Incisional ventral hernias: Review of the literature and recommendations regarding the grading and technique of repair

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Despite advances in surgical technique and prosthetic technologies, the risks for recurrence and infection are high following the repair of incisional ventral hernias. High-quality data suggest that all ventral hernia repairs should be reinforced with prosthetic repair materials. The current standard for reinforced hernia repair is synthetic mesh, which can reduce the risk for recurrence in many patients. However, permanent synthetic mesh can pose a serious clinical problem in the setting of infection. Assessing patients' risk for wound infection and other surgical-site occurrences, therefore, is an outstanding need. To our knowledge, there currently exists no consensus in the literature regarding the accurate assessment of risk of surgical-site occurrences in association with or the appropriate techniques for the repair of incisional ventral hernias. This article proposes a novel hernia grading system based on risk factor characteristics of the patient and the wound. Using this system, surgeons may better assess each patient's risk for surgical-site occurrences and thereby select the appropriate surgical technique, repair material, and overall clinical approach for the patient. A generalized approach and technical considerations for the repair of incisional ventral hernias are outlined, including the appropriate use of component separation and the growing role of biologic repair materials. (Surgery 2010;148:544-58.)

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THE REPAIR OF INCISIONAL VENTRAL HERNIAS is a common surgical procedure; in the United States, it is estimated that 250,000 ventral hernia repairs are performed each year.[1] The indications for repair are well established. However, controversies exist with regard to technique of repair, whether the repair should be reinforced, and, if so, what type of material should be used. One reason for these controversies is the lack of consensus as to when specific techniques and materials should be applied. In addition, a controversy has developed as to what the most important endpoint is in the repair of a ventral hernia: surgical-site occurrence (SSO) or hernia recurrence.

The American Medical Association published a system for the development of evidence-based guidelines that provides for best-practice measures to be employed in patient care.[2] Over the last 15 years, this system has been used in various areas of medicine to arrive at best-care recommendations. To date, no guidelines have been established to address ventral hernia repair.

A Ventral Hernia Working Group (VHWG) has been established to evaluate new technologies and techniques as they apply to ventral hernia repair.

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Table I. Recommendations of the VHWG for the technique of repair of incisional ventral hernias[3,6-9,31,32,62]

Recommendation	*Strength of recommendation*	*Level of evidence*	*Evidence*
1. Reinforcement recommended for repair of all incisional ventral hernias	1	A/B	Burger et al[6] Espinosa-de-los-Monteros et al[7] Luijendijk et al[3]
2. Centralize and reapproximate rectus muscles when feasible under physiologic tension	1	C	de Vries Reilingh et al[8] Espinosa-de-los-Monteros et al[7] Kolker et al[9] VHWG opinion
3. Reduce bioburden prior to repair	1	B	Mangram et al[32] VHWG opinion
4. Placement of repair material: Underlay is the recommended technique for the placement of appropriate repair material for open and laparoscopic repairs; overlay placement of repair material should only be considered when complete fascia-to-fascia repair has been achieved	2	B	Awad et al[31] Espinosa-de-los-Monteros et al[7] Korenkov et al[62] VHWG opinion
5. In the setting of gross, uncontrolled contamination, it is appropriate to consider delayed repair	1	C	VHWG opinion

This group has a common interest in studying ventral hernia as a complex process, similar to that for other surgical diseases. One of the topics that has been addressed is the stratification of patients with a ventral hernia regarding risk for postoperative SSO, specifically surgical-site infection. The goal of this review is to stratify patients by their risk for postoperative SSO and to identify the most favorable techniques for addressing ventral hernia repair in each patient population.

There are few randomized controlled trials in this field and few head-to-head studies of devices or techniques. Many studies are limited by small sample size, lack of comparator group, short follow-up, vague endpoints, variations in surgical technique, and differing definitions of complications. It is the contention of the VHWG, however, that sufficient evidence exists to recommend certain principles for an overall approach to the assessment and repair of incisional ventral hernias and that these recommendations will contribute to improved patient outcomes.

The recommendations of the VHWG describe evidence-based options for the selection of surgical techniques and appropriate reinforcement material (Tables I and II).[3-21] These guidelines are graded according to strength of recommendation and supporting evidence in accordance with previously described methods (Table III).[1,22,23] This review outlines the history of the clinical problem, the rationale and literature supporting the grading system and recommendations, and the application of the recommendations to clinical practice.

BACKGROUND

Despite significant advances in hernia repair techniques and technologies, recurrence rates following standard ventral herniorrhaphy remain unacceptably high. Evidence from the seminal randomized, prospective, controlled trial conducted by Luijendijk et al[3] suggests that nearly one quarter of ventral hernias repaired with synthetic mesh recur within 3 years; the rate approaches 50% for primary repair alone. In addition, the risk of hernia recurrence increases with each additional operation. This relationship was illustrated in a retrospective cohort study of a population-based hospital discharge database.[24] The investigators reported that 12% of patients undergoing incisional hernia repair required at least 1 subsequent reoperation within 5 years; the length of time between reoperations was progressively shorter after each additional hernia repair. The 5-year rate of reoperation was 24% after the first reoperation, 35% after the second, and 39% after the third; the 7-year rate after 3 reoperations approached 50%. These data underscore the importance of minimizing the risk for subsequent reoperations by employing the best evidence-based approach to the first hernia repair.

In 1990, Ramirez et al published their work on local tissue transfer for the repair of ventral hernias.[25] This demonstration ushered in a new

Table II. Recommendations of the VHWG for choice of repair material for incisional ventral hernias, by grade[4,5,11-21]

	Recommendation	*Strength of recommendation*	*Level of evidence*	*Evidence*
Grade 1	Choice of repair material by surgeon preference and patient factors	1	C	VHWG opinion
Grade 2	Increased risk for surgical site occurrence suggests additive risk of permanent synthetic repair material, and potential advantage for appropriate biologic reinforcement	1	B	Dunne et al[12] Finan et al[13] Pessaux et al[14] Petersen et al[20] VHWG opinion
Grade 3	Permanent synthetic repair material generally not recommended; potential advantage to biologic repair material	1	B	Diaz et al[5] Houck et al[11] Jones et al[18] Kim et al[4]
Grade 4	Permanent synthetic repair material not recommended; biologic repair material should be considered	1	A	Diaz et al[5] Jones et al[18] Kim et al[4] Paton et al[16] Patton et al[15] Sczczerba et al[19] van't Riet et al[21] Voyles et al[17]

era in hernia repair, where incisions to release fascia allowed for a tension-free closure of the midline. In an effort to improve recurrence rates, synthetic mesh was employed to reinforce hernia repairs.[6] However, there were significant complications associated with use of synthetic mesh, including infection of the prosthesis and the formation of enterocutaneous fistulae.[17,26-28] In the late 1990s, biologic repair materials were introduced as a possible ventral hernia solution. Although multiple products are available for use, no consensus exists as to the indicated patient population, how they should be implanted, and their overall risk of complication and recurrence.

THE VHWG PROCESS

In September 2008, the VHWG met for a 2-day summit with the goal of developing an initial statement regarding the repair of incisional ventral hernias. The group consisted of 8 surgeons (4 general and 4 plastic), all of whom have extensive experience in abdominal wall reconstruction. The purpose of the summit was 2-fold: (1) to propose a grading system to guide surgeons in the assessment of patients with incisional ventral hernias with regard to risk for SSO, especially infection; and (2) to propose evidence-based recommendations regarding the approach to advanced surgical techniques for the repair of incisional ventral hernia. All aspects related to hernia repair were evaluated and broken down to their core components. A literature search was then undertaken to identify known best practices in each core area determined to be important to a successful ventral hernia repair. These articles were graded based on level of evidence and used to develop the recommendations, grading system, and treatment algorithm.

RESULTS OF LITERATURE REVIEW

Initial discussions identified SSO and recurrence as the 2 main issues in ventral hernia repair. For SSO, patient factors, wound factors, and choice of implant were deemed to be most important. For recurrence, surgical technique was thought to be most important, although patient and wound factors should also be considered. A search of the literature identified various factors related to the status of the patient and wound that should be addressed when evaluating the overall complication risk in a patient with ventral hernia (discussed in the following paragraphs).

