Eastern Association for the Surgery of Trauma: Management of the open abdomen, Part III—Review of abdominal wall reconstruction

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The development of the "damage control" concept and the utility of the open abdomen (OA) technique in trauma, general, and vascular surgical emergencies have resulted in improved survival of the critically ill or injured patient.[1] The indications for damage-control surgery and the management of the OA have been published in the two previous publications from the Eastern Association for the Surgery of Trauma (EAST) Practice Management Guidelines Committee: Open Abdomen Parts I and II.[2,3] Every surgical procedure carries with it benefits and risks, which may not manifest themselves until later. For the patients recovering with an OA, the decision of when and how to close the abdomen can become quite complicated. This is especially true if there has been loss of abdominal domain or after an enteroatmospheric fistula has occurred.

In the acute setting, once intra-abdominal injuries have been addressed, visceral edema has subsided, and the degree of bacterial contamination has minimized, the abdomen should be closed. The etiology of the intra-abdominal pathology determines the ability to close the abdomen. The highest rates of abdominal closure are in trauma patients, followed by vascular emergencies. The lowest rates of abdominal closure are in emergency general surgery, with pancreatitis having the lowest rate of abdominal closure.[4] In 1994, Fabian et al.[5] described the planned ventral hernia as the initial stage in the management of the OA.

During the last 30 years, patients with catastrophic injury or illness have survived with the use of damage control and a planned ventral hernia. There has been intense interest in both addressing the shortcomings of the planned ventral hernia and how to electively repair these very complex of ventral hernias. Our aim was to develop an organized evidence-based approach to the management of the elective repair of the planned ventral hernia.

PATIENTS AND METHODS

An extensive computerized literature search was performed using the National Library of Medicine, National Institutes of Health, MEDLINE database, www.guidelines.gov, and EMBASE. This was performed using PubMed Entrez interface www.pubmed.gov. An MLS (master of library and information science) librarian performed the search. Only English language articles were used. The focus was on the "elective" and "planned" repair of complex abdominal wall defects and abdominal wall reconstruction published between 1984 and 2012. Given the complexity of this literature, several strategies were necessary to appropriately capture the breadth of evidence on the topic. The search excluded case reports, reviews, letters/commentary, editorials, and articles focusing only on pediatric participants.

There were 278 articles identified by the initial search criteria; only prospective or retrospective studies examining "complex ventral hernia," "open abdominal management," "abdominal wall reconstruction," "component separation," "laparoscopic component separation," "endoscopic component separation," "Rives-Stoppa hernia repair," and "elective" complex ventral hernia repair were selected.

Four of the authors (J.J.D., G.H.T., M.O., and R.J.) reviewed all of the abstracts and selected 125 articles for full review by the study group. The articles were classified according to the EAST classes of evidence based on the 2000 EAST Primer for the development of practice management guidelines.[6] The reviewers were asked to provide their assessments of the articles based the on the EAST Primer and to formulate their conclusions based on the study results. All the reviewers' comments were collated. and 99 articles were selected for the development of this review (Fig. 1).

The Review

Currently, there is no uniformly accepted classification or grading system for complex ventral hernias. Three classification systems have recently been proposed for complex ventral hernias. The leadership of the World Society of the Abdominal Compartment Syndrome has described a grading system for the acute OA.[7] The grading is as follows: Grade 1A, clean OA without adherence between bowel and abdominal wall or fixity of the abdominal wall (lateralization); Grade 1B, contamination OA without developing adherence/fixity; Grade 2A, clean OA developing adherence/fixity; Grade 2B, contaminated OA developing adherence/fixity; Grade 3, OA complicated by fistula formation; Grade 4, frozen OA with adherent/fixed bowel, unable to close surgically with or without fistula. The Ventral Hernia Working Group, which was supported by LifeCell Corporation, was specifically developed for late stage complex ventral hernia.[8] The grading system has four grades which are as follows: Grade 1, low risk (low risk of complications, no history of wound infections); Grade 2, comorbidities (smoker, obese, diabetic, immunosuppression, chronic obstructive pulmonary disease); Grade 3, potentially contaminated (previous wound infection, stoma, violation of the gastrointestinal tract); and Grade 4, infected (infected mesh, septic dehiscence). Neither grading system has been validated in clinical studies.

