

INNOVATIONS IN VENTRAL HERNIA REPAIR

Materials and techniques to reduce MRSA and other infections

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The use of mesh in ventral hernia repair substantially reduces recurrence rates; however, the risk of infection rises with prosthesis use. New antimicrobial meshes and nuanced technique have reduced infection risks, as has the adoption of laparoscopic approaches to ventral hernia repair. In this roundtable session, experts discuss strategies to control infection risk factors, surgical techniques that optimize outcomes, and techniques to manage infection when it does occur.

■ IMPACT OF APPROACH ON INFECTION RISK

LeBlanc: At the most basic level, in hernia repair, we have to deal with risk of recurrence and risk of infection. In light of these challenges, what factors do you consider in selecting an approach?

Heniford: Using sutures alone to close a hernia carries a relatively low risk of infection, but this type of repair is associated with risk of recurrence that can be 40% to 50%, or even higher.^{1,2} Conversely, the use of mesh substantially reduces hernia recurrence; however, in open hernia repair, the reported rate of infection is between 3% and 18%.³⁻⁶

The laparoscopic approach reduces both wound complications and infections (TABLE).^{3,7-13} In our most recent study of 850 patients, the risk of mesh infection was less than 0.7%.¹² The low infection rate is, in fact, the most attractive benefit of a laparoscopic ventral hernia repair.

Dr LeBlanc reports that he serves as a consultant to Ethicon, Inc., I-Flow Corporation, and W.L. Gore & Associates and is on the speakers' bureaus of Ethicon, Inc., Ethicon Endo-Surgery, Inc., and W.L. Gore & Associates. Dr Voeller reports that he serves on the speakers' bureaus of Ethicon, Inc., U.S. Surgical, and W.L. Gore & Associates. Dr Heniford reports that he receives grants/research support from Cook Group Incorporated, Ethicon, Inc., Ethicon Endo-Surgery, Inc., Karl Storz Endoscopy-America, Inc., ValleyLab, and W.L. Gore & Associates. This supplement is supported by a grant from W.L. Gore & Associates.

TABLE

Infection and Recurrence: Studies of Laparoscopic Ventral Hernia Repair Using ePTFE

Study	Patients (N)	Infection rate (%)	Recurrence rate (%)	Average followup (m)
Toy, 1998	144	3	4	8
Bageacu, 2002	159	3	16	49
Ben-Haim, 2002	100	1	2	19
Berger, 2002	150	0	2.7	-
Carbajo, 2003	270	0	4.4	44
LeBlanc, 2003	200	2	6.5	36
Heniford, 2003	850	0.7	4.7	20.2
Frantzides, 2004	208	0	1.4	24
Overall	2081	1	5	27

Toy FK, et al. *Surg Endosc.* 1998;12:955-959; Bageacu S, et al. *Surg Endosc.* 2002;16:345-348; Ben-Haim M, et al. *Surg Endosc.* 2002; 16:785-788; Berger D, et al. *Surg Endosc.* 2002;16:1720-1723; Carbajo MA, et al. *Surg Endosc.* 2003;17:118-122.

LeBlanc KA, et al. *Hernia.* 2003;7:118-124; Heniford BT, et al. *Ann Surg.* 2003;238:391-400; Frantzides CT, et al. *Surg Endosc.* 2004;18:1488-1491.

Voeller: I am most concerned about risk factors for infection when an open procedure is performed on a patient with a large hernia that features a large incision or prosthetic mesh. Sterile technique is essential in this setting.

Heniford: Yes, the increased rate of infection with large, open ventral hernia repairs results from the tissue damage inflicted during the procedure as well as from the exposed skin, the exposure of the mesh to the skin, fluid collection, hematomas, etc.

Voeller: Because of these issues, I mainly perform an open repair in difficult cases that are likely to require lengthy surgical time and/or present the risk of bowel injury. I also do an open repair in those who need or desire an abdominoplasty to bring their rectus muscles to the midline. The abdominal wall functions best with the muscles brought together.