Infection and other SSOs. Common SSO following ventral hernia repair include infection, seroma, wound dehiscence, and the formation of enterocutaneous fistulae. Each of these complications conveys morbidity and the risk for additional sequelae. Each also relates to the management of the wound and to risks associated with the use of repair materials. A wound dehiscence, for example, may lead to exposure of the repair material; if the material is a permanent synthetic mesh, then it will likely require removal because of continued risk for infection.[3] Infection is a common and significant postoperative occurrence that increases

Table III. Grading of recommendations[22]

	Grade of recommendation	*Type of evidence*	*Strength of recommendation*
1: Strong recommendation	A: High-quality evidence	RCTs without important limitations, or overwhelming evidence from observational studies	Strong recommendation that can be applied to most patients and circumstances
	B: Moderate-quality evidence	RCTs with important limitations or strong evidence from observational studies	
	C: Low-quality evidence	Observational studies or case series	Strong recommendation, but may change when higher quality evidence becomes available
2: Weak recommendation	A: High-quality evidence	RCTs without important limitations, or overwhelming evidence from observational studies	Weak recommendation, best action may depend on circumstances or other factors
	B: Moderate-quality evidence	RCTs with important limitations or strong evidence from observational studies	
	C: Low-quality evidence	Observational studies or case series	Very weak recommendation; other alternatives may be equally reasonable

RCT, Randomized controlled trial.

the risk of hernia recurrence.[29] Studies have reported rates of infection following ventral hernia repair ranging from 4% to 16%, compared with only 2% following other clean surgical procedures.[3,11-13,30] In a study by Houck et al, a history of previous wound infection predicted greater risk for new infection in a group of patients undergoing incisional hernia repair.[11] Forty-one percent of patients with previous wound infection had a new infection versus 12% of patients with no history of wound infection ($P < .05$).

Wound infection appears to significantly increase the risk for hernia recurrence.[29] In the study by Luijendijk et al, for example, the rate of recurrence among patients with postoperative infection was 80%, compared with 34% for those without infection (relative risk [RR] versus no infection: 4.3; $P = .007$).[3] Previously, Awad et al proposed a classification system that cited 2 factors influencing recurrence following ventral hernia repair with prosthetic repair material: patient factors (increased intra-abdominal pressure, diminished tissue integrity) and technical factors (infection, lateral mesh distraction, missed hernia). They estimated that more than 75% of all recurrence is due to infection and inadequate repair material fixation and/or overlap.[31]

Table IV. Comorbidities shown to increase the risk for postoperative infection[12-14,32]

Smoking
Diabetes
COPD
CAD
Nutritional status
Immunosuppression
Chronic corticosteroid use
Low serum albumin
Obesity
Advanced age

COPD, Chronic obstructive pulmonary disease; *CAD,* coronary artery disease.

Comorbidities and risk for infection. Several comorbidities have been identified that increase the risk of infection following hernia repair (Table IV).[12-14,32] Analyses of the National Surgical Quality Improvement Program (NSQIP) database have reported that corticosteroid use, smoking, coronary artery disease, chronic obstructive pulmonary disease, low preoperative serum albumin levels, prolonged operative time, and use of absorbable synthetic mesh (likely a surrogate for more complex procedures) were significant independent predictors of wound infection.[12,13] Findings from

other studies suggest that age and obesity are independent predictors of infectious complications.[14] Guidelines for the prevention of surgical-site infections[32] also cite altered immune response and nutritional status as risk factors for wound infection. The presence of individual comorbidities may increase the risk for postoperative infection as much as 4-fold.[13]

Permanent synthetic mesh and infection. Synthetic mesh is currently the most common repair material used for reinforcement of ventral hernias.[1] However, despite significant advantages such as reduced recurrence rates, ease of use, and comparatively low cost, permanent synthetic mesh has certain drawbacks. These disadvantages include increased risk for visceral adhesions to the repair site, erosion into the bowel leading to formation of enterocutaneous fistulae and/or bowel obstruction, extrusion of the repair material, and infection.[17,18,26,33-35] For example, permanent synthetic mesh can complicate the treatment of postoperative infection. In this setting, permanent synthetic mesh often requires later surgical removal, necessitating reoperation.[8,16,19-21,36] Following removal of an infected prosthesis, the surgeon is left with a contaminated field and a hernia deficit larger than the original that still requires a repair material. Data suggest that reimplantation of synthetic prostheses into contaminated fields leads to a high rate of reinfection.[37]

Multiple pathways may lead to infection of synthetic mesh. Patients may have acute postoperative mesh infection, or dehiscence of the wound that may expose the mesh, leading to colonization and infection of the prosthesis. Reoperation through synthetic mesh may also lead to infection. Furthermore, seromas that develop may become infected, leading to subsequent contamination and removal of the prosthesis.[8,17,18,33]

Choice of prosthetic repair material. When risk for SSO is deemed to be high based on assessment of risk factors, surgeons may consider the use of biologic repair materials in place of permanent synthetic mesh, because of their ability to support revascularization. Some biologic repair materials have been shown to remain intact even in the setting of active infection; these materials are more resistant to infection and do not require removal when exposed or infected.[4,15,38,39] Some biologic repair materials have also demonstrated antimicrobial activity in vitro and in animal models,[40] and the ability of certain biologic prostheses to support revascularization may contribute to clearance of bacteria.[41] A recent study in a rabbit model, for example, found that a human acellular dermal matrix repair material was significantly superior to polytetrafluoroethylene (PTFE) in terms of the ability to allow for clearance of *Staphylococcus aureus* inoculate at the level expected for contamination ($P = .002$).[42] Studies in animal models also suggest that certain biologic repair materials can be placed in contact with the bowel. In one study, acellular dermal matrices placed directly over the bowel were shown to better resist visceral adhesions in ventral hernia repair sites compared with polypropylene mesh ($P = .004$).[34]

Clinical studies have reported good outcomes with some biologic repair materials for incisional hernia repair in high-risk patient groups. In these reports, patients could be managed nonsurgically even when their wound became frankly infected.[4,5,15,38,39] Some biologic repair materials have been used successfully to repair large contaminated and/or irradiated abdominal wall defects in patients with cancer when placed directly over the bowel.[43,44]

GRADING SYSTEM

The choice between synthetic and biologic repair material for many surgeons is often based on several considerations including cost, choice of technique (eg, open versus laparoscopic), technical expertise, and the risk for SSO. Due to these complex considerations, surgeons would benefit from an assessment tool that helps them develop patient assessment strategies, including the selection of appropriate repair material based on each patient's risk for developing SSO. The VHWG proposes an SSO-risk grading system as an instrument to help surgeons stratify patients' risk of developing postoperative complications (Fig 1).

The novel grading system described herein is intended as a framework for the assessment of risk for SSO based on characteristics of individual patients and hernia defects. The instrument is based on the best available evidence, but will benefit from vetting and validation through clinical use and study. The grading system is proposed as an initial stratification of risk factors and, it is hoped, to serve as a framework for future research. The system consists of 4 grades (Fig 1). These grades do not represent discrete or didactic categories, but rather, salient points along a continuum of risk from low-risk (eg, healthy patients with uncomplicated wounds) to high-risk (eg, patients with multiple comorbidities and uncontrolled infection).

Grade 1 (low risk) captures those patients who have no comorbidities, no history of wound infection, and no evidence of contamination; typically these are younger, healthy individuals.