A recent study preoperatively classified different types of complex ventral hernias as follows: normal wound, healing

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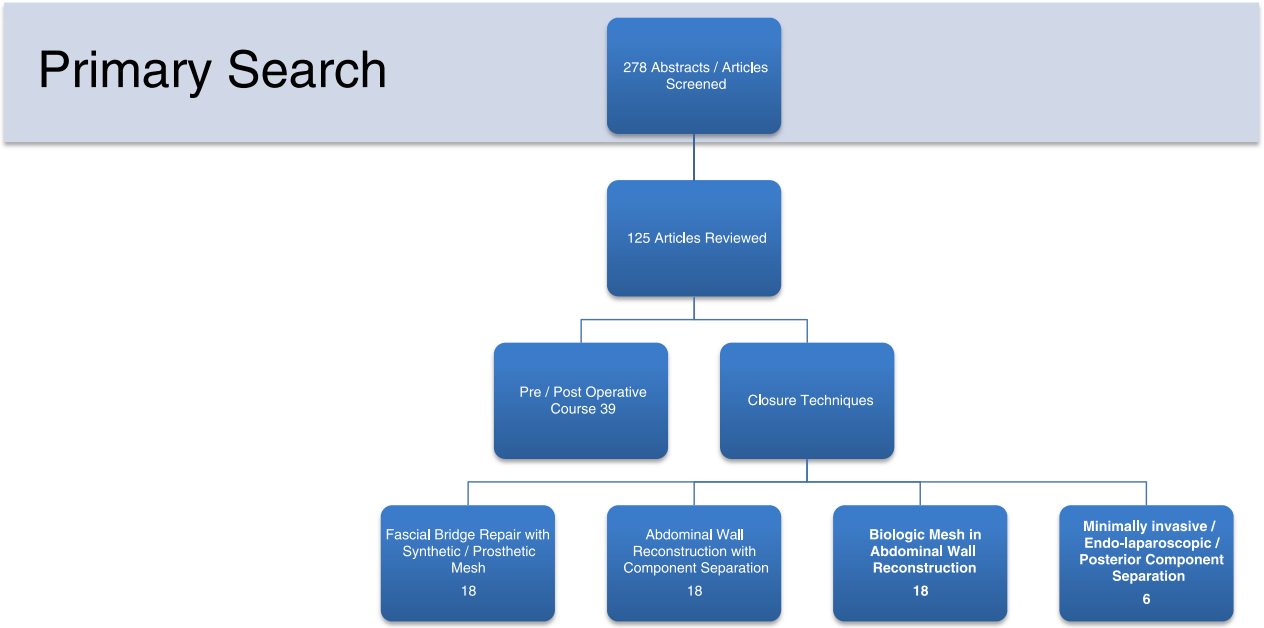

Figure 1. Flow diagram of articles identified and included in this review.

(Type I), impaired wound healing (Type II), contaminated wound (Type III), massive weight loss (Type IV), and loss of domain (Type V). However, the study lacked the necessary power to delineate outcomes based on hernia types.[9]

Preoperative Considerations

Patients with significant comorbidities are at increased risk of adverse outcomes after ventral hernia repair.[10] Risk modification is an ideal approach to preoperative preparation for a major abdominal wall reconstruction. All patients should undergo cardiac and pulmonary preoperative evaluations. In the morbidly obese patient, identifying obstructive sleep apnea before surgery is helpful to modify the preoperative risk. Patients with a history of tobacco abuse must be counseled to stop smoking because they have the highest risk of wound complications, intestinal leak rates, and pulmonary complications.[11–15] Other risk factors associated with preoperative morbidity after ventral hernia repair failure are steroids,[16] chronic obstructive pulmonary disease, diabetes mellitus, body mass index (BMI) of greater than 30, previous wound infection, and infected mesh.[17]

A major decision point is the timing of abdominal wall reconstruction. In the setting of trauma or emergency surgery, the patient has survived a catastrophic illness or injury with an OA. Tissue coverage is generally achieved with either a skin closure only or a skin graft. A sufficient period must be allowed for healing to occur. Specifically, the abdominal adhesions must mature to the point where the viscera can be safely dissected free and the skin graft can be removed. While most abdominal reconstructive surgeons will recommend waiting a minimum of 6 months before a planned abdominal wall reconstruction, only one study has demonstrated this period as a safe approach without significantly affecting the morbidity rates.[18]

The patient with an enteroatmospheric fistula requires an organized approach to preoperative preparations and planning for fistula takedown with an abdominal wall reconstruction. The initial step is skin coverage during the early stages of the OA. With distal intestinal fistulas (especially colocutaneouas fistulas), patients may be fed enterally to allow for the benefits of enteral nutrition. Rarely, a very proximal enteroatmospheric intestinal fistula may be accessed with a feeding tube directly to feed the gut distally, once it has been demonstrated that a significant length of small bowel is present distal to the fistula. Aggressive parental nutritional support is often the only option to maintain the patient's nutritional status. Wound healing vitamins (vitamin C) and antioxidants (Zn, selenium) have been used in this severely malnourished patient population.[19,20] Most of these recommendations arise from retrospective case reviews, case reports, or expert opinion.