Heniford: Regardless of approach, the most effective remedy for infection is prevention, which includes prophylactic antibiotics, impeccable attention to asepsis, minimal handling and careful introduction of the prosthesis, and, perhaps, the use of an antimicrobial-impregnated mesh.

■ MRSA INFECTION: CONTROLLING RISK FACTORS

LeBlanc: How prevalent is methicillin-resistant *Staphylococcus aureus* (MRSA)?

Heniford: *Staphylococcus aureus* and MRSA account for more than 90% of infections in our hospital. In one recent study, 63% of the infections were caused by MRSA in prostheses.¹⁴ The multi-drug-resistant nature of MRSA makes these infections difficult, costly, or impossible to treat. The bacteria can encapsulate themselves in a “slime layer” that adheres to the prosthesis and remains dormant. It’s extremely difficult to kill bacteria attached to a foreign body.

Voeller: While our infection rate is low, MRSA is responsible for most of the infections.

LeBlanc: For the most part, I see infections in patients who have had a prior mesh repair or a prior mesh infection or who are smokers. With laparoscopic repairs, I have seen infections, especially late prosthetic infections, mainly in patients who have had a prior mesh repair.

Voeller: A previous prosthetic infection is an important

consideration in assessing risk. Bacteria may remain in the wound for a year or longer. I don't know that surgeons fully appreciate that fact.

LeBlanc: For this reason, I typically would prefer to wait to reoperate, if possible, for 6 to 9 months.

Heniford: We talk to our patients about quitting or limiting smoking prior to an open ventral hernia repair. We recently presented an abstract at the Southeastern Surgical Congress showing that smoking was the only factor that predicted wound infection following laparotomy and hernia repair. We don't see the smoking-infection risk with laparoscopic procedures, so we are not as hesitant to proceed with this repair.

We also try to reduce use of steroids when possible. Good glucose control for patients with diabetes also is more important than we used to believe.

■ PREOPERATIVE STEPS TO PREVENT INFECTION

LeBlanc: What preoperative steps do you take to prevent infection?

Voeller: I give preoperative antibiotics and use a first-generation cephalosporin.

Heniford: If a patient is allergic to that, we use vancomycin or a fluoroquinolone. The prophylactic antibiotics should be circulating prior to skin incision: if the drugs are given as the incision is made, it is too late. When I perform a laparoscopic repair in a large patient, we use 2 g of the first-generation cephalosporin 30 minutes prior to incision. We repeat 1 g 2 hours after beginning the procedure. I use the same protocol for open ventral hernia repairs. The literature suggests that there is no need to continue administration postoperatively.

We use electric clippers instead of razors; the incidence of wound infection is higher in patients who have had a razor shave. Patients certainly should not shave themselves before coming to the hospital.

LeBlanc: Using electric clippers is the general trend, though some people no longer even cut the hair.

Heniford: I still like to operate on a bare abdomen.

LeBlanc: Do you prep in the operating room?

Voeller: Yes, although it might be better to do so in the holding room.

■ SURGICAL TECHNIQUES TO MINIMIZE INFECTION RISK

LeBlanc: Good surgical technique is essential in preventing mesh infections. With the availability of new antimicrobial meshes, some surgeons may have a false sense of security. We need to remember that whenever mesh is exposed to the skin, an infection may result.

Voeller: Yes. Careful handling and placement of the mesh is critical. Whether I use a laparoscopic or open approach, I use an Ioban™ drape (3M, St. Paul, Minn). Neither my gloved hand nor the prosthetic touches the unprotected skin. The surgeon should treat the mesh like a vascular graft.

Heniford: That obviously makes sense, because the most common pathogens are from the skin. Guy's point is a good one: I minimize handling of the prosthesis by opening it just before I need it, and I do what I can to keep it from touching the skin.

The most effective way to treat infection is to prevent one. Surgeons need to be attentive to their own aseptic technique and to that of everyone in the operating room.

Voeller: When I perform an open repair, I use an intraperitoneal Stoppa technique. I'll develop the skin and subcutaneous flaps and sew the mesh at least 5 cm to 7 cm from the fascial edge. I cover the mesh with the redundant hernia sac or fascia. I insert an expanded polytetrafluoroethylene [ePTFE] prosthesis only if I know I can cover it adequately with more than just skin and subcutaneous tissues. If I cannot do so, I use a polypropylene or polyester prosthetic that I may be able to salvage more easily if it becomes infected.