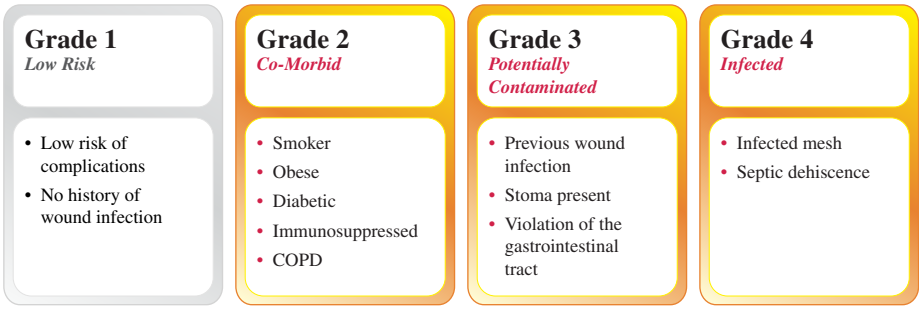

Fig 1. Hernia grading system: assessment of risk for surgical site occurrences. Wound infection defined as being contained within the skin or subcutaneous tissue (superficial), or involving the muscle and/or fascia (deep).[13]

Grade 2 (comorbid) includes patients who have comorbidities that increase the risk for surgical-site infection (Table IV), but who do not have evidence of wound contamination or active infection. The relative contribution of different comorbidities is a matter for consideration and debate. To our knowledge, no data currently exist that dictate which comorbidities carry the most weight, or which combination of comorbidities increases risk. Similarly, there are only minimal data to delineate the tipping point for a characteristic to be considered a comorbidity (eg, how recent a history of infection, how much smoking, what degree of malnutrition, how much corticosteroid use). Certain thresholds have been described. Thresholds at which the risk for infection increases include blood glucose ≥110 mg/dL (hemoglobin A1c >7.0) and age ≥75 years.[45,46] Further research is required to better understand the contribution of comorbidities to risk. Until such data become available, surgeons must rely on their clinical judgment.

Grade 3 (potentially contaminated) is a higher-risk category based on evidence of contamination of the wound. Factors that suggest contamination include the presence of a nearby stoma, violation of the gastrointestinal tract, or history of wound infection. Grade 4 (infected) patients are at highest risk for SSO. Characteristics in grade 4 include active infection, especially infected synthetic mesh, and septic dehiscence. Each of these grades represents a wide swath of risk and patient types. Assessment of risk, therefore, will continue to rely to some degree on individual surgeon judgment and experience. The inclusion criteria for each grade will be further refined as new data regarding comorbidities and outcomes become available.

Each grade relates to the aforementioned risk factors for SSO but does not consider the size or complexity of the defect or the proposed approach to repair. For example, relatively small hernias with infected mesh would still be considered grade 4 because of the presence of active infection. Conversely, relatively large hernias in a healthy individual may be considered grade 1 if there are no comorbidities or signs of contamination, such as violation of the bowel or history of wound infection.

There are characteristics of the patient, defect, and surgical site that may influence the risk for recurrence as well as SSO. For example, a greater number of previous repairs increases the risk of hernia recurrence.[24] For the current statement, however, the VHWG concluded that there are still insufficient data in the literature to reliably grade the risk of recurrence according to the proposed grading scale. It was also agreed that inclusion of hernia recurrence risk in the grading scale would make it too complex for its intended purpose, which is to serve as a simple and memorable guide assessing a patient's risk of SSO.

VHWG APPROACH TO THE TECHNIQUE FOR THE REPAIR OF INCISIONAL VENTRAL HERNIAS

The application of advanced surgical techniques and materials may reduce the risks of recurrence and SSO such as infection. With the goal of minimizing recurrence and complications, the VHWG offers evidence-based recommendations regarding technical approaches to the repair of incisional ventral hernias (Table I). Although these recommendations pertain mainly to open repairs, laparoscopic approaches will be discussed briefly.

The recommendations are not intended to be prescriptive or definitive but to serve as principles to guide the selection of surgical techniques. The VHWG noted significant variation in technical details between surgeons, both within the panel and in the community, and concluded that any extensive discussion of technique is beyond the scope of this article. Therefore, the details of the techniques cited in this statement are not fully described herein.

Table V. Principles for the repair of incisional ventral hernia

Optimize patient condition
Nutritional status
Blood sugar levels
Smoking cessation
Prepare wound
Reduce bioburden
Take down adhesions, fistulae
Reapproximate midline to the extent possible using component separation when appropriate
Use appropriate reinforcement material
Consider biologic repair material in patients at increased risk for surgical-site occurrences

The overall principles agreed on by the VHWG (Table V) are optimization of the patient, preparation of the wound, centralization and reapproximation of the rectus muscles along the midline to the extent possible, and the use of appropriate prosthetic repair material to reinforce the closure. Surgical principles are described in relation to each of the 4 grades of risk in the grading system described above and will focus primarily on open repair.

Patient optimization. Patient optimization includes encouraging smoking cessation (≥4 weeks preoperatively), maintaining blood glucose levels (<110 mg/dL), improving oxygenation in patients with chronic hypoxia (using bronchodilators, inhaled corticosteroids, and/or prostaglandin inhibitors), and setting patient expectations.[12,39,47] Additional factors include weight loss, optimization of nutritional status, and management/control of any infection, if possible. Relevant sites of distal infection include an ileal conduit or the bladder in a patient who requires chronic catheterization to drain urine.

Wound preparation. There are 2 stages of wound preparation. The first occurs prior to surgery; this stage may include percutaneous drainage of any abscesses or management of skin irritation from an enterocutaneous fistula. The second stage occurs in the operating room; sharp debridement of all devitalized or infected tissue to reduce the bioburden of the wound is critical, and contaminated wounds should be cleaned by pulse lavage.[32] If the bioburden can be successfully managed, then immediate reconstruction can be performed. If not, then a staged approach with multiple wound debridements prior to reconstruction may be needed. All fistulae should be definitively managed with excision and reanastomosis or externalization, and infected synthetic prostheses should be removed.

Reapproximation of the rectus muscles. It is the recommendation of the VHWG to centralize and reapproximate the rectus muscles along the midline for ventral hernia repairs to the extent possible. This step attempts to restore the functional, innervated abdominal wall and create a true dynamic repair without undue tension. The phrase "without undue tension" refers to the attempt to restore normal physiologic tension. The abdominal wall is a load-bearing structure and reacts dynamically to internal and external forces (hence "dynamic repair"). Too little tension in a hernia repair results in wound edge separation and poor collagen organization in the incision; too much tension leads to ischemia and wound dehiscence. Physiologic tension attempts to achieve a balance between these opposing outcomes.[48]

Techniques for the repair of ventral hernias commonly used by the VHWG and community surgeons include retrorectus (ie, Rives-Stoppa procedure) and component separation. Retrorectus repair has been widely employed in Europe and is considered by some surgeons to be the standard for repair of ventral hernias. The technique allows for placement of repair material behind the defect without contacting the viscera. The technique of retrorectus repair is described in detail by other authors.[49,50] Consideration should be given to the use of biologic or synthetic repair materials with lower risk for adhesions in case the posterior sheath is absent or breaks down. Retrorectus repair alone, however, does not reduce large defects or centralize the midline.

For larger defects, formal component separation, as first described by Ramirez et al[25] and modified by numerous authors,[8,9,51-57] is the preferred approach for reapproximating the midline with minimal or no tension. Component separation creates a dynamic repair by using incisions that create fascial release to bring the rectus muscles together at the midline, thereby recreating an innervated, functional abdominal wall. Elements of each technique may be used in conjunction. The VHWG recommends the use of component separation or other appropriate techniques to reapproximate the midline for all ventral hernias, except for very small defects or cases where reapproximation is not feasible.

Case series suggest that open component separation has utility in challenging cases, and can reduce recurrence[53,58,59]; however, patients will still benefit from prosthetic repair material, particularly in complex defects (eg, degraded fascia, tight closure, multiple comorbidities, contamination).[7,8,9,58] A recent retrospective review, for example, compared component separation without reinforcement to component separation plus

biologic repair material overlay.[7] This study reported a significantly lower recurrence rate when component separation was reinforced with biologic repair material (0%, component separation plus overlay versus 13%, component separation alone; $P = .006$). One randomized, prospective trial compared component separation to primary repair with expanded PTFE (ePTFE).[8] An interim analysis reported hernia recurrence in 10 of 19 patients in the component separation group (mean time to recurrence, 7 months) and 4 of 18 in the ePTFE group (mean time to recurrence, 22 months). Seven patients in the ePTFE group had an infection of the mesh that required removal of the prosthesis, followed by reconstruction using component separation. It should be noted, however, that no published data have been found directly comparing component separation to primary repair alone (or any other repair technique), nor are there any prospective data evaluating the addition of prosthetic repair material to component separation.