Radiographic assessment of the abdominal wall anatomy before elective abdominal wall reconstruction is an essential step. Multidetector computer tomography can demonstrate the size of the ventral defect and assess the degree of abdominal loss of domain. Multidetector computer tomography has the ability to demonstrate the amount of tissue loss after trauma or necrotizing wound infections as well as the presence of heterotopic ossification within the scar can be assessed.[21]

Closure Techniques

Fascial Bridge and/or Repair With Synthetic/Prosthetic Mesh

The landmark study of 2000 Luijendijk et al.[22] demonstrated that large (>4 cm) repaired with mesh had a lower incidence of hernia recurrence. Since before this study, tension-free repair of large ventral hernias with prosthetic mesh (polypropylene or polytetrafluoroethylene [PTFE]) was the standard with hernia recurrence rates of 19% to 32% and complication rates of 10% to 17%.[23–25] The position of the mesh has a direct impact on the hernia recurrence rate, with underlay having a lower recurrence rates than onlay placement.[26] The majority

of these cases were elective and not after trauma or abdominal catastrophes. They rarely had an intestinal fistula or an ostomy repaired at the same setting. Even without contamination, the risk of mesh infection was reported to be 10% to 17%.[27–32]

The mesh can be placed in the various positions and each has its benefits and risk:

- Onlay—placed directly on top of the anterior rectus fascia
- Inlay—interposition sewn directly to the edge of the fascia as a bridge repair for patients in whom the fascia cannot be directly reapproximated
- Sublay—positioned posterior to the rectus muscle between the muscle and the posterior rectus fascia, in the retrorectus space, just superficial to the peritoneum
- Underlay—positioned intra-abdominally, posterior to the rectus fascia and directly on the peritoneum

The "inlay" or "interpositional" placement of the mesh is not recommended because it is associated with the highest rate of recurrence followed by an "onlay" bridge repair technique.[33] There is no definitive evidence that "underlay/sublay" compared with "onlay" position of the mesh is superior. Each is equally effective for open surgical procedures for ventral hernia repairs.[34,35] The "sublay" position (posterior to the rectus muscle) allows for better tissue incorporation and lower chance of bacterial contamination when implanted adjacent to the rectus muscle. In addition, posterior rectus sheath and the peritoneum keep the mesh from coming into direct contact

TABLE 1. Synthetic Ventral Hernia Repairs (Bridge and Modified "Rives-Stoppa")

Author	Reference #	Date	n	Class*	Comments
White et al.	29	1998	206	III	Use of synthetic mesh increases incidence of infection compared with repairs without mesh. Drains do not prevent SSI.
Balen et al.	24	1998	45	III	ePTFE is an option as mesh for CVHR with acceptable rates of complication and recurrence.
Bauer et al.	23	1999	98	III	ePTFE mesh is a potential option for use in CVHR with large abdominal wall defects.
Luijendijk et al.	22	2000	200	I	Synthetic mesh repair is superior to primary suture repair alone with regard to the HR, regardless of the size of the hernia.
Chrysos et al.	44	2000	52	III	Tension-free CVHR using ePTFE stitched directly to the fascial edge is an option. Postoperative SSI requires removal of ePTFE mesh.
Veillette et al.	41	2001	76	III	Stoppa repair may have similar recurrence rates as other types of mesh CVHR.
Paajanen et al.	40	2004	84	III	Rives-Stoppa repair with synthetic mesh is safe and effective in low-risk CVHR
Diaz et al.	45	2004	55	III	Large CVHR with ePTFE mesh may have higher likelihood of postoperative SSI than those repaired with PP mesh.
Heartsill et al.	39	2005	81	III	Intraperitoneal synthetic mesh placement is an optional technique for CVHR (15% recurrence and >35% postoperative complication rate). Patients with pulmonary disease had significantly higher HR.
Paajanen and Laine	37	2005	10	III	PP mesh repair of giant ventral hernias placed in the retromuscular space is an option for CVHR in the morbidly obese patient.
Le and Bender	36	2005	150	III	Open CVHR with retrofascial PP mesh has acceptable rates of HR.
Afifi	26	2005	41	III	Intraperitoneal placement of a composite of PP mesh and polyglactin mesh (with the polyglactin toward the bowel) has advantages when compared with patients that have primary VHR and PP onlay repair
Pavlakis et al.	28	2006	200	III	ePTFE underlay mesh repair is safe (4% complication rate) and 10% HR.
Halm et al.	30	2007	66	III	Intraperitoneal placement of PP mesh should be avoided during open CVHR when possible in favor of preperitoneal placement.
Cobb et al.	27	2009	206	III	Synthetic underlay mesh for CVHR = 10% risk of SSI
Stremitzer et al.	76	2010	476	III	Operation time—a significant risk factor associated with mesh graft infection in CVHR/conservative treatment should be applied in case of infection of absorbable mesh grafts such as polyglactin, while nonabsorbable meshes such as CoM or PP are much less amenable to conservative treatment, usually requiring removal of the mesh.
Mehrabi et al.	43	2010	176	III	Rives-Stoppa technique of CVHR using a PF mesh is a safe and durable technique [HR 1.1%] and minimal serious morbidity.
Maman et al.	42	2012	89	III	59 patients, 32.2% had ePTFE, and 67.8% had PP mesh. Average range of follow-up was 40.0 mo. HR (1.7%). SSI requiring removal of the prosthesis (5.1%).