In a large open repair, the skin often is not good quality and may be ischemic afterward. Epidermolysis may be unavoidable. Therefore, mesh must be kept covered whenever possible.

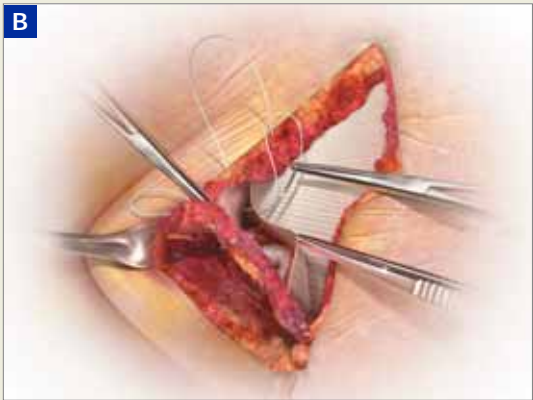
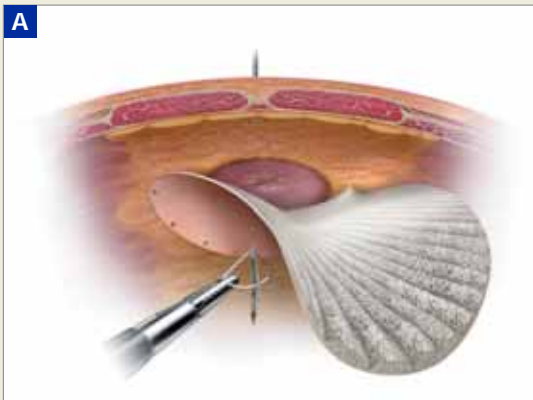
LeBlanc: Do you use drains?

Voeller: Drains may introduce bacteria. Often I see bigger seromas with open repairs compared with those that form after laparoscopic procedures, so I do drain open wounds.

Recently, I have begun using a platelet gel product, made with products from the patient's blood that are separated in a special centrifuge, after open repairs. I place about 120 cc of gel in the wound. I've noticed a significant decrease in the amount of drainage in open repairs. Whether or not it tends to decrease seroma formation long term remains to be seen.

FIGURE 1

**GORE DUALMESH® PLUS
Biomaterial in laparoscopic (A) and
open (B) ventral hernia repairs**



Images courtesy of W.L. Gore & Associates.

Heniford: I use drains in open procedures; I never use them laparoscopically.

LeBlanc: I have heard of a laparoscopic technique in which the surgeon actually incises the hernia skin and drops the mesh into the hernia. If you violate the protective skin over the mesh in this way, the risk of infection will increase.

Voeller: This technique concerns me as well. I will be interested to see the data.

LeBlanc: We all advocate the use of transfascial sutures to reduce the risk of recurrence.^{8,15} Do sutures increase the risk of infections?

Voeller: I have never had an infection at a suture site.

LeBlanc: Neither have I. Many surgeons do not use sutures because it is quicker to use a fixation

device. Some may worry that transfascial sutures increase pain. In my experience, this has not been a problem.

Voeller: I have long argued in favor of using sutures. Ingrowth of mesh to the peritoneum does not provide attachment to strong fascia.

**■ MESH PROPERTIES THAT
MINIMIZE INFECTION**

LeBlanc: When we started to perform laparoscopic hernia repair, we used the original GORE DUALMESH® Biomaterial. When the GORE DUALMESH® PLUS Biomaterial became available, we used that (FIGURE 1). Our infection rate was only 2% before we switched, but with the antimicrobial agents, our infection rate dropped to about 1%,³ similar to Todd's published results.¹² I attribute the improvement to the use of the GORE DUALMESH® PLUS Biomaterial because our technique has not changed significantly.