SELECTION AND USE OF PROSTHETIC REPAIR MATERIAL

Level 1A data from the study by Luijendijk et al indicate that all clean, grade 1 ventral hernia repairs should be reinforced with some type of repair material.[3,6] Even in the small hernias in relatively healthy patients included in this study (fascial defect length or width ≤6 cm), the use of prosthetic repair material halved the rate of recurrence, both over short-term (23% vs 46%; $P = .005$)[3] and longer-term (32% vs 63%; $P < .001$) follow-up.[6] Based on these data, the VHWG recommends the use of prosthetic repair material to reinforce the repair of all incisional ventral hernias, regardless of whether or not the midline fascia can be reapproximated.

The diversity of synthetic and biologic repair materials available for the reinforcement of hernia repair complicates the selection of an appropriate prosthesis. At least 80 different prosthetic materials are available for hernia repair,[60] and the characteristics and types of prostheses vary considerably even within the classes of synthetic and biologic materials. The choice of material may be based on a variety of considerations, including characteristics of the patient and defect, surgeon familiarity with material, and cost. The risk for SSO and subsequent infection may determine the selection of a synthetic versus a biologic repair material. Based on the grading system described above, the VHWG recommends that biologic repair materials with specific characteristics (see below) are preferred over synthetic mesh for use in infected fields and should be strongly considered when contamination is suspected (Table II). The VHWG also notes that the increased risk for SSO associated with comorbidities within grade 2 may suggest potential advantages to some biologic repair materials, depending on choice of technique (eg, open versus laparoscopic) and the balance of benefits and risks. It should be emphasized that this suggestion is based on the presumption that certain patients with comorbidities (ie, grade 2) will, in fact, develop SSOs such as wound infection, and that biologic repair materials may facilitate management of infection without necessitating removal. To date, we have found no published controlled clinical studies comparing biologic and synthetic repair materials in this patient population.

Although the VHWG does not make any recommendation regarding choice of specific prosthetic repair materials, certain features of synthetic and biologic repair materials should be considered during the selection process. The VHWG calls attention to specific characteristics such as adequate strength, ease of handling during procedures, ability to resist adhesions when placed in contact with the bowel, and reduced risk of infection through support for tissue incorporation and revascularization.

Synthetic repair materials. Synthetic meshes are most often categorized as macroporous, microporous, or composite.[61,62] Macroporous meshes include monofilament and double-filament polypropylene, among many others. These materials have large pore sizes that allow for in-growth of scar tissue. When placed in contact with abdominal viscera, macroporous meshes are associated with the formation of bowel adhesions and obstructions and enterocutaneous fistulae.[63,64] Therefore, these materials should be avoided or used in combination with vascularized tissue (eg, greater omentum, hernia sac) or antiadhesive barriers when contact with the bowel is likely. Microporous meshes, such as ePTFE, have a smaller pore size that does not allow for tissue in-growth, but may lead to encapsulation and the persistence of bacteria. Therefore, microporous mesh has a lower affinity for adhesions, but may be more susceptible to infection.

A wide variety of composite materials is now available that combine different qualities, such as having macroporous mesh on one side to promote tissue in-growth and microporous mesh on the other to reduce risk for adhesions to the mesh (eg, polypropylene/ePTFE). Synthetic meshes with antiadhesive coatings have also been developed. Such coatings include nonabsorbable (eg, titanium,

polyurethane) and absorbable coatings (eg, omega-3 fatty acid, collagen hydrogel, oxygenated regenerated cellulose). Preclinical evidence suggests reduced risk of adhesions to composite and coated synthetic meshes compared with traditional synthetic meshes.[65-69] The relative benefits of these different prostheses with regard to adhesion formation and risk for infection vary according to different study models, methodologies, and outcomes.[63,67,70-73] Furthermore, prospective data are lacking regarding the clinical benefits of these prostheses for ventral hernia repair, and no comparative clinical data are currently available.

Finally, a new category of lightweight mesh is currently being used in both open and laparoscopic hernia repairs. There are data to suggest better functional outcomes than those achieved with traditional synthetic mesh, although definitive studies are lacking.[74]

Biologic repair materials. Biologic repair materials are an equally diverse and expanding class. Certain specific characteristics are thought to contribute to the successful use of particular biologic repair materials in the setting of contamination or low-grade infection, whereas others are contraindicated. These properties include intact extracellular matrix and the ability to support tissue regeneration through revascularization and cell repopulation in a clinically relevant timeframe. It has been hypothesized that resistance to infection for some biologic repair materials may be related to the in-growth of cells and vasculature.[75] Numerous animal studies have shown that altering the extracellular matrix through suboptimal processing and/or crosslinking may have a negative impact on host response to the repair material.[76,77] The neovascularization demonstrated in studies of some biologic repair materials may allow these materials to better resist infection when placed in a potentially contaminated field.[42,75]

The ability of some biologic repair materials to support regeneration is based on studies in animal models that describe the immunologic response of the host to the prosthesis. Positive recognition (ie, recognition of the prosthesis as "self") leads to regeneration and integration of the repair material into native tissue. Negative recognition (ie, recognition of the prosthesis as foreign) may lead to resorption or encapsulation.[76,78] Resorption and encapsulation have been demonstrated with several biologic repair materials in a nonhuman primate model of abdominal wall repair.[76] The investigators suggested that the lack of integration and tissue regeneration with these materials may account for poor initial wound healing. Integration of 1 non–cross-linked, intact biologic repair material into native tissue was demonstrated in the same nonhuman primate model. These results are similar to those reported in clinical studies.[44,79] In one study of abdominal repair following harvest of transverse rectus abdominus musculocutaneous flaps for breast reconstruction, biopsies of the biologic repair material showed similar cell density, vasculature, and collagen orientation to those of normal abdominal fascial tissue.[79] A second study found that explanted biologic repair material from an irradiated, contaminated abdominal wall repair site 14 months after implantation demonstrated remodeling of the biologic repair material, including revascularization and cellular repopulation.[44]

It should be emphasized that no comparative trials have been performed to date evaluating different biologic repair materials in incisional hernia repair, and differentiation between products is based on early findings with a limited number of the available prostheses. Data describing the qualities of biologic repair materials are only available for certain prostheses. Similar animal and clinical studies are awaited for the majority of products in this class.

TECHNIQUE OF PLACEMENT

There are technical aspects of the use of biologic repair material that must be considered in order to achieve successful outcomes. Studies have documented high rates of seroma, diastasis, bulging, and recurrence with biologic repair materials[80,81]; critical techniques of placement were described that may influence the risk of these complications.[43] In one study, recurrence was reduced when component separation was combined with biologic repair material; conversely, bridging with biologic repair material without reducing the size of the defect was associated with a recurrence rate of 80%.[81] The tensile qualities of repair materials differ and may impact technique. The VHWG notes that most biologic repair materials should be implanted under appropriate tension to help prevent the development of laxity. (This use of *tension* for repair material implantation should be distinguished from the avoidance of *undue tension*—or physiologic tension—that describes the fascial closure.) Surgeons should be aware that the use of a biologic repair material necessitates technical familiarity with its appropriate placement.

Overlay, underlay, or interpositional placement of prosthetic repair material. In open incisional hernia repair, prosthetic repair material may be placed to reinforce a primary repair or to bridge a remaining defect if reapproximation of the

midline is not possible. The repair material may be sutured superficial to the primary repair or fascial edges (overlay), deep to the primary repair or fascial edges (underlay), or to the edge of the defect with minimal overlap (interpositional). The overlay technique is easier to perform, does not require devascularization of the rectus, and prevents contact between the repair material and the underlying viscera. Overlay placement also allows for reinforcement of the lateral releasing incisions after component separation, if desired. Overlay placement, therefore, may be preferred for types of synthetic mesh that are associated with formation of bowel adhesions to minimize the risk that the mesh may erode into the abdominal compartment and become exposed to the viscera.

