



An Evaluation of the Evidence Guiding Adult Midline Ventral Hernia Repair

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Abstract

Purpose: Several guidelines have been published in recent years to guide the clinician in ventral hernia repair. This review distils this advice, critically assesses their evidence base, and proposes avenues for future study.

Methods: A PUBMED search identified four guidelines addressing midline ventral hernia repair published by major surgical societies between 2016 and 2020. The studies used to inform the advice have been critically appraised, including 20 systematic reviews/meta-analyses, 10 randomized controlled trials, 32 cohort studies, and 14 case series.

Results: Despite a lack of randomized controlled trials, case heterogeneity, and variation in outcome reporting, key themes have emerged.

Preoperative computed tomography scan assesses defect size, loss of domain, and the likely need for component separation. Prehabilitation, frailty assessment, and risk stratification are beneficial in complex cases. Minimally invasive component separation techniques, Botox injection, and progressive pneumoperitoneum represent novel techniques to promote closure of large fascial defects.

Rives-Stoppa sublay mesh repair has become the “gold” standard for open and minimally invasive repairs. Laparoscopic repair promotes early return to functional status. The enhanced-view totally extraperitoneal approach facilitates laparoscopic sublay mesh placement, avoiding mesh contact with viscera. Robotic techniques continue to evolve, although the evidence at present remains immature.

Synthetic mesh is recommended for use in clean and clean-contaminated cases. However, optimism regarding the use of biologic and biosynthetic meshes in the contaminated setting has waned.

Conclusions: Surgical techniques in ventral hernia repair have advanced in recent years. High-quality data has struggled to keep pace; rigorous clinical trials are required to support the surgical innovation.

Keywords

- ventral hernia
- incisional hernia
- laparoscopic hernia repair
- robotic hernia repair

The European Hernia Society (EHS) defines ventral hernias (VHs) as “hernias of the abdominal wall excluding the inguinal area, pelvic area and diaphragm.”^{1,2} The EHS classification of VHs is provided in ► **Table 1**.

Approximately 2 million VH repairs (VHRs) are performed annually worldwide.³ In recent years, VH surgery has benefitted from surgical and technological innovation, expanding the limits of what is considered surgically

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Table 1 Definitions of VHs, set out by EHS²

Umbilical hernia	Primary VH with its center at the umbilicus
Epigastric hernia	Primary VH close to the midline with its center above the umbilicus
Incisional hernia	VH that developed after surgical trauma to the abdominal wall, including recurrences after repair of primary VHs
Small VH	VH with fascia defect < 1cm
Medium-sized VH	VH with fascia defect 1–4 cm
Large VH	VH with fascia defect >4 cm

Abbreviation: EHS, European Hernia Society; VHs, ventral hernias.

feasible. A wealth of data has been generated over a short period of time. However, the quality of evidence is variable and significant heterogeneity in practice exists.⁴

In this context, advancement has been made across the spectrum of VHR, from patient selection and preoperative assessment, through to novel techniques of fascia advancement and minimally invasive repair. Study in this field represents an intersection of biomechanics, material science, and surgery. If a burgeoning relationship between these complementary disciplines can be combined with rigorous clinical trials, we can be cautiously optimistic that the therapeutic possibilities offered to patients will continue to improve.

Methodology and Limitations of Studies

A PUBMED search was undertaken to identify the guidelines addressing midline (primary and incisional) VHR published by major surgical societies between 2016 and 2020. Guidelines specifically addressing nonmidline VHR were excluded. The following guidelines were included: European Hernia Society (EHS)/American Hernia Society (AHS)¹; International Endohernia Society (IEHS)³; Society of Gastro-intestinal Endoscopic Surgeons (SAGES)⁵; and World Society of Emergency Surgeons (WSES).⁶ The key recommendations have been distilled to allow comparison between the guidelines. The review critically appraises the studies used to establish this guidance, identifies areas where evidence is weak, and suggests avenues for future study.

This process has identified a paucity of high-quality data in VHR. Less than 3% of published studies of VHs are randomized-controlled trials (RCTs)⁷; of the 76 studies in this literature review, 10 are RCTs.