Heniford: We evaluated the GORE DUALMESH® PLUS Biomaterial antimicrobial agents, silver and chlorhexidine, in several studies. In a series of in vitro and in vivo studies, we infected GORE DUALMESH® PLUS Biomaterial and most of the other meshes available in the United States with *S. aureus* and MRSA.^{5,16} We noted that the antimicrobials silver and chlorhexidine in the GORE DUALMESH® PLUS Biomaterial killed both *S. aureus* and MRSA very effectively. These beneficial results were not seen with other meshes (FIGURES 2, 3, AND 4).^{5,16}

In an animal model, we even tested infected GORE DUALMESH® PLUS Biomaterial in comparison with the animal's own peritoneum used as a mesh. Both were infected with the same quantity of bacteria. We were all quite surprised to find that the GORE DUALMESH® PLUS Biomaterial was less susceptible to infection than was the native peritoneum: Because of the antimicrobial agents, GORE DUALMESH® PLUS Biomaterial was even less infectible than the animal's own tissue.⁵

LeBlanc: What about results in surgery?

Heniford: Our mesh infection rate in Charlotte is approximately 1% and is actually lower when the antimicrobial mesh is used. The only infections we do see are in patients who have had previous mesh infections.

LeBlanc: Guy, your infection rate is very low. What has been your experience?

FIGURE 2

**Bacterial adherence:
loosely attached bacteria removed
from mesh implants**

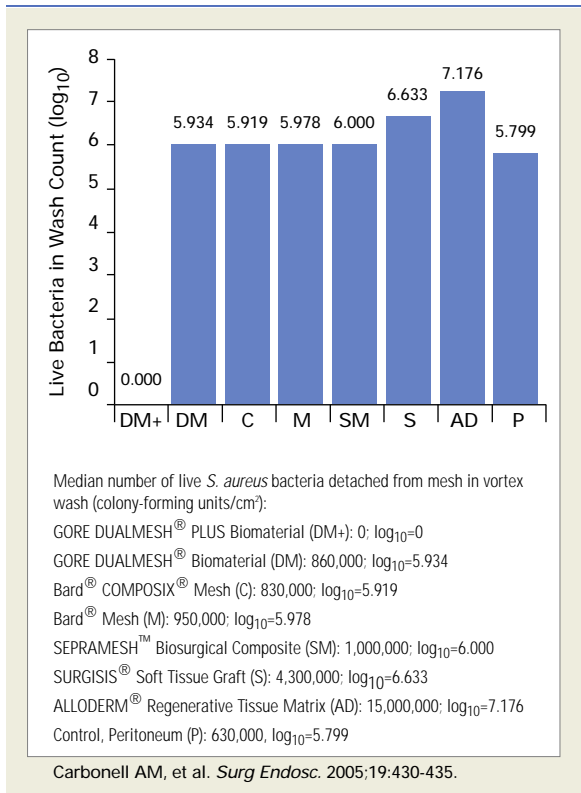
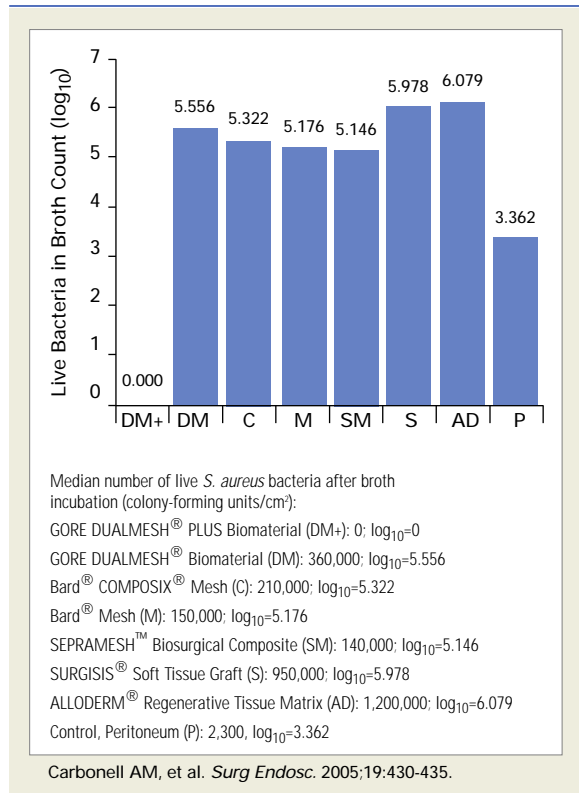