There are also theoretical advantages to the placement of repair material as an underlay. When the material is placed deep to the abdominal musculature, increases in intra-abdominal pressure press the repair material into the defect and against the native tissue, rather than away from the defect. Intra-abdominal forces may also be more evenly distributed across the repair material when placed as an underlay.[82] Furthermore, cutaneous exposure does not result in exposure of the repair material, because the prosthesis remains below the musculofascial layer.

Bridging of defects, which refers to the use of prosthetic repair material to span tissue gaps when reapproximation of the fascial edges is not possible, has been associated with high rates of recurrence and complications. Bridging may not generally be recommended except in cases where component separation is not feasible or is insufficient to bring the fascial edges together (see discussion of algorithm, below).[83]

The VHWG notes that underlay may be preferred because of the theoretical advantages of this technique. However, there are no reliable data supporting the use of one technique over another.[83] Patient factors and surgeon preference should also be considered. Regardless of placement, repair material should overlap with intact fascia by at least 3–5 cm.[34,84-89]

TECHNICAL OPTIONS BY GRADE

The overriding recommendation of the VHWG regarding the repair of incisional ventral hernia is to reinforce the primary fascial closure with a prosthetic repair material.[6] The selection of type of repair material between biologic and synthetic with regard to hernia grade should be based on risk for SSO (Table II). For patients at low risk for SSO (grade 1), the choice of reinforcement should be based on surgeon preference and patient factors. Grade 2 encompasses patients with comorbidities, such as smoking, diabetes, or malnutrition (Table IV). Data from analyses of the NSQIP database and other studies suggest that patients in grade 2 have a wound infection rate that is 4-fold greater than what is predicted based solely on wound classification.[12,13] Current published evidence does not delineate the relative contribution of each comorbidity to increased risk. Ongoing and future clinical studies may provide a more thorough evidence-based estimate of which and how many comorbidities contribute most significantly to increased risk of SSO. In the absence of more definitive data, the VHWG notes that the increased risk associated with these comorbidities suggests a potential advantage for the use of appropriate biologic repair material for reinforcement of open repairs.

Grade 3 includes patients with contamination of the wound or suspicion of contamination, including a previous wound infection. Based on the increased risk for infection associated with contaminated wounds, the VHWG notes that permanent synthetic mesh is generally not recommended for patients considered to be grade 3. Appropriate biologic repair material is a good option for reinforcement in these patients, because it does not necessitate removal even in the setting of active infection.

Grade 4 patients have frankly infected wounds, most notably those associated with an existing infected synthetic mesh. Studies suggest that the replacement of infected synthetic mesh with new permanent synthetic mesh leads to a high rate of reoperation and additional mesh infection and replacement.[8] The use of permanent synthetic mesh in patients considered to be grade 4, therefore, is not recommended by the VHWG. In accordance with the surgical principles outlined above and in Table V, infected wounds should be thoroughly prepared by meticulously reducing the bioburden prior to placement of repair material and definitive closure. No repair material should be used in the setting of gross, uncontrolled contamination, and surgeons may consider a delayed repair in such situations.

LAPAROSCOPIC REPAIR OF INCISIONAL VENTRAL HERNIA

This statement focuses primarily on the open repair of incisional ventral hernia. However, the growing popularity of laparoscopic techniques deserves discussion with relation to the grading system and recommendations of the VHWG.

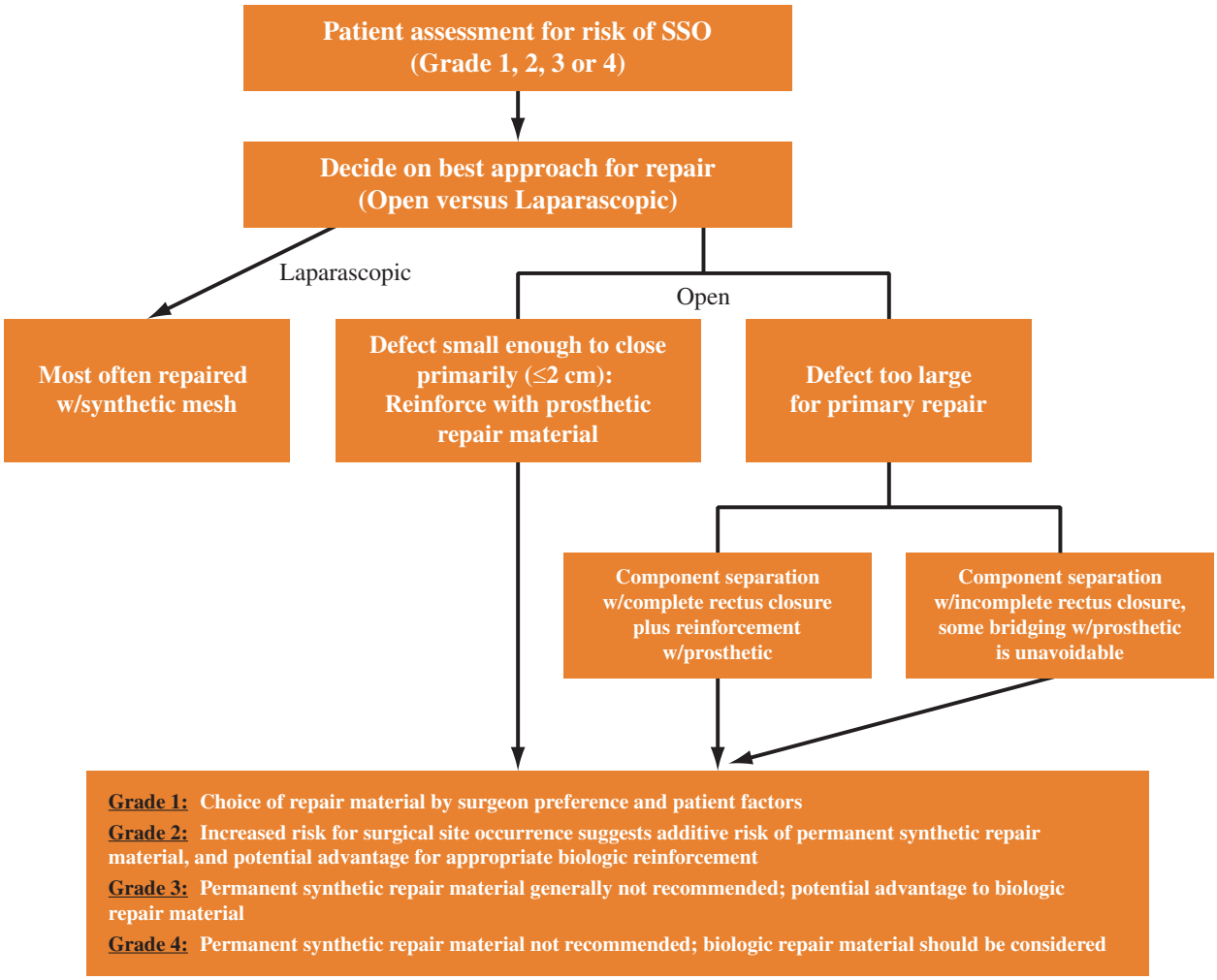

Fig 2. Algorithm for repair of incisional ventral hernia.