*EAST class.

CoM, composite PTFE/PP mesh; CVHR, complex ventral hernia repairs; ePTFE, expanded polytetrafluoroethylene; HR, hernia recurrence; PF, polyester fiber; PP, polypropylene; SSI, surgical site infection.

with the viscera.[36,37] The "sublay" in the "preperitoneal space or retrorectus fascial position" protects the mesh from direct contact with the viscera but requires an identifiable peritoneal layer to be dissected out and closed posterior to the mesh. Hernia recurrent rates of 3% have been reported, and short-term follow-up studies have shown a 2% to 15% recurrence rate.[12,38] When a sublay repair includes closure of the posterior fascia in the midline, the procedure is described as a "modified Rives-Stoppa repair." Synthetic mesh is safe and effective technique in low-risk ventral hernia repairs with hernia recurrence rates of 1.1% to 18% and 6.8% infection rate.[39–41] The "underlay" position is the placement of the mesh directly on the peritoneum and is the default position (Table 1).

If a prosthetic mesh develops an infection, explantation is almost universally required, which will often result in an immediate hernia recurrence.[41,42] It is well documented that once PTFE has become infected, the only viable option is removal of the mesh.[43,44] PTFE should not be used for abdominal wall reconstruction after patients are managed with an OA. Prosthetic synthetic mesh remains a viable option in the repair of large ventral hernias but should be strictly limited to clean cases.

Abdominal Wall Reconstruction with Component Separation

Component separation was initially described by Ramirez et al.[45] as a tissue-only repair. The initial description of the component separation involved the development of large skin flaps off the anterior rectus fascia. The dissection exposed the aponeurosis of the external oblique fascia. The aponeurosis is divided longitudinally starting at the anterior superior iliac spine and onto the costal margin. In the majority of cases, the component separation technique will close an abdominal wall fascial defect of 15 cm to 20 cm in the midabdomen. There are other variations on the "component separation." Fabian et al.[5] described what is commonly called the "separation of parts." The anterior rectus fascia and muscle are separated from the posterior rectus fascia. The anterior rectus fascia and muscle are mobilized medially, allowing for the recreation of the linea alba. The lateral edge of the anterior rectus fascia is sewn to the medial edge of the posterior rectus fascia. This technique does result in three suture lines. Other described the release of the anterior rectus fascia in an anterior or posterior position.

The initial reports of component separation repairs had significant morbidity with 37% to 39% wound complications and 32% hernia recurrence with follow-up period of 15 months.[46–50] Since component separation is a tissue-only repair, the technique was commonly applied to wounds with bacterial colonization or contaminated surgical fields.[51] Large skin flaps used to expose the external oblique muscles and subsequent dead space allow for the development of seromas and wound infections (Table 2).

Component Separation With Synthetic Mesh

Several studies have reported the use of prosthetic mesh to support the component separation repair in either an onlay and/or underlay position with the goal to decrease the hernia recurrence rates. The procedure still has significant morbidity, with wound infection rates of 10% to 35% and with a recurrence rate of 5.5% to 15% during a 50-month follow-up period.[34,38]

Bridge Repair With Biologic Mesh

Biologic mesh has been used extensively as an option to repair hernia defects in wounds with bacterial colonization or contamination. The hope was that a biologic mesh would be able to "resist" infection if the wound became infected. The theory was that a biologic mesh would quickly become vascularized and incorporated, allowing it to tolerate bacterial contamination better. A vascularized mesh would be able to bring inflammatory cells and antimicrobials to the wound. In the acute setting, the initial results were promising. The need for explantation of biologic mesh was low when used to close ventral defects, but many of these studies suffered from short follow-up times.