Although primary VHs represent a distinct entity to incisional VHs,⁸ analysis is often pooled. Forty-six of the 76 studies in this review combine analysis of primary and incisional VHs. The proliferation of novel surgical approaches and materials in VHR³ has resulted in a large number of discrete techniques, limiting the total sample size of each and again resulting in pooled analyses of disparate treatments.

The primary outcome measures of most studies (recurrence, patient satisfaction and pain) suffer from lack of standardization in definition^{9,10} and measurement.¹¹ Follow-up tends to be short relative to the usual time-scale of recurrence development.¹²

Patient Selection

Indications for VHR include symptom relief, cosmesis, and avoidance of future emergency presentation. However, non-operative management in the elective setting is safe.¹

In a cohort study of 1,358 patients with VHs, 636 underwent watchful waiting. The most common reasons for non-operative management were lack of symptoms, patient comorbidities, and patient's wish. After 5 years, 17% crossover to surgical repair, with 4% presenting emergently. There was no difference in adverse events compared to those who underwent initial operative management.¹³

Female gender, advanced age, defect size between 2 and 7 cm, and incisional and umbilical hernias are more likely to incarcerate, supporting elective repair.¹⁴ By contrast, obesity, smoking, and hemoglobin A1c > 6.5% are associated with increased wound morbidity.¹⁵

A RCT of 118 patients with body mass index (BMI) 30 to 40 kg/m² demonstrated that prehabilitation (nutritional counseling and exercise) resulted in an increase in patients who were complication-free postoperatively.¹⁶ The EHS/AHS guidelines advise weight loss to BMI < 35 kg/m² and smoking cessation for at least 4 to 6 weeks prior to elective epigastric and umbilical hernia repair.¹

In select cases, this may involve a staged surgical approach: a case series described 15 patients undergoing laparoscopic sleeve gastrectomy followed by staged VHR with favorable outcomes.¹⁷

The Carolinas Equation for Determining Associated Risks (CeDAR) equation was developed through multivariate logistic regression to identify weighted risk factors for wound complications in open VHR,¹⁸ although its reliability has been questioned in other studies.¹⁹

The modified frailty index (mFI) is an additional predictor of complications and mortality following VHR.²⁰ The factors included in the CeDAR equation and mFI are described in ►Table 2. Both CeDAR and mFI provide tools to aid in shared decision-making discussion with patients.

Mesh Selection

Mesh may be synthetic, biosynthetic, or biologic. Of synthetic meshes, medium weight options are associated with fewest complications.⁷ Polypropylene is an example of a commonly employed synthetic mesh. In contaminated fields, synthetic mesh carries a prohibitively high surgical site infection rate of 19%²¹ and is not recommended.⁶ This led to the development of potential alternatives.

Biosynthetic meshes absorb over a period of 6 to 18 months,²² with the theoretical benefit of reduced surgical site infection. However, this has not been borne out in practice: biosynthetic mesh is associated with increased

Table 2 Features of CeDAR equation and mFI. The OR for surgical site infection in the original CeDAR study are included

CeDAR equation	mFI
Tobacco use (OR: 2.17)	Diabetes mellitus
Previous ventral hernia repair (OR: 2.64)	Partially/totally dependent
Uncontrolled diabetes (OR: 2.01)	COPD/preoperative pneumonia
Presence of stoma (OR: 2.65)	Congestive cardiac failure
BMI > 26 kg/m ² (1.08 per unit BMI)	History of myocardial infarction
Presence of active infection (OR: 2.07)	History of angina/PCI
	Hypertension
	Peripheral vascular disease
	Impaired sensorium
	History of TIA/CVA
	History of CVA with neurological deficit

Abbreviations: BMI, body mass index; CeDAR, Carolinas Equation for Determining Associated Risks; COPD, chronic obstructive pulmonary disease; CVA, cerebrovascular accident; mFI, modified frailty index; OR, odds ratio; PCI, percutaneous coronary intervention; TIA, transient ischemic attack.

infective complications compared to biologic and synthetic mesh in clean-contaminated and contaminated surgery,²³ as well as high recurrence rates.²⁴