Although recurrence rates following reinforced laparoscopic hernia repair are comparable to those of open repair with reinforcement,[90,91] there are several documented advantages of the laparoscopic approach, including smaller incisions, lower risk for complications, shorter hospital stay, and patient preference.[90-92] A recent meta-analysis of randomized controlled trials comparing open and laparoscopic incisional hernia repairs reported a significantly higher rate of complications with open repair (RR .49, $P < .001$ by fixed-effects model; RR .53, $P = .028$ by random-effects model).[89] Reported complications included seroma, abscess, incarceration, hematoma, cellulitis, wound infection, bowel obstruction, and ileus. A single-institution cohort study comparing open and laparoscopic ventral hernia repair (N = 360) reported major morbidities in 15% of the open group and 7% of the laparoscopic group ($P = .01$) over a mean follow-up period of 30–36 months, respectively.[91] Postoperative inpatient admission was also more frequent in the open group (28% vs 16%; $P < .05$). However, seromas may be more common following laparoscopic hernia repair. In the aforementioned cohort study, seromas were significantly more common in the laparoscopic group (16% vs 8%; $P = .01$). Indeed, higher rates of seroma have been widely reported with laparoscopic repairs. Lower incidence of seroma in open procedures may relate to the use of drains, which are not generally placed in laparoscopic repairs. Seromas often resolve uneventfully, and many surgeons do not consider this occurrence to be pathologic unless intervention is required due to the risk of contamination and subsequent infection of the seroma.[82]

In addition to a higher rate of seroma formation, the limitations of laparoscopic repair include

the inability to restore functional abdominal wall anatomy. Other difficulties include the inability to manage skin redundancy and the hernia sac. Current approaches to laparoscopic repair do not routinely employ extensive mobilization of tissue, meaning that the repair material is almost always bridging some aspect of the defect. Laparoscopically inserted repair material is placed intraperitoneally as an underlay below the fascial defect.[82] These repairs do not recreate an innervated abdominal wall under physiologic tension.

Recently, several investigators have described minimally invasive techniques of component separation.[54] Experience with these techniques has been reported in studies of cadavers,[55] a porcine model,[56] select patients with infected repair material,[57] and small comparative groups.[54] Preliminary results suggest that minimally invasive techniques are feasible, and may be associated with fewer complications.

TREATMENT ALGORITHM

The first step in the treatment of ventral hernia is patient assessment, starting with risk factors and size of the defect. Smaller defects (≤2 cm) may be suitable for primary repair; larger defects where the fascia does not meet without undue tension should be reduced as much as possible. Each patient's risk for SSO should be assessed using the grading system.

A proposed algorithm for the treatment of incisional ventral hernias is illustrated in Fig 2. Following assessment for risk of SSO, patients are categorized by size of defect. Very small defects may be closed primarily along with reinforcing prosthetic repair material, potentially using a retrorectus repair. Most defects too large for primary repair can be closed with component separation and reinforced with prosthetic repair material. For the rare cases in which component separation is not feasible or is insufficient to completely reduce the defect, surgeons may consider bridging the defect with prosthetic repair material. (The repair material should underlie the rectus muscles by at least 5 cm.) Examples of patients for whom component separation may not be feasible include those with intensive radiation treatment of the abdominal wall or extensive scarring of the rectus muscles. Surgeons should exercise their judgment when considering the feasibility of component separation. When using component separation and/or other techniques to reapproximate the rectus muscles, the authors find that bridging of defects with biologic repair material is rarely necessary.

The nature of a laparoscopic ventral hernia repair as currently performed leads to a bridged repair. For surgeons who practice laparoscopic repairs, patients in grade 1, many in grade 2, and some in grade 3 may be suitable for this approach, depending on individual risk for infection and other considerations. Hernias in grade 4 should be repaired with open procedures. The same principles of selecting prosthetic repair material apply regardless of technique (open versus laparoscopic): most patients in grade 1, some in grade 2, and a few in grade 3 may be suitable for repair with permanent synthetic mesh; all patients considered at increased risk for SSO (including some in grade 2, most in grade 3, and all in grade 4) should be considered for repair with appropriate biologic repair material.

OTHER CONSIDERATIONS IN SELECTION OF REPAIR MATERIAL AND TECHNIQUE

One key consideration in the selection of prosthetic repair material deserves mention. Currently, there is wide variation in the cost of available prostheses. For some institutions and practices, cost may limit or eliminate the use of more expensive devices. A thorough discussion of cost considerations is not the intended purpose of this article. However, future analyses of the cost-benefit relationship accounting for the expense of materials, surgical procedures, and potential complications would be greatly beneficial to practitioners and administrators alike.

Many of the advanced techniques described in this consensus statement require extensive hospital resources and a high level of training. Surgeons in settings with less extensive resources may give consideration to the referral of resource-intensive patients to tertiary care centers that have appropriate surgical resources.

SUMMARY

Incisional ventral hernias are common and challenging for surgeons. The lack of high-quality evidence leaves surgeons without clear guidance regarding the selection of technique or material. The ultimate goal of this effort was to produce a simple, generally accepted grading system and surgical technique recommendations for the repair of incisional ventral hernias. The first step in this effort was the creation of an initial literature review and set of recommendations. This statement represents the current state-of-the-art technique and materials as described by thought leaders in the field and supported by the best available evidence. It is hoped that the grading system and recommendations will serve to assist surgeons and stimulate discussion and research.

As new data become available, the VHWG will revisit this statement to reflect the evolving understanding of ventral hernias. Future updates will be provided as data emerge and novel techniques and materials are developed.