Subsequent studies with longer follow-up times showed that most patients repaired with a biologic mesh positioned as a bridge repair developed an eventuation or attenuation of the repair described as hernia recurrence.[33,52–56] The most studied biologic mesh is human acellular dermal matrix (HADM) (LifeCell, Branchburg, NJ). There have been multiple theories why HADM had high failure rates: from the high content of elastin found in the dermal matrix, the remodeling/reabsorption of the implant over time, the constant increased intra-abdominal pressure resulting in attenuation, and the thinning out of the implant in the setting of the exposed wound. The common use of a negative-pressure dressing on the HADM might have also resulted in the thinning of the implant. The end result was increased propensity for weakness of the repair, resulting in recurrent ventral hernia. At this point, the use of a biologic mesh bridge repair without primary fascial closure is discouraged (Table 3).

Component Separation With Biologic Mesh Support

The next step in the evolution of abdominal wall reconstruction was to combine component separation with the biologic mesh reinforcement. Many surgeons began to combine complex gastrointestinal procedures, stoma repairs, and intestinal fistula repairs with abdominal wall reconstruction.

The position of the biologic mesh in the conjunction with component separation technique is felt to be critical to avoid recurrence. The sublay or underlay positions have been described, and both techniques seem to have similar hernia recurrence rates.[57,58] One further technical issue in placing the mesh in a "sublay" or "underlay" position is the suturing technique used to secure the mesh. The mesh should be sewn in using interrupted transfascial "U" sutures through the anterior abdominal wall.[55,58] The interrupted "U" suture technique allows for secure placement of the mesh against the abdominal wall and limits the degree of potential ischemia or edema to the tissues medial to the placement of the sutures. A continuous suture technique to secure the mesh should be avoided. The key step is the approximation of the linea albae/midline fascia, reestablishing the normal anatomy to the abdominal wall. In independent studies, Kolker et al.[59] and Satterwhite et al.[60,61] both have described a "sandwich" techniques using HADM as a dual layer with both an underlay

TABLE 2. Abdominal Wall Reconstruction With Component Separation

Author	Reference #	Date	n	Class*	Comments
de Vries Reilingh et al.	48	2003	43	III	CS is safe and effective in the setting of contaminated field and CVHR.
Szczerba and Dumanian	49	2003	11	III	CS is an option for CVHR in an infected field.
Lindsey	50	2003	10	III	CS for CVHR of large abdominal wall defects with severe loss of intra-abdominal domain.
Ewart et al.	17	2003	60	III	CS is a viable option for CVHR. Risk factors for CVHR failure regardless of the technique may be BMI > 30 and SSI, with smoking, and BMI > 30 risk factors for wound complications.
Vargo	47	2004	27	III	CS effective for large CVHR. 37% complication rate.
Kolker et al.	60	2005	16	III	CS and onlay of HADM is a viable option for CVHR.
Joels et al.	71	2006	21	III	Complication rates for acute CS after temporary abdominal closure are high at 57%.
Alaedeen et al.	52	2007	19	III	CS may be a useful technique for the treatment of CVHR in a contaminated field.
Moore et al.	34	2008	90	III	CS with overlay synthetic mesh is safe and effective CVHR.
Ko et al.	70	2009	54	III	Reinforcement of CS of CVHR with underlay of PP mesh decreased HR over primary repair in a clean setting. HADM reinforcement did not improve HR.
Ko et al.	75	2009	200	III	CS is an acceptable option for large CVHR. HADM may lead to higher HR. High BMI leads to higher recurrence rates and perioperative complications. Contaminated fields and diabetes mellitus are associated with higher perioperative complications.
Hadad et al.	51	2009	102	III	CS may improve intra-abdominal domain in patients with large CVHR who have lost domain.
DiCocco et al.	82	2010	114	II	CS is successful at large CVHR
Sailes et al.	83	2010	545	II	CS 18.3% HR in 545 patients; obesity (BMI > 30 kg/m^2), age > 65 years, male sex, postoperative seroma, and preoperative infection as risk factors for hernia recurrence.
Satterwhite et al.	61	2012	106	III	Postoperative complication (63%): skin necrosis (19.8%), seroma (17.9%), cellulitis (17.9%), abscess (13.2%), fistula (7.5%). Risk of postoperative complications: obesity, diabetes, hypertension, fistula at the time of the operation, history of hernia repairs, previous abdominal operations, defect size of >300 cm^2, and the use of HADM. CVHR using a "sandwich" repair with both a mesh overlay and underlay and CS.
Krpata et al.	91	2012	111	III	Retrorectus access to the transversalis muscle with division of the muscle, retrorectus sublay of mesh, wound complications occurred in significantly more anterior CS than posterior CS patients (48.2% vs. 25.5%). HR higher in the anterior CS group (14.3% vs. 3.6%).
Kanaan et al.	64	2011	63	III	CS for CVHR offers acceptable complication rate in high-risk population: 1 ECF, 24%, HR, 19% SSI
Yegiyants et al.	79	2012	34	III	CVHR with CS with or without contamination—higher complication rate in the setting of contamination (77% vs. 38%, $p = 0.03$) mean follow-up of 47 mo