FIGURE 3

**Bacterial activity:
live bacteria after incubation
on mesh**



Voeller: When I use ePTFE, I always use antimicrobial-impregnated mesh. It simply makes sense, and I have done so since our original study demonstrated that GORE DUALMESH[®] PLUS Biomaterial produces no significant adverse systemic or clinical effects.¹⁷

I have never had an infection with a laparoscopic repair. For open procedures, I have had to remove only one piece of ePTFE in the last 2 or 3 years. I believe my success rate results from careful placing and covering of the mesh and because I use antimicrobial materials.

Heniford: We have seen one interesting by-product of the mesh. After the repair, some patients with GORE DUALMESH[®] PLUS Biomaterial developed a slight increase in temperature. Their white blood cell count was not elevated and they looked to be otherwise normal. In a review of 120 consecutive patients, our data showed that about 38% of patients treated with GORE DUALMESH[®] PLUS Biomaterial developed a noninfectious fever immediately postoperatively, compared with about 16% of patients in whom we used untreated GORE

DUALMESH[®] Biomaterial.¹⁸ Looking at this in a broad scope, the fever may have been a reaction to the antimicrobial agents.

Voeller: We were the first to describe 3 patients with a fever of unknown origin after GORE DUALMESH[®] PLUS Biomaterial placement. We do not know what causes it, and I don't consider it a real problem.

■ QUALITIES OF MESH

LeBlanc: What other qualities do you consider when selecting a mesh?

Heniford: Abdominal wall compliance is a key criterion: One of our goals should be that patients do not feel the mesh. I also consider tissue ingrowth and the possibility of adhesions and their tenacity.

LeBlanc: Because of concern about adhesions, many surgeons no longer place polypropylene against the intestinal contents of the abdomen. Do you concur?

Heniford: Yes, this represents a standard of care issue. To place an unprotected mesh in contact with the intestine is not acceptable today. There are simply too many alternative meshes and techniques.

We have studied these meshes in vivo for over 1 year.¹⁹ We found that adhesions form within 7 days and do not occur thereafter. Preventing the formation of adhesions during this initial period is the key to long-term prevention.

Voeller: In this respect, the protective barriers of the mesh product are critical. I am very careful not to traumatize the barrier. However, ingrowth into the visceral surface is of greater concern to me than just adhesions. GORE DUALMESH® Biomaterials are the only products that prohibit this type of ingrowth and still have good ingrowth into the peritoneum.

LeBlanc: It has been said that the ingrowth of some ePTFE products is less than that associated with other types of mesh, although these arguments are based on data from studies of early generations of this product. Having reoperated on patients that have the GORE DUALMESH® Biomaterials, I can certainly attest to their significant ingrowth.

We studied this in a rabbit model. The tissue ingrowth at 3 days was actually stronger with the GORE DUALMESH® Biomaterial than that obtained with a polypropylene mesh (FIGURE 5).²⁰

Voeller: There is a pseudocapsule underneath the visceral surface of the GORE DUALMESH® PLUS Biomaterial that facilitates adhesion removal. When reoperating to remove adhesions, surgeons may need to go deeper than anticipated, through the adhesion to the capsule, which will come off cleanly, looking almost like the original patch.