REFERENCES

1. Millennium Research Group. US markets for soft tissue repair 2009. Toronto, ON: Millennium Research Group, Inc; 2008.
2. American Medical Association. Attributes to guide the development and evaluation of practice parameters/guidelines. Chicago: American Medical Association; 1996.
3. Luijendijk RW, Hop WC, van den Tol MP, de Lange DC, Braaksma MM, IJzermans JN, et al. A comparison of suture repair with mesh repair for incisional hernia. N Engl J Med 2000;343:392-8.
4. Kim H, Bruen K, Vargo D. Acellular dermal matrix in the management of high-risk abdominal wall defects. Am J Surg 2006;192:705-9.
5. Diaz JJ Jr, Guy J, Berkes MB, Guillamondegui O, Miller RS. Acellular dermal allograft for ventral hernia repair in the compromised surgical field. Am Surg 2006;72:1181-7.
6. 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;240:578-83.
7. Espinosa-de-los-Monteros A, de la Torre JI, Marrero I, Andrades P, Davis MR, Vasconez LO. Utilization of human cadaveric acellular dermis for abdominal hernia reconstruction. Ann Plast Surg 2007;58:264-7.
8. de Vries Reilingh TS, van Goor H, Charbon JA, Rosman C, Hesselink EJ, van der Wilt GJ, et al. Repair of giant midline abdominal wall hernias: "components separation technique" versus prosthetic repair: interim analysis of a randomized controlled trial. World J Surg 2007;31:756-63.
9. Kolker AR, Brown DJ, Redstone JS, Scarpinato VM, Wallack MK. Multilayer reconstruction of abdominal wall defects with acellular dermal allograft (AlloDerm) and component separation. Ann Plast Surg 2005;55:36-41.
10. Fabian TC, Croce MA, Pritchard FE, Minard G, Hickerson WL, Howell RL, et al. Planned ventral hernia. Staged management for acute abdominal wall defects. Ann Surg 1994; 219:643-50.
11. Houck JP, Rypins EB, Sarfeh IJ, Juler GL, Shimoda KJ. Repair of incisional hernia. Surg Gynecol Obstet 1989;169:397-9.
12. Dunne JR, Malone DL, Tracy JK, Napolitano LM. Abdominal wall hernias: risk factors for infection and resource utilization. J Surg Res 2003;111:78-84.
13. Finan KR, Vick CC, Kiefe CI, Neumayer L, Hawn MT. Predictors of wound infection in ventral hernia repair. Am J Surg 2005;190:676-81.
14. Pessaux P, Lermite E, Blezel E, et al. Predictive risk score for infection after inguinal hernia repair. Am J Surg 2006;192: 165-71.
15. Patton JH Jr, Berry S, Kralovich KA. Use of human acellular dermal matrix in complex and contaminated abdominal wall reconstructions. Am J Surg 2007;193:360-3.
16. Paton BL, Novitsky YW, Zerey M, Sing RF, Kercher KW, Heniford BT. Management of infections of polytetrafluoroethylene-based mesh. Surg Infect (Larchmt) 2007;8:337-41.
17. Voyles CR, Richardson JD, Bland KI, Tobin GR, Flint LM, Polk HC Jr. Emergency abdominal wall reconstruction with polypropylene mesh: short-term benefits versus long-term complications. Ann Surg 1981;194:219-23.
18. Jones JW, Jurkovich GJ. Polypropylene mesh closure of infected abdominal wounds. Am Surg 1989;55:73-6.
19. Szczerba SR, Dumanian GA. Definitive surgical treatment of infected or exposed ventral hernia mesh. Ann Surg 2003; 237:437-41.
20. Petersen S, Henke G, Freitag M, Faulhaber A, Ludwig K. Deep prosthesis infection in incisional hernia repair: predictive factors and clinical outcome. Eur J Surg 2001;167:453-7.
21. van 't Riet M, de Vos van Steenwijk PJ, Bonjer HJ, Steyerberg EW, Jeekel J. Mesh repair for postoperative wound dehiscence in the presence of infection: is absorbable mesh safer than non-absorbable mesh? Hernia 2007;11:409-13.
22. Guyatt G, Gutterman D, Baumann MH, Addrizzo-Harris D, Hylek EM, Phillips B, et al. Grading strength of recommendations and quality of evidence in clinical guidelines: report from an american college of chest physicians task force. Chest 2006; 129:174-81.
23. Shekelle PG, Woolf SH, Eccles M, Grimshaw J. Clinical guidelines: developing guidelines. BMJ 1999;318:593-6.
24. Flum DR, Horvath K, Koepsell T. Have outcomes of incisional hernia repair improved with time? A population-based analysis. Ann Surg 2003;237:129-35.
25. Ramirez OM, Ruas E, Dellon AL. "Components separation" method for closure of abdominal-wall defects: an anatomic and clinical study. Plast Reconstr Surg 1990;86:519-26.
26. Leber GE, Garb JL, Alexander AI, Reed WP. Long-term complications associated with prosthetic repair of incisional hernias. Arch Surg 1998;133:378-82.
27. Cobb WS, Harris JB, Lokey JS, McGill ES, Klove KL. Incisional herniorrhaphy with intraperitoneal composite mesh: a report of 95 cases. Am Surg 2003;69:784-7.
28. Karakousis CP, Volpe C, Tanski J, Colby ED, Winston J, Driscoll DL. Use of a mesh for musculoaponeurotic defects of the abdominal wall in cancer surgery and the risk of bowel fistulas. J Am Coll Surg 1995;181:11-6.
29. Iqbal CW, Pham TH, Joseph A, Mai J, Thompson GB, Sarr MG. Long-term outcome of 254 complex incisional hernia repairs using the modified Rives-Stoppa technique. World J Surg 2007;31:2398-404.
30. White TJ, Santos MC, Thompson JS. Factors affecting wound complications in repair of ventral hernias. Am Surg 1998;64:276-80.
31. Awad ZT, Puri V, LeBlanc K, et al. Mechanisms of ventral hernia recurrence after mesh repair and a new proposed classification. J Am Coll Surg 2005;201:132-40.
32. Mangram AJ, Horan TC, Pearson ML, Silver LC, Jarvis WR. Guideline for prevention of surgical site infection, 1999. Hospital Infection Control Practices Advisory Committee. Infect Control Hosp Epidemiol 1999;20:250-78.
33. Stone HH, Fabian TC, Turkleson ML, Jurkiewicz MJ. Management of acute full-thickness losses of the abdominal wall. Ann Surg 1981;193:612-8.
34. Butler CE, Prieto VG. Reduction of adhesions with composite AlloDerm/polypropylene mesh implants for abdominal wall reconstruction. Plast Reconstr Surg 2004;114:464-73.
35. Bauer JJ, Harris MT, Kreel I, Gelernt IM. Twelve-year experience with expanded polytetrafluoroethylene in the repair of abdominal wall defects. Mt Sinai J Med 1999;66:20-5.
36. Martin-Duce A, Noguerales F, Villeta R, et al. Modifications to Rives technique for midline incisional hernia repair. Hernia 2001;5:70-2.
37. Clagett GP, Bowers BL, Lopez-Viego MA, Rossi MB, Valentine RJ, Myers SI, et al. Creation of a neo-aortoiliac system