Biologic meshes provide a collagen based extracellular matrix scaffold to promote fibroblast collagen deposition, cellular repopulation, and neovascularization.⁶ Two types exist: cross-linked and non-crosslinked, with the former being more durable.²⁵ Although a multicenter retrospective study found biologic mesh in the contaminated setting to be associated a nonsignificant reduction in wound infection and recurrence,²⁶ this was not confirmed in a systematic review.²⁷

The LAPSIS RCT assessing mesh use in the clean environment was concluded prematurely due to excessive recurrence rate in the biologic group.²⁸ A cohort study found biosynthetic mesh to be superior to biologic mesh in elective complex VHR.²⁹

Biologic mesh is significantly more expensive than synthetic mesh.³⁰ At present, there is no strong evidence to support its use in contaminated cases.^{1,3,7} It is not recommended for large defects in the clean setting.²² Fundamental studies of biosynthetic and biologic meshes are presented in ►Table 3.

Plane of Mesh Placement

The keys planes in VH surgery are described in ►Table 4.³¹ An appreciation of the relevant anatomy is central.³²

Table 3 Key studies assessing biosynthetic and biologic mesh outcomes

Reference	Type of study	Sample size	Intervention	Comparison	Follow-up (mo)	Outcome
Sahoo et al 2017 ²³	Retrospective cohort study	469	Biosynthetic mesh	Synthetic mesh	1	Biosynthetic mesh associated with increased surgical site infection ($p = 0.03$) and reoperation rates ($p = 0.009$) compared to synthetic mesh in clean-contaminated and contaminated cases
Renard et al 2020 ²⁴	Retrospective cohort study	81	Biosynthetic mesh (Vicryl)	Biologic mesh (Strattice)	36	Biosynthetic mesh associated with increased early ($p = 0.03$) and late ($p = 0.046$) infectious complications and recurrence (HR = 0.091 $p < 0.001$) compared to biologic mesh in contaminated incisional hernia repair
Bondre et al 2016 ²⁶	Retrospective cohort study	761	Biologic mesh	Synthetic mesh	15	Biologic mesh associated with nonsignificant reduction in infection complication (15.1 vs. 17.8%, $p = 0.28$) and increase in recurrence (17.8 vs. 13.5%, $p = 0.074$) relative to synthetic mesh in contaminated VHR
Lee et al 2014 ²⁷	Systematic review	1,304	Biologic mesh	Synthetic mesh	23.2	In clean contaminated cases, biologic mesh associated with increased wound infection rates (31.6%, [14.5–48.7%] vs. 6.4% [3.4–9.4%]) with similar recurrence rates. In contaminated cases, biologic mesh associated with increased recurrence (27.2% [9.5–44.9%] vs. 3.2% [0.0–11.0%]) with similar wound infection rates
Miserez et al 2010 ²⁸	RCT (prematurely closed)	257	Noncross linked biologic mesh (Surgisis Gold)	Synthetic mesh	12	Biologic mesh associated with higher recurrence across all study arms (laparoscopic 19 vs. 5%; open (11 vs. 3%) in elective VHR
Buell et al 2017 ²⁹	Retrospective cohort study	73	Biosynthetic mesh (P4HB)	Biologic mesh (porcine cadaveric)	-	Biosynthetic mesh associated with reduced complication ($p < 0.046$) and recurrence ($p < 0.049$) compared to biologic mesh in elective complex abdominal wall reconstruction

Abbreviations: RCT, randomized controlled trial; VHR, ventral hernia repair.

Table 4 Planes for mesh placement in ventral hernia surgery, adapted from ref.³¹

Plane	Anterior relation	Posterior relation
Onlay	Subcutaneous tissue	Anterior rectus sheath and external oblique
Inlay	Mesh attached to edges of hernia defect	
Retrorectus	Rectus abdominis muscle	Posterior rectus sheath
Preperitoneal	Transversalis fascia	Peritoneum
Intraperitoneal	Peritoneum	Abdominal cavity

The EHS/AHS guidelines advise sublay mesh placement for VHR.¹ This refers to mesh placed in either a retrorectus or preperitoneal location. A retrospective cohort study of incisional hernia repairs found sublay placement to improve recurrence and complication rates.³³ The MORPHEUS RCT evaluating primary VHR found preperitoneal mesh to be associated with reduced complications and cost with no difference in recurrence compared to intraperitoneal patch repair.³⁴ A further cohort study³⁵ and meta-analysis³⁶ evaluating both primary and incisional VHs found the retrorectus location to be associated with reduced recurrence and wound infection rates.