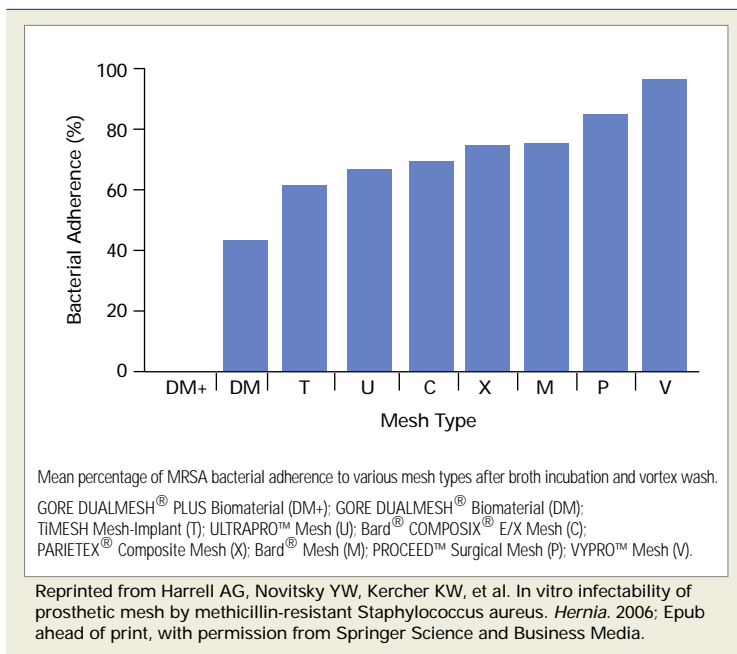
LeBlanc: Do you use biologic meshes?

Voeller: If used for an overlay or underlay, biologic meshes have vascular ingrowth, but for bridging a gap, they do not hold up over time. In those repairs, I use a polypropylene-based or polyester material, which is more easily salvaged if infected.

Heniford: We use biologic meshes only in a compromised abdomen when we have few other options, and

FIGURE 4

Adherence of MRSA to mesh



we have not been pleased with the results we have seen. Frequently, the human dermis product stretches and either becomes a very expensive hernia sac or gives way completely. Many of these patients will require reoperations for their hernias. The porcine submucosal product preliminarily has shown somewhat better results, but more follow-up is needed.

MANAGING A MESH INFECTION

Heniford: How do you typically treat a patient who has developed a wound or mesh infection after an open ventral hernia repair?

LeBlanc: I first consider the organism and type of mesh I have used. Polypropylene-based meshes can be treated more successfully than the ePTFE-based mesh, which is very difficult to treat if infected.

Heniford: I agree; it is much harder for the ePTFE to become infected, but a generalized infection with this mesh almost always requires mesh removal.

Voeller: If a patient has only a chronic draining sinus and a polypropylene mesh, I use a vacuum-assisted closure [VAC] on the wound to clear the infection and try to salvage the mesh. If there is an abscessed infection, I take out any mesh. With these infections, the ePTFE prosthetic floats in the pus and is removed more readily than is polypropylene mesh.

Heniford: We have seen 8 cases of a *S. aureus*- or MRSA-infected ePTFE mesh where the hernia sac used to be. We've been able to cut down on that infection above the mesh, evacuate the infection, and irrigate the wound. If the mesh is sealed to the abdominal wall everywhere else, we will put a wound VAC on the mesh there.

We give these patients intravenous vancomycin and change their wound VAC every 3 days or so for 2 to 3 weeks. When we return them to the operating room, we frequently see granulation tissue growing across the corrugated surface of the mesh. When ready, we excise the ungranulated areas of mesh, sew that area of mesh together with a permanent suture, place drains, and close the skin and subcutaneous tissues over the mesh and drain in layers. Antibiotics are continued for a total of about 6 weeks.

With this technique, we have been able to salvage all but one of these meshes long term.

LeBlanc: That is a tremendous save. With small infected areas, I have just excised the central portion and closed the wound without using even a wound VAC. Some of these patients have recovered without additional treatment. I also have made a vancomycin paste that I put on the ePTFE itself to seal the infection. This method has successfully cleared some infections.

When you can't close the defect after removing an infected mesh, would you use a collagen-based mesh or just close the skin and reoperate later?

Voeller: I put in a biologic mesh, but I tell the patient it may just be a temporary solution until we can permanently repair the hernia.

■ REOPERATING AFTER REMOVAL OF INFECTED MESH

LeBlanc: How do you handle a patient who returns for a hernia repair 6 to 9 months after you have removed an infected mesh?