from lower extremity deep and superficial veins. Ann Surg 1993;218:239-48.
38. Helton WS, Fisichella PM, Berger R, Horgan S, Espat NJ, Abcarian H. Short-term outcomes with small intestinal submucosa for ventral abdominal hernia. Arch Surg 2005;140: 549-60.
39. Maurice SM, Skeete DA. Use of human acellular dermal matrix for abdominal wall reconstructions. Am J Surg 2009; 197:35-42.
40. Sarikaya A, Record R, Wu CC, Tullius B, Badylak S, Ladisch M. Antimicrobial activity associated with extracellular matrices. Tissue Eng 2002;8:63-71.
41. Badylak SF, Coffey AC, Lantz GC, Tacker WA, Geddes LA. Comparison of the resistance to infection of intestinal submucosa arterial autografts versus polytetrafluoroethylene arterial prostheses in a dog model. J Vasc Surg 1994;19:465-72.
42. Milburn ML, Holton LH, Chung TL, Li EN, Bochicchio GV, Goldberg NH, et al. Acellular dermal matrix compared with synthetic implant material for repair of ventral hernia in the setting of peri-operative Staphylococcus aureus implant contamination: a rabbit model. Surg Infect (Larchmt) 2008;9:433-42.
43. Butler CE, Langstein HN, Kronowitz SJ. Pelvic, abdominal, and chest wall reconstruction with AlloDerm in patients at increased risk for mesh-related complications. Plast Reconstr Surg 2005;116:1263-75.
44. Nemeth NL, Butler CE. Complex torso reconstruction with human acellular dermal matrix: long-term clinical follow-up. Plast Reconstr Surg 2009;123:192-6.
45. Malone DL, Genuit T, Tracy JK, Gannon C, Napolitano LM. Surgical site infections: reanalysis of risk factors. J Surg Res 2002;103:89-95.
46. van den Berghe G, Wouters P, Weekers F, Verwaest C, Bruyninckx F, Schetz M, et al. Intensive insulin therapy in the critically ill patients. N Engl J Med 2001;345:1359-67.
47. Lindstrom D, Sadr Azodi O, Wladis A, Tonnesen H, Linder S, Nasell H, et al. Effects of a perioperative smoking cessation intervention on postoperative complications: a randomized trial. Ann Surg 2008;248:739-45.
48. Franz MG. The biology of hernias and the abdominal wall. Hernia 2006;10:462-71.
49. Bauer JJ, Harris MT, Gorfine SR, Kreel I. Rives-Stoppa procedure for repair of large incisional hernias: experience with 57 patients. Hernia 2002;6:120-3.
50. Heartsill L, Richards ML, Arfai N, et al. Open Rives-Stoppa ventral hernia repair made simple and successful but not for everyone. Hernia 2005;9:162-6.
51. Vargo D. Component separation in the management of the difficult abdominal wall. Am J Surg 2004;188:633-7.
52. Ennis LS, Young JS, Gampper TJ, Drake DB. The "openbook" variation of component separation for repair of massive midline abdominal wall hernia. Am Surg 2003;69:733-42.
53. de Vries Reilingh TS, van Goor H, Rosman C, Bemelmans MH, de Jong D, van Nieuwenhoven EJ, et al. "Components separation technique" for the repair of large abdominal wall hernias. J Am Coll Surg 2003;196:32-7.
54. Lowe JB, Garza JR, Bowman JL, Rohrich RJ, Strodel WE. Endoscopically assisted "components separation" for closure of abdominal wall defects. Plast Reconstr Surg 2000;105:720-9.
55. Milburn ML, Shah PK, Friedman EB, et al. Laparoscopically assisted components separation technique for ventral incisional hernia repair. Hernia 2007;11:157-61.
56. Rosen MJ, Williams C, Jin J, et al. Laparoscopic versus open-component separation: a comparative analysis in a porcine model. Am J Surg 2007;194:385-9.
57. Rosen MJ, Jin J, McGee MF, Williams C, Marks J, Ponsky JL. Laparoscopic component separation in the single-stage treatment of infected abdominal wall prosthetic removal. Hernia 2007;11:435-40.
58. DiBello JN Jr, Moore JH Jr. Sliding myofascial flap of the rectus abdominus muscles for the closure of recurrent ventral hernias. Plast Reconstr Surg 1996;98:464-9.
59. Levine JP, Karp NS. Restoration of abdominal wall integrity as a salvage procedure in difficult recurrent abdominal wall hernias using a method of wide myofascial release. Plast Reconstr Surg 2001;107:707-16.
60. Kingsnorth A, LeBlanc K. Hernias: inguinal and incisional. Lancet 2003;362:1561-71.
61. den Hartog D, Dur AH, Tuinebreijer WE, Kreis RW. Open surgical procedures for incisional hernias. Cochrane Database Syst Rev 2008:CD006438.
62. Korenkov M, Paul A, Sauerland S, et al. Classification and surgical treatment of incisional hernia. Results of an experts' meeting. Langenbecks Arch Surg 2001;386:65-73.
63. Harrell AG, Novitsky YW, Peindl RD, Cobb WS, Austin CE, Cristiano JA, et al. Prospective evaluation of adhesion formation and shrinkage of intra-abdominal prosthetics in a rabbit model. Am Surg 2006;72:808-13.
64. Novitsky YW, Harrell AG, Cristiano JA, Paton BL, Norton HJ, Peindl RD, et al. Comparative evaluation of adhesion formation, strength of ingrowth, and textile properties of prosthetic meshes after long-term intra-abdominal implantation in a rabbit. J Surg Res 2007;140:6-11.
65. Bellon JM, Rodriguez M, Garcia-Honduvilla N, Gomez-Gil V, Pascual G, Bujan J. Postimplant behavior of lightweight polypropylene meshes in an experimental model of abdominal hernia. J Invest Surg 2008;21:280-7.
66. Emans PJ, Schreinemacher MH, Gijbels MJ, Beets GL, Greve JW, Koole LH, et al. Polypropylene meshes to prevent abdominal herniation. Can stable coatings prevent adhesions in the long term? Ann Biomed Eng 2009;37: 410-8.
67. van 't Riet M, de Vos van Steenwijk PJ, Bonthuis F, Marquet RL, Steyerberg EW, Jeekel J, et al. Prevention of adhesion to prosthetic mesh: comparison of different barriers using an incisional hernia model. Ann Surg 2003;237:123-8.
68. Schug-Pass C, Sommerer F, Tannapfel A, Lippert H, Kockerling F. The use of composite meshes in laparoscopic repair of abdominal wall hernias: are there differences in biocompatibility?: experimental results obtained in a laparoscopic porcine model. Surg Endosc 2009;23: 487-95.
69. Pierce RA, Perrone JM, Nimeri A, Sexton JA, Walcutt J, Frisella MM, et al. 120-day comparative analysis of adhesion grade and quantity, mesh contraction, and tissue response to a novel omega-3 fatty acid bioabsorbable barrier macroporous mesh after intraperitoneal placement. Surg Innov 2009;16:46-54.
70. Harrell AG, Novitsky YW, Kercher KW, Foster M, Burns JM, Kuwada TS, et al. In vitro infectability of prosthetic mesh by methicillin-resistant Staphylococcus aureus. Hernia 2006; 10:120-4.
71. Schreinemacher MH, Emans PJ, Gijbels MJ, Greve JW, Beets GL, Bouvy ND. Degradation of mesh coatings and intraperitoneal adhesion formation in an experimental model. Br J Surg 2009;96:305-13.
72. de Vries Reilingh TS, van Goor H, Koppe MJ, Bodegom ME, Hendriks T, Bleichrodt RP. Interposition of polyglactin mesh does not prevent adhesion formation between viscera and polypropylene mesh. J Surg Res 2007;140:27-30.

73. Burger JW, Halm JA, Wijsmuller AR, ten Raa S, Jeekel J. Evaluation of new prosthetic meshes for ventral hernia repair. Surg Endosc 2006;20:1320-5.
74. Cobb WS, Kercher KW, Heniford BT. The argument for lightweight polypropylene mesh in hernia repair. Surg Innov 2005;12:63-9.
75. Holton LH 3rd, Kim D, Silverman RP, Rodriguez ED, Singh N, Goldberg NH. Human acellular dermal matrix for repair of abdominal wall defects: review of clinical experience and experimental data. J Long Term Eff Med Implants 2005;15:547-58.
76. Sandor M, Xu H, Connor J, Lombardi J, Harper JR, Silverman RP, et al. Host response to implanted porcine-derived biologic materials in a primate model of abdominal wall repair. Tissue Eng Part A 2008;14:2021-31.
77. Jarman-Smith ML, Bodamyali T, Stevens C, Howell JA, Horrocks M, Chaudhuri JB. Porcine collagen crosslinking, degradation and its capability for fibroblast adhesion and proliferation. J Mater Sci Mater Med 2004;15:925-32.
78. Xu H, Wan H, Sandor M, Qi S, Ervin F, Harper JR, et al. Host response to human acellular dermal matrix transplantation in a primate model of abdominal wall repair. Tissue Eng Part A 2008;14:2009-19.
79. Glasberg SB, D'Amico RA. Use of regenerative human acellular tissue (AlloDerm) to reconstruct the abdominal wall following pedicle TRAM flap breast reconstruction surgery. Plast Reconstr Surg 2006;118:8-15.
80. Gupta A, Zahriya K, Mullens PL, Salmassi S, Keshishian A. Ventral herniorrhaphy: experience with two different biosynthetic mesh materials, Surgisis and Alloderm. Hernia 2006;10:419-25.
81. Jin J, Rosen MJ, Blatnik J, McGee MF, Williams CP, Marks J, et al. Use of acellular dermal matrix for complicated ventral hernia repair: does technique affect outcomes? J Am Coll Surg 2007;205:654-60.
82. Turner PL, Park AE. Laparoscopic repair of ventral incisional hernias: pros and cons. Surg Clin North Am 2008;88:85-100.
83. Kingsnorth A. The management of incisional hernia. Ann R Coll Surg Engl 2006;88:252-60.
84. Wassenaar EB, Raymakers JT, Rakic S. Impact of the mesh fixation technique on operation time in laparoscopic repair of ventral hernias. Hernia 2008;12:23-5.
85. Tsimoyiannis EC, Tsimogiannis KE, Pappas-Gogos G, Nikas K, Karfis E, Sioziou H. Seroma and recurrence in laparoscopic ventral hernioplasty. JSLS 2008;12:51-7.
86. Klinge U, Conze J, Krones CJ, Schumpelick V. Incisional hernia: open techniques. World J Surg 2005;29:1066-72.
87. LeBlanc KA. Laparoscopic incisional and ventral hernia repair: complications-how to avoid and handle. Hernia 2004; 8:323-31.
88. Schumpelick V, Klinge U, Junge K, Stumpf M. Incisional abdominal hernia: the open mesh repair. Langenbecks Arch Surg 2004;389:1-5.
89. Tagaya N, Mikami H, Aoki H, Kubota K. Long-term complications of laparoscopic ventral and incisional hernia repair. Surg Laparosc Endosc Percutan Tech 2004;14:5-8.
90. Sajid MS, Bokhari SA, Mallick AS, Cheek E, Baig MK. Laparoscopic versus open repair of incisional/ventral hernia: a meta-analysis. Am J Surg 2009;197:64-72.
91. Bingener J, Buck L, Richards M, Michalek J, Schwesinger W, Sirinek K. Long-term outcomes in laparoscopic vs open ventral hernia repair. Arch Surg 2007;142:562-7.
92. Goodney PP, Birkmeyer CM, Birkmeyer JD. Short-term outcomes of laparoscopic and open ventral hernia repair: a meta-analysis. Arch Surg 2002;137:1161-5.

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