*EAST class.
CS, component separation; CVHR, complex ventral hernia repair; ECF, enterocutaneous fistula; HR, hernia recurrence; PP, polypropylene; SSI, surgical site infection.

and onlay with midline fascial approximation. Others have described using a biologic (porcine dermis) mesh underlay with a polypropylene mesh onlay in conjunction with a component separation and a 33% wound infection rate.[62] During the early experience of biologic mesh and component separation repairs in complex ventral hernia repairs, HADM was commonly used and an overall complication rate is as high as 19% to 50%.[63–66]

Porcine biologic non–cross-linked mesh has been used to support the repair of the component separation. Placing the mesh in an underlay position has been reported to have the best short-term outcomes with hernia recurrence rates of 7%.[67] One study compared 58 patients with cross-linked, non–cross-length porcine mesh and HADM. Cross-linked porcine mesh had relatively higher infection and explantation rates. Equivalent hernia recurrence and explantation rates were observed for the non–cross-linked porcine biologics and HADM. These data indicate that there is currently no ideal biologic for complex ventral hernia repair.[68]

One study compared polypropylene mesh with cadaveric dermis in an underlay position to support the component separation repair. Polypropylene mesh versus cadaveric mesh with

TABLE 3. Biologic Mesh in Abdominal Wall Reconstruction

Author	Reference #	Date	n	Class*	Comments
Ueno et al.	66	2004	20	III	Porcine small intestinal submucosa—an option for CVHR in the setting of a contaminated field but has high complication rate (50%).
Gupta et al.	54	2006	74	II	HADM has increased risk of HR, Porcine small intestinal submucosa may have increased risk of seroma formation in VHR.
Diaz et al.	73	2006	75	III	HADM can be used in the compromised surgical field with an acceptable SSI rate for CVHR
Kim et al.	59	2006	29	III	HADM is safe and effective when used as an underlay mesh CVHR for high-risk wounds.
Jin et al.	56	2007	33	III	HADM is an option for biologic mesh in the CVHR; use of this mesh as a fascial bridge instead of fascial reinforcement has high HR rates.
Candage et al.	53	2008	53	III	HADM may be effective as a fascial reinforcement in CVHR, but eventration may occur when used as a fascial bridge/
Bluebond-Langner et al.	33	2008	9	II	HADM onlay leads to very high rate of abdominal wall laxity in CVHR
Blatnik et al.	57	2008	11	III	Use of HADM for repair of large CVHR may have a high rate a HR.
Limpert et al.	55	2009	26	III	Acellular bovine pericardium may be used to repair CVHR in infected fields; use of the mesh as a fascial bridge rather than fascial reinforcement is associated with high HR.
Lee et al.	65	2009	77	III	HADM is an option for biologic mesh CVHR; use of this mesh may carry a high risk of postoperative complications and HR.
Diaz et al.	77	2009	240	III	HADM is a useful alternative in CVHR; EAF, removal of skin graft or stoma takedown increased the risk wound complication and hernia recurrence.
Shah et al.	69	2010	58	III	Cross-linked porcine dermal mesh showed higher SSI and explantation rates. Equivalent HR and explantation rates were observed for the non–cross-linked porcine biologics and HADM.
Byrnes et al.	68	2011	57	III	Fascia should be closed above the underlay/sublay mesh; this technique provides a more durable repair than using the mesh as a "fascial bridge." Lack of fascial reapproximation was associated with early HR.
Satterwhite et al.	62	2012	19	III	Increased risk of postoperative complications: smoking, presence of preoperative enterocutaneous fistulae, extended postoperative hospital stay (>2 wk), and a defect size > 300 cm.
Patel et al.	58	2012	78	III	Porcine dermal matrix placed as underlay is an effective adjunct to CVHR when used as reinforcement during CS, 24.4% complications with 82.9% perforator sparing 0% HR, follow-up of 474 days.
Novitsky et al.	92	2012	42	III	Retrorectus access to transversalis muscle with retrorectus sublay of mesh (23.8% patients developed various wound complications requiring reoperation/debridement in three patients. Median follow-up period of 26.1 mo (4.7%) HR.
Ghazi et al.	67	2011	165	III	HR associated with a history of HR, and hypertension, HR similar for synthetic and HADM, complication rates higher with synthetic mesh 28.6%; CS + mesh lowest HR 9.4%.
Nasajpour et al.	63	2011	18	III	CS with underlay porcine dermal mesh and onlay PP mesh, 33% SSI 33% seroma formation, 40% of SSI required surgical intervention, 0% HR; 63% of smokers developed complications

*EAST class.
CS, component separation; CVHR, complex ventral hernia repair; EAF, enteroatmospheric fistula; HR, hernia recurrence; PP, polypropylene mesh; SSI, surgical site infection.

a short-term follow-up had hernia recurrence rates of 11% versus 45%.[69]

Complications of Component Separation

The overall complication rate of abdominal wall reconstruction is in the range of 50% to 60%.[70] Intestinal fistula, hernia defect size of greater than 300 cm^2, active abdominal infection, and open repair have all been shown to be independent risk factors for 30-day readmission after complex ventral hernia repair.[71] Complications from abdominal wall reconstruction with component separation are of three major categories as follows: (1) wound infection, (2) flap loss, and (3) hernia recurrence.

