to come to an accurate assessment of the additional workload on surgeons, not to mention the suffering endured by the many patients who must undergo multiple surgeries in order to repair the almost inevitable damage associated with many types of surgical interventions.

### Strategies for Prevention of Postsurgical Adhesion Formation

Any discussion of approaches to preventing postsurgical adhesions must take several facts into consideration. First, there are a variety of options for surgeons that will effectively minimize the risk for adhesion formation. Second, it must be acknowledged that adhesion prevention is not always possible; taking into consideration how extraordinarily common adhesions are in the surgical

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**Table. Aspects of Meticulous Surgical Technique for the Prevention of Adhesion Formation**1,39

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<tr>
<th>Aspect of Meticulous Surgical Technique</th>
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<td>Delicate handling of tissues</td>
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<td>Achievement of optimal hemostasis</td>
<td>Minimal use of suture material</td>
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<td>Minimal introduction of foreign material</td>
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<td>Pelvic lavage</td>
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setting, it is difficult to conceive, at least in the near future, that they can be avoided altogether.\textsuperscript{39} Third, awareness of surgical adhesions among health care professionals is alarmingly low, and even among surgeons who are well aware of adhesion risk, many are reluctant to use adhesion barriers despite their proven utility in reducing adhesion risk.\textsuperscript{1,40,41} Thus, the situation of adhesion risk in the postsurgical setting is one in which, at present, a very large problem is under recognized at the same time that available resources are being underutilized. Although this is unfortunate, there is every reason to believe that greater awareness of effective adhesion prevention techniques will result in significant reductions in their occurrence. There are, overall, 4 basic strategies for the prevention of postsurgical adhesions:

1. Employing surgical best practices to minimize peritoneal injury
2. Reducing local and inflammatory responses
3. Promoting fibrinolysis and limiting the coagulation cascade
4. Employing barriers to reduce adhesion formation.\textsuperscript{1}

Best surgical practices recommended by the 2010 Society of Obstetricians and Gynaecologists of Canada (SOGC) guidelines for adhesion prevention include minimizing tissue trauma, ensuring tissue hydration, controlling bleeding, and employing the least reactive sutures.\textsuperscript{39,42} In support of the goals of limiting damage to the serosa and avoiding the presence of foreign bodies, while recognizing that excess blood and clotting increases the likelihood of adhesions because they constitute an additional fibrinolysis burden, it is advisable that prior to abdominal wall closure, careful hemostasis and repetition of irrigation with saline and Ringer’s solution be undertaken. Use of humidified and warmed gases with laparoscopy to limit mesothelial injury also is recommended.\textsuperscript{42} Meticulous surgical technique represents the primary means of adhesion prevention, and a list of some of the top-line surgical approaches are shown in the Table. In general, these techniques are focused on limiting tissue damage and avoiding contaminants, while allowing for ample irrigation.\textsuperscript{39}

Although laparoscopy is generally thought to be superior to laparotomy for adhesion risk, this advantage is not absolute, and adhesions do still occur in laparoscopic surgery.\textsuperscript{41} Nevertheless, when possible, laparoscopy is preferred for its association with fewer adhesions due to less tissue damage, less introduction of foreign material, and less risk for drying out of tissues.\textsuperscript{1} The SOGC guidelines call for employing the least invasive surgical method available, recommend laparoscopy over the abdominal approach when feasible, and also prefer vaginal or laparoscopic hysterectomy to abdominal hysterectomy.\textsuperscript{39}

Peritoneal closure following cesarean delivery remains an area of ongoing debate. A prospective cohort study by Lyell et al evaluated the effect on adhesion risk for peritoneal closure in 173 women after their first cesarean delivery. Women included in the study were undergoing their first repeat cesarean delivery, which offered the opportunity to determine the presence of adhesions resulting from their previous (ie, first) cesarean delivery. Patients were excluded from the study if adhesions had been detected at the time of their first cesarean delivery.\textsuperscript{44} Of the 173 women in the study, 106 had had the parietal peritoneum left open during their first cesarean delivery, whereas 67 patients had the parietal peritoneum closed. The risk for having a dense and filmy adhesion was found to be significantly lower in those with peritoneal closure: 52% versus 73%, respectively ($P=0.006$). After a multivariant regression analysis controlling for, among other things, prior infections, socioeconomic variables, age, and the presence of gestational diabetes—adhesions were 80% less common among women who had had peritoneal closure compared with those who had not (odds ratio, 0.20; 95% confidence interval, 0.08-0.49).\textsuperscript{44}