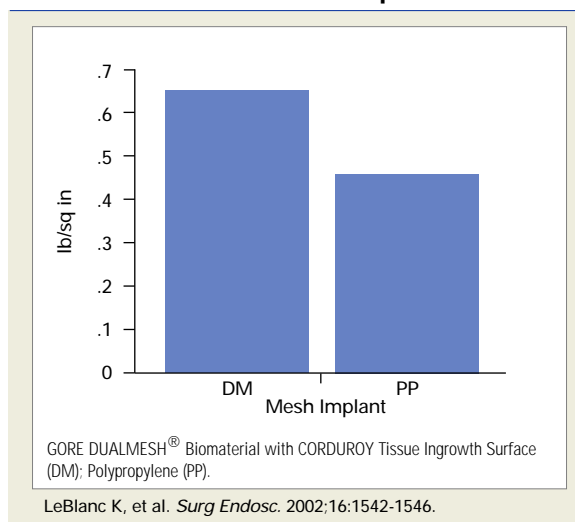
Heniford: Though supporting data are lacking, we have worked out a plan with our infectious disease experts to give minocycline to these patients for 30 days prior to reoperation if their meshes were infected by *S. aureus*.

Voeller: I tell my patients that waiting to reoperate improves their chance of an infection-free repair, but that the first infection puts them at an increased risk of a second one.

Heniford: For patients who have multiple scars on their abdominal wall from numerous previous hernia repairs, we'll actually do an abdominal wall resection

FIGURE 5

Mean force required to remove mesh implant



to eliminate the tissue we think might break down and cause infection after we close up the wound.

We typically work with our plastic surgeons and perform a type of panniculectomy. Instead of removing the skin from the panis though, we make a large horizontal incision and resect the midabdominal skin and subcutaneous fat. We obviously leave the fascia and muscle and remove the scar. We pull the low skin from the panis upward to fill in and close the gap.

In our last study, we performed this in more than 30 patients with very difficult abdominal anatomy. Only the smokers developed infections; for all other patients, the abdominal wall resection was very successful.²¹

LeBlanc: What mesh do you use for these patients and how long do you continue antibiotics postoperatively?

Heniford: Postoperative antibiotics do not make much of a difference in infection rates in the standard patient. If the infection has been cleared and the foreign body has been entirely removed, I don't alter my mesh selection; I will use a mesh impregnated with an antimicrobial substance.

■ THE FUTURE OF INFECTION PREVENTION

LeBlanc: What do we need to do better to prevent infections and improve outcomes for our patients?

Heniford: We must be diligent about sterile technique within the operative field and on the back table. Large hernias and complex abdominal walls typically are the result of previous failures or mesh infections, so preventing recurrence and reoperation is the key.

LeBlanc: What technologic innovations do you anticipate?

Heniford: I believe that lighter-weight meshes may somewhat decrease the risk of infection. The meshes we currently use are much stronger than necessary, and the pure mass of a foreign body may increase the risk of infection and chronic inflammation.²²

Voeller: The current antimicrobials cover many organisms, but new antimicrobials may need to destroy more. We also will see meshes that the body doesn't reject as readily.

Heniford: Future meshes may be part biologic and part permanent, so that they look like a patient's own tissue. Coating it with living tissue will hide the mesh from the patient and from bacteria and could prevent infection and decrease chronic inflammation.

Voeller: The development of laparoscopic techniques for ventral hernia repair was a huge step in preventing infection. The next challenge is to reduce infection rates in open repairs with better techniques and better meshes.