First, the classical open approach to component separation requires the creation of large skin flaps to expose the

aponeurosis of the external oblique fascia. This predisposes the wound to infection by the formation of seromas, along with possible skin and subcutaneous ischemia. After an abdominal catastrophe, the surgical field may remain colonized for a prolonged period and can increase the risk of infection.[7] With the increasing incidence of the complex ventral hernia, the surgeon has had a need for a product to help close abdominal wall defects in contaminated fields. This resulted in the rapid increase in the use of biologic mesh for repair of the complex ventral hernia in the compromised surgical fields.[72] Untreated postoperative complications have been associated with delayed presentation of prosthetic mesh infections most commonly with *Staphylococcus* species.[73] The rate of wound infection after component separation ranges from 24% to 33%.[74] Operative times greater than 4 hours have been shown to be a risk factor for the development wound infection.[75] Treatment of wound infections after a component separation requires a graduated approach. Wound infection is a spectrum of disease. Early wound infections are manifested as simple cellulitis and may be successfully treated medically with antibiotics alone. Late or deep-seated wound infections may require percutaneous or surgical drainage of infected subcutaneous collections.[72,76]

The second and more serious complication with component separation is flap loss cause by ischemia/necrosis. Anterior abdominal wall skin flap loss can be a catastrophic postoperative complication. Ischemia can range from a limited periincisional skin and fat necrosis to complete skin and soft tissue loss of large portions of the anterior abdominal wall. Precise surgical technique is an essential component to the success of skin flap survival. The plane of dissection must be directly along the anterior rectus fascia in the adventitial layer between the fascia and the subcutaneous tissue. This allows the superficial and deep capillary networks in the subcutaneous tissue to remain intact because they become the primary blood supply to these large skin flaps. In most series, the wound infection rate is reported to be 30%, and the skin flap necrosis rate is reported to 1%.[77] One study evaluated component separation for complex ventral hernia repairs and demonstrated a higher rate of complications in patients with contaminated wounds (77%) compared with clean wounds (38%).[78]

A modified periumbilical sparing technique that preserves the large arterial perforators from the periumbilical area has been shown to decrease skin flap loss.[79] Presence of old subcostal or transverse incisions is a risk factor for compromised circulation to the skin and subcutaneous tissue. However, a recent study from MD Anderson examined the use of component separation with previous incisional scars and stomas and showed no increase in tissue loss with an experienced reconstructive surgeon.[80]

The third major complication of component separation is hernia recurrence. In three recent series, the rate of hernia recurrence ranged from 5% to 14% to 30%.[74,78,81] In another recent study on 545 component separations, there was an 18.3% hernia recurrence rate. Obesity (BMI > 30 kg/m^2), older than 65 years, male sex, postoperative seroma, and preoperative infection were identified as risk factors for hernia recurrence.[82] Moreover, the history of hernia repairs increases the risk of hernia recurrence.[83]

Minimally Invasive/Endolaparoscopic Anterior Component Separation/Posterior Component Separation

The most common morbidity of the component separation technique is wound complication rate. To help minimize these issues, several authors began to develop minimally invasive techniques to component separation. A key goal was to limit the dead space and preserve the feeding perforating vessels to the anterior skin. This newer surgical techniques has been shown to decrease the wound complications rates from 20% to 2%.[79] Both laparoscopic and minimally invasive surgical

TABLE 4. Minimally Invasive/Endolaparoscopic/Posterior Component Separation

Author	Reference #	Date	n	Class*	Comments
Rosen et al.	85	2007	7	III	E/LCS for CVHR is technically feasible and possible lower wound complications.
Milburn et al.	86	2007	10	III	Cadaver study—E/LDS for CVHR is technically feasible and similar amounts of fascial release compared with OCS
Albright et al.	87	2011	25	III	E/LCS associated with reduced wound complications (9% vs. 57%) compared with OCS
Giurgius et al.	88	2012	35	III	E/LCS technique is associated with reduced wound complications (19% vs. 57%) compared with OCS.
Ghali et al.	90	2012	107	III	MICS for CVHR fewer wound healing complications than OCS (skin dehiscence [11% vs. 28%; $p = 0.011$], all wound healing complications [14% vs. 32%], abdominal wall laxity/bulge [4% vs. 14%], and HR [4% vs. 8%] MICS vs. OCS.
Butler and Campbell	89	2011	38	III	MICS for CVHR fewer wound healing complications than OCS in initial series.