A study published in 2011 by Greenberg et al found that among 145 women undergoing first repeat cesarean delivery, peritoneal closure had no significant effect on the risk for delay of delivery, although women with more severe adhesions did experience significant delivery delays.\textsuperscript{45} Finally, a 2008 Cochrane review of 14 trials involving 2,908 women undergoing cesarean deliveries arrived at somewhat equivocal conclusions regarding the ultimate advantages and disadvantages of peritoneal closure. No clear conclusions regarding adhesion risk were arrived at, nor were there any clear conclusions regarding long-term outcomes. The analysis did, however, find a reduction of operating time of between 6 and 6.3 minutes in nonclosure procedures, as might be expected. The risk for fever and wound infection also was somewhat reduced in cases of nonclosure based on a small number of studies.\textsuperscript{46}

The goal of reducing local and inflammatory responses requires strict adherence to sterile technique, avoiding gloves coated with talcum powder, and using as little suture material as is practical.\textsuperscript{1,39} The use of corticosteroids, heparin, antihistamines, and nonsteroidal anti-inflammatory drugs (NSAIDs) are not uncommon to reduce inflammation, although their effectiveness in reducing adhesions has not been proven. Similarly, the use of NSAIDs has been suggested to reduce thromboxane production, but this, too, remains unproven as an effective means of reducing adhesions.\textsuperscript{1,36}

In cases where surgery must be performed and adhesions are present that interfere with the required surgery, adhesiolysis is typically necessary. That said, the presence of adhesions makes surgery more difficult and more fraught with risk. Moreover, the chances of adhesion reformation after adhesiolysis has been performed is approximately 90%, and it often is the case that adhesiolysis creates as many problems as it solves.\textsuperscript{1,47} Recombinant tPA and streptokinase (another form of plasminogen activator) have demonstrated success in the reduction of adhesions in animal models.\textsuperscript{48,49} This approach, however, is expensive, impractical, and associated with hemorrhagic risk in humans.

### Mechanical Barriers for Prevention Of Postsurgical Adhesions

A number of different agents with different means of delivery have been developed to prevent postsurgical adhesions. For example, the use of CO\textsubscript{2} pneumoperitoneum in laparoscopic surgery decreases the risk for adhesions, whereas hydroflotation, the use of liquid barriers to limit adhesions, has been extensively developed.\textsuperscript{2} In addition to saline and Ringer’s solution, which are limited by the rapidity of their absorption, Dextran 70, a hypertonic solution, was used extensively for a time, but has since been abandoned due to unacceptable side effects.\textsuperscript{2,50} At present, among liquid agents, icodextrin has the best supportive data demonstrating safety and efficacy, and is FDA-approved for postsurgical adhesion reduction in patients undergoing gynecologic laparoscopic adhesiolysis.\textsuperscript{51} An international double-blind, randomized trial of 402 patients undergoing laparoscopic surgery for adhesiolysis found 4% icodextrin to be significantly better than Ringer’s solution for “clinical success” ($P=0.018$), defined as a reduction of adhesions at 3 or 30% of sites lysed (whichever was more numerous) between the first surgery and the follow-up laparoscopic surgery.\textsuperscript{52} At the same time, the GENEVA (Gynaecological ENdoscopic Evaluation of Adept) study, a multicenter double-blind, randomized trial, undertaken at 25 centers across Europe, and involving
498 (330 evaluable) women undergoing surgery for removal of uterine fibroids or endometriotic cysts, found no advantage with 4% icodextrin compared with Ringer's solution for the prevention of de novo adhesions.55 Although hydroflotation is certainly used in the surgical setting for the prevention of adhesions, mechanical barriers are, in general, considered the most effective available means of preventing postsurgical adhesions.

**Oxidized Regenerated Cellulose**

Oxidized regenerated cellulose (ORC) is a knitted membrane with a net-like appearance, and has been FDA-approved for gynecologic pelvic laparotomy, after meticulous hemostasis, to prevent postsurgical adhesions.54 ORC is a gelatinous substance that is applied to areas of peritoneal injury after hemostasis and, thus, does not require suturing after placement. This is a significant advantage because of the propensity of suturing material to cause adhesions.40 Moistening before use limits the risk for slippage.1 ORC may be used in both open and laparoscopic surgery, and is reabsorbed in 2 to 4 weeks after application.1,40

In a clinical trial comparing ORC in 50 women undergoing laparoscopic myomectomy, patients were randomized to surgery alone or surgery accompanied by the use of ORC.53 ORC-treated patients experienced significantly fewer de novo adhesions than surgery-only patients. A meta-analysis of ORC for adhesion prevention in pelvic adhesions in women undergoing gynecologic laparotomy included 7 studies and 398 patients, and found that the use of ORC was 1.5 to 2.5 times more effective than no ORC in achieving an outcome without adhesions (P<0.001).56 A Cochrane review also found ORC to be effective in reducing pelvic adhesions in gynecologic laparotomy, but data also suggest that it is ineffective when blood is present, and if hemostasis is performed before application, ORC may increase the risk for adhesions.57