References

- Luijendijk RW, Hop WC, van den Tol MP, et al. Comparison of suture repair with mesh repair for incisional hernia. *N Engl J Med*. 2000;343:392-398.
- Burger JW, Luijendijk RW, Hop WC, Halm JA, Verdaasdonk EG, Jeekel J. Long-term follow-up of a randomized controlled trial of suture versus mesh repair of incisional hernia. *Ann Surg*. 2004;240:578-583.
- LeBlanc KA, Whitaker JM, Bellanger DE, Rhynes VK. Laparoscopic incisional and ventral hernioplasty: lessons from 200 patients. *Hernia*. 2003;7:118-124.
- Rios A, Rodriguez JM, Munitiz V, Alcaraz P, Perez Flores D, Parrilla P. Antibiotic prophylaxis in incisional hernia repair using a prosthesis. *Hernia*. 2001;5:148-152.
- Carbonell AM, Matthews BD, Dreau D, et al. The susceptibility of prosthetic biomaterials to infection. *Surg Endosc*. 2005;19:430-435.
- Klinge U, Conze J, Krones CJ, Schumpelick V. Incisional hernia: open techniques. *World J Surg*. 2005;29:1066-1072.
- Toy FK, Bailey RW, Carey S, et al. Prospective, multicenter study of laparoscopic ventral hernioplasty. *Surg Endosc*. 1998;12:955-959.
- Bageacu S, Blanc P, Breton C, et al. Laparoscopic repair of incisional hernia: a retrospective study of 159 patients. *Surg Endosc*. 2002;16:345-348.
- Ben-Haim M, Kuriansky J, Tal R, et al. Pitfalls and complications with laparoscopic intraperitoneal expanded polytetrafluoroethylene patch repair of postoperative ventral hernia. *Surg Endosc*. 2002;16:785-788.
- Berger D, Bientzle M, Müller A. Postoperative complications after laparoscopic incisional hernia repair. *Surg Endosc*. 2002;16:1720-1723.
- Carbajo MA, Martp del Olmo JC, Blanco JI, et al. Laparoscopic approach to incisional hernias. *Surg Endosc*. 2003;17:118-122.
- Heniford BT, Park A, Ramshaw BJ, Voeller G. Laparoscopic repair of ventral hernias: nine years experience with 850 consecutive hernias. *Ann Surg*. 2003;238:391-400.
- Frantzides CT, Carlson MA, Zografakis JG, Madam AK, Moore RE. Minimally invasive incisional herniorrhaphy: a review of 208 cases. *Surg Endosc*. 2004;18:1488-1491.
- Cobb WS, Harris JB, Lokey JS, McGill ES, Klove KL. Incisional herniorrhaphy with intraperitoneal composite mesh: a report of 95 cases. *Am Surg*. 2003;69:784-787.
- LeBlanc KA, Booth WV, Whitaker JM, Bellanger DE. Laparoscopic incisional and ventral herniorrhaphy in 100 patients. *Am J Surg*. 2000;180:193-197.
- Harrell AG, Novitsky YW, Kercher KW, et al. In vitro infectability of prosthetic mesh by methicillin-resistant *Staphylococcus aureus*. *Hernia*. 2006; Epub ahead of print.
- DeBord JR, Bauer JJ, Grischkan DM, et al. Short-term study on the safety of antimicrobial-agent-impregnated ePTFE patches for hernia repair. *Hernia*. 1999;3:189-193.
- Cobb WS, Paton BL, Rosen MJ, Kercher KW, Kuwanda TS, Heniford BT. Intra-abdominal placement of antimicrobial impregnated mesh is associated with non-infectious fever following laparoscopic ventral hernia repair. Paper presented at: Southeastern Surgical Congress; February 21, 2006; Lake Buena Vista, Fla.
- Novitsky YW, Harrell AG, Peindl R, Cristiano JA, Kercher KW, Heniford BT. Comparative evaluation of adhesion formation, strength of ingrowth, and textile properties of various prosthetic biomaterials one year after intra-abdominal implantation in a rabbit. Paper presented at: Academic Surgical Congress; February 7-10, 2006; San Diego, Calif.
- LeBlanc K, Bellanger D, Rhynes KV, Baker DG, Stout RW. Tissue attachment strength of prosthetic meshes used in ventral and incisional hernia repair. A study in the New Zealand White rabbit adhesion model. *Surg Endosc*. 2002;16:1542-1546.
- Novitsky YW, Porter JR, Rucho ZC, Sing RF, Kercher KW, Heniford BT. Open Rives-Stoppa repair for massive multiply recurrent ventral incisional hernias. Paper presented at: Southeastern Surgical Congress; February 21, 2006; Lake Buena Vista, Fla.
- Cobb WS, Kercher KW, Heniford BT. The argument for lightweight polypropylene mesh in hernia repair. *Surg Innov*. 2005;12:63-69.