*EAST class.

CVHR, complex ventral hernia repair; E/LCS, endo/laparoscopic component separation; E/LDS, endo/laparoscopic component separation; HR, hernia recurrence; MICS, minimally invasive component separation; OCS, open component separation.

techniques for component separation have been described. A transverse incision is made medial to the anterior superior iliac spine and lateral to the rectus muscle, which allows one to dissect down to the external oblique fascia. The endo/laparoscopic technique use a hernia balloon to develop a plane in between the external and internal oblique muscles. The area is insufflated, and the external oblique aponeurosis can be seen anteriorly and divided.[84–87] In the minimally invasive technique, the external oblique aponeurosis is directly visualized and divided[88,89] while using a narrow Deaver-type retractor to elevate the tunnel. Both techniques allow the rectus muscle and fascial component to be mobilized medially and avoid creation of large dead space. These approaches preserve the rectus vascular perforators, which decrease the risk of wound infection and potential flap loss compared with the conventional approach (Table 4).

A retrorectus approach to the transversalis muscle with division of the muscle has been described.[90,91] In a study of 111 patients, they demonstrated a lower wound complication rate (48.2% vs. 25.5%) as well as a lower hernia recurrence rate (14.3% vs. 3.6%) versus the anterior component separation approach. A retrorectus sublay mesh is placed to support the repair similar to a Rives-Stoppa–type repair. This approach also eliminates creation of large skin flaps.

Perioperative/Postoperative Management

There are several other aspects of the perioperative abdominal wall reconstruction patient, which are essential to its success by preventing bacterial contamination. Prophylactic antibiotics should be dosed at least 2 hours before incision and every 4 hours.[92]

Intraoperatively, the patient's core temperature should remain greater than 35°C during the entire case.[93] During the time of abdominal closure, pulmonary peak airway pressures should be monitored because the risk of developing intra-abdominal hypertension increases particular if there was loss of domain. With increasing plateau pressures of 9 cm H_2O or greater, consideration must be given to keeping the patient intubated postoperatively to manage intra-abdominal hypertension and potential respiratory complications.[13] One study used preoperative assessment of loss of domain called *component separation index*. Computed tomographic scan was used to determine the angle of diastasis to predict the need for interposition mesh placement in addition to component separation.[94] Another study used intraoperative tensiometry as a decision tool for abdominal wall reconstruction. If a result exceeded 1.5 kp, component separation of the lateral abdominal wall was performed.[95] One study prospectively measured bladder pressures during abdominal wall reconstitution with component separation. They noted a bladder pressure of greater than 20 mm Hg correlated with an increase in postoperative complications.[96] Postoperative monitoring of bladder pressures should be performed to monitor for intra-abdominal hypertension.[97,98]

CONCLUSION

The OA technique has been used in traumatic, general surgical, and vascular surgical emergencies with great success. It is a heroic approach, which is work intensive at the front end. If the patient survives with a planned ventral hernia, there must be a focused approach to the planning of the abdominal wall reconstruction. There are multiple pitfalls during the preoperative, operative, and postoperative course. Knowledge of all aspects of this complex approach is essential if one is to successfully repair these complex ventral hernias. A void in the literature persists regarding the postoperative management of these patients, and future study should focus on these aspects of the surgical care.

AUTHORSHIP

J.J.D., G.H.T., and M.O. contributed in the study design, initial literature search, and initial review and paring of the articles. J.J.D., G.H.T., M.O., and R.J. performed the initial screening of all abstracts and identification of articles to be review. J.J.D., D.C.C., K.A.K., G.H.T., M.O., R.J., A.J.K., B.R.C., P.A.P., A.T.S., J.C.J., F.B., E.R.H., L.M.S., E.S.W., J.W.B., C.L.T., R.S., and M.A.C. contributed in the EAST Primer Classification—2000 review, ranking, and written assessment of assigned articles. G.H.T., M.O., and J.J.D. contributed in the gathering, collating of the responses in categories, and database development. G.H.T., M.O., and J.J.D. contributed in the development and presentation of the project at the EAST plenary session 2011. G.H.T., M.O., and J.J.D. contributed in the gathering and incorporation of the recommendations from the EAST membership during the PMG plenary presentation. J.J.D., D.C.C., and K.A.K. were responsible for the manuscript development, writing, and additional literature search. J.J.D., J.C.J., and E.R.H. edited the manuscript.

DISCLOSURE

The authors declare no conflicts of interest.

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