**Combined Sodium Hyaluronic Acid and Carboxymethylcellulose**

Combined sodium hyaluronic acid and carboxymethylcellulose (SHA+C) is a translucent, resorbable membrane that is FDA-approved for patients undergoing abdominal or pelvic laparotomy for reduction of postsurgical adhesions between the abdominal wall and the underlying viscera such as omentum, small bowel, bladder, and stomach, and between the uterus and surrounding structures such as tubes and ovaries, large bowel, and bladder.58 SHA+C is intended to keep tissue planes separate for a period of 7 days after surgery, and is probably the most commonly used adhesion barrier, offering certain significant advantages and disadvantages. For example, it is designed such that after the 7-day critical period of adhesion risk has elapsed, the membrane is resorbed and eliminated. SHA+C also has the advantage of not having its efficacy affected by the presence of blood.1 However, SHA+C is, fragile, limiting the range of its utility, particularly in minimally invasive surgeries.40

A double-blind, randomized clinical trial was performed at 11 centers to evaluate the safety and efficacy of SHA+C in patients undergoing colectomy and IPAA with temporary diverting-loop ileostomy. One hundred and eighty-three patients were randomized to undergo surgery with or without SHA+C. At the time of ileostomy closure, 8 to 12 weeks after the initial surgery, examination of adhesion status was conducted.59 At that time, 94% of patients who were not given SHA+C had at least one adhesion compared with 49% of those who were treated with SHA+C (Fisher’s Exact Test P<0.00000000001).59 A separate clinical trial from Japan, which involved 62 patients with rectal carcinoma receiving radiotherapy and chemotherapy, randomized the study participants to undergo surgery with or without SHA+C. Those for whom SHA+C was used experienced fewer adhesions, without any adverse events related to interaction between chemotherapy or radiotherapy and SHA+C use.60

A slurry of SHA+C has been studied to overcome the problems related to its fragility, and has demonstrated efficacy in laparoscopic gynecologic surgery, whereas a spray version of SHA+C currently is available in a number of European and Asian countries.40,61

**Expanded Polytetrafluoroethylene**

Expanded polytetrafluoroethylene (EP) is an FDA-approved 0.1-mm thick, synthetic, nonresorbable adhesion barrier. Although EP is a highly effective mechanical barrier to prevent adhesions, it is significantly limited by the fact that it requires suturing and, perhaps, by the need for subsequent removal, although the question as to whether removal is strictly necessary remains a matter of debate.36,40,57 The efficacy of EP was demonstrated in a small randomized, nonblinded, head-to-head study against ORC, in which EP was shown to result in fewer and smaller adhesions than ORC in 32 women undergoing reconstructive surgery.62

**Lyophilized Porcine Collagen, Polyactic Acid, and a Hydrophilic Collagen Film**

Lyophilized porcine collagen, polyactic acid, and a hydrophilic collagen (LPH) film is a resorbable mesh material, FDA-approved, and applicable for laparoscopic and open surgery.40 The safety of LPH was demonstrated in a study that included 78 patients undergoing abdominal surgery and that resulted in relatively few wound complications, no serious adverse events, and in the case of 10 patients for whom unrelated additional surgery was necessary (allowing for later assessment), no observed cases of SBO.63 A study published in 2008 involved 52 patients undergoing open surgery for myomectomy who were randomized to treatment with LPH or Ringer’s solution; 34 of these patients subsequently underwent laparoscopic second-look surgery after a mean follow-up period of 105 days.64 Adhesions were observed in 9 of 18 (50%) of the LPH patients compared with 15 of 16 of the patients treated with Ringer’s solution (P=0.005).

**Conclusions**

Postsurgical adhesions are an extraordinarily common outcome in a variety of surgeries, most notably abdominal surgery. These adhesions are associated with numerous serious complications, including SBO, pain, infertility, and even death. The costs incurred as a consequence of adhesions also are substantial, and the likelihood of a patient requiring repeat surgery, and rehospitalization, for the purpose of adhesiolysis—and, in many cases, additional repeat surgery to address the new adhesion formation resulting from earlier repeat surgery—is extremely high. Clinical recommendations to reduce the risk for surgery-related adhesions include the application of surgical best practices, meticulous surgical technique, reduction of local inflammation, promotion of fibrinolysis, and use of mechanical barriers to reduce the initial risk for adhesion formation. Despite the availability of mechanical barriers that have demonstrated efficacy in significantly reducing the risk for adhesions, their acceptance in the surgical setting is, at present, unusually low. Increased use of these mechanical barriers represents the simplest and most direct means of reducing adhesion risk and, consequently, reducing the enormous burden in terms of morbidity, mortality, and medical expenditures with which they are associated.
CME Post-Test

1. What is the approximate rate of adhesion reformation following adhesiolysis?
   a. 82%
   b. 90%
   c. 75%
   d. 70%

2. How common is inadvertent enterotomy in adhesiolysis?
   a. 9%
   b. 4%
   c. 19%
   d. 14%

3. Which of the following adhesion barriers requires eventual removal?
   a. Lyophilized porcine collagen, polylactic acid, with hydrophilic collagen (LPC)
   b. Sodium hyaluronic acid and carboxymethylcellulose (SHAC)
   c. Expanded polytetrafluoroethylene (EP)
   d. Oxidized regenerated cellulose (ORC)

4. Which of the following appropriately describes the pattern of postsurgical adhesion risk over the long term (≥10 years)?
   a. Increasing risk
   b. Diminishing risk
   c. Unchanging risk
   d. Unpredictable risk

5. Which of the following gynecologic surgical procedures is the most likely to cause an adhesion-related small bowel obstruction?
   a. Hysterectomy
   b. Cesarean delivery
   c. Myomectomy
   d. Adnexal surgery

6. Which of the following adhesion barriers loses efficacy in the presence of blood?
   a. LPC
   b. SHA+C
   c. EP
   d. ORC

7. What is the approximate mortality rate due to undiagnosed bowel obstruction resulting from postsurgical adhesions?
   a. 10%
   b. 15%
   c. 20%
   d. 22%

8. What is a type 2A postsurgical peritoneal adhesion?
   a. A reformed adhesion where a previous surgical intervention had occurred (not including adhesiolysis).
   b. A new adhesion at a site where no previous adhesions had occurred, but where a previous surgical intervention had occurred.

9. Which of the following is not a feature of postsurgical adhesion formation?
   a. Successful postoperative spontaneous fibrinolysis.
   b. Infiltration of the fibrin matrix by collagen-secreting fibroblasts
   c. Vascularization
   d. Inflammation

10. Which of the following approaches has not been definitely shown to reduce the inflammatory response in the prevention of adhesions?
    a. Using the minimum practical amount of suture material
    b. Administering nonsteroidal anti-inflammatory drugs
    c. Adhering to strict sterile technique
    d. Avoiding talcum powder on surgical gloves
Answer Sheet and Evaluation

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Participant Information (please print clearly)

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☐ Physician I am claiming ____ AMA PRA Category 1 Credit™

☐ Pharmacist  ☐ Nurse  ☐ Other (specify):

**Evaluation Questions**

Circle the number that corresponds with your answer

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<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
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After completing this activity, I am better able to:

- Review the pathophysiology and complications of postoperative adhesion formation. 1 2 3 4
- Summarize current strategies used to prevent postoperative adhesion formation. 1 2 3 4
- Describe the various types of barrier materials used to prevent postoperative adhesion formation. 1 2 3 4
- The information presented in this activity was pertinent to my professional needs. 1 2 3 4
- The faculty for this activity were effective. 1 2 3 4
- The content of this activity offers valuable information that will assist me in improving patient outcomes. 1 2 3 4
- The information was presented in a fair and balanced manner and examined the topic with scientific rigor. 1 2 3 4
- This activity was free from bias. 1 2 3 4
- Of the patients you will see in the next week, about how many will benefit from the information you learned today? ≤10 11-25 26-50 >50

Based on your experience, which of the following are the primary barriers to implementing changes in practice (check all that apply)?

- Lack of knowledge regarding evidence-based strategies
- Lack of convincing evidence to warrant change
- Lack of time/resources to consider change
- Insurance, reimbursement, or legal issues
- Other: ________________________________

Which delivery method do you find most effective for CME learning (select one)?

- Printed materials
- Live symposia at national meetings
- Live symposia at local/regional meetings
- Live grand rounds
- Web-based
- Mobile apps
- Other: ________________________________

What motivated you to participate in this activity?

- CME credits
- Faculty
- Topic or therapeutic area
- Format type

Applied Clinical Education is interested in adding to a database of faculty occasionally invited to participate in educational planning in this therapeutic area. If you opt NOT to be contacted, please check the box below:

☐ NO, I do NOT want to be contacted in the future.

**Post-Test Answer Section**

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