By contrast, intraperitoneal mesh placement may promote adhesion formation. In a series of 733 patients undergoing laparoscopic intraperitoneal mesh repair, 2% required reoperation for bowel obstruction after mean follow-up of 19 months.³⁷

Antibiotic Prophylaxis

The EHS/AHS, IEHS, and SAGES guidelines advise a single perioperative dose of antibiotics if mesh is used for VHR.^{1,3,5} The SAGES guidelines advise cephalosporin (+ vancomycin for patients with known MRSA).⁵

A meta-analysis highlighted the paucity of data.³⁸ The single RCT did not find benefit to antibiotic prophylaxis; however, it included only 19 patients.³⁹ The guidelines acknowledge that the strength of this recommendation is weak.

Preoperative Planning and Adjuncts to Abdominal Wall Reconstruction

Preoperative Imaging

For simple elective primary VHR, the EHS/AHS guidelines recommend that clinical examination should be sufficient. Ultrasound or computed tomography (CT) imaging may be considered if clinical examination is inconclusive.¹

For complex primary and incisional hernias, CT is helpful in preoperative planning³: to define defect size, loss of domain (hernia sac volume divided by total peritoneal sac volume⁴⁰), to predict requirement for component separation,⁴¹ risk of complications,⁴² and to guide adjuncts such as preoperative progressive pneumoperitoneum.⁴⁰ Loss of domain >15% is likely to lead to significant respiratory impact on return of the visceral contents to the abdominal cavity,⁴³ while loss of domain >20% is associated with failure of

tension-free closure.⁴⁴ Visceral fat volume is a significant predictor of recurrence, while hernia sac volume and subcutaneous fat volume predict infection rates.⁴²

The SAGES guidelines acknowledge the utility of preoperative CT in select cases; however, they reiterate that CT is not able to detect intra-abdominal adhesions or assess abdominal wall compliance, two key factors in operative planning.⁵ The IEHS guidelines recommend that dynamic measurement of defect size at different pressures of pneumoperitoneum improves quality of mesh size selection.³

Techniques to Allow Fascia Closure

Primary fascia closure (with sublay mesh) is associated with reduced recurrence rates compared to bridged inlay mesh repair.⁷ A number of techniques have been developed to extend the abdominal wall musculature to permit this with large defects. The IEHS guidelines advise that these are likely to be required for fascia defects of 8 to 10 cm.³ Component separation techniques (CSTs) represent the best-studied examples of these methods.⁴⁵

► **Table 5** presents a description of key CSTs.

Open anterior component separation (OACS) allows fascia advancement by approximately 10 cm. However, the undermining of subcutaneous tissue and interruption of perforator vessels leads to up to 40% wound morbidity.⁵¹ This led to the development of alternative techniques. The perforator-sparing OACS spares the periumbilical perforator vessels, with theoretical improvement in wound healing. Endoscopic CST and minimally invasive CST further reduce tissue trauma with intended reduction in wound morbidity.

As with other aspects of VHR, the evidence regarding CSTs is limited by heterogeneity and lack of RCTs.³ A systematic review found reduced wound complication rates in endoscopic or minimally invasive CST compared to open.⁵² Regarding transversus abdominis release (TAR), a meta-analysis reported no difference in wound infection or rate of hernia recurrence between OACS and TAR.⁵³

Although the IEHS guidelines acknowledge the lack of strong data, they advise consideration of endoscopic/minimally-invasive ACS or TAR as an alternative to OACS to reduce wound morbidity.³ Importantly, when a CST is used, the associated weakening of the lateral abdominal wall necessitates mesh reinforcement.³

Additional examples of techniques to improve fascia coverage include preoperative Botox injection,⁵⁴ progressive pneumoperitoneum,⁵⁵ and tissue expanders. Indeed, Botox injection and progressive pneumoperitoneum can be safely

Table 5 Description of component separation techniques

Technique	Description
OACS	Subcutaneous adipose tissue is dissected from the anterior rectus sheath to beyond the linea semilunaris. External oblique is incised along its length and dissected from internal oblique. Rectus abdominis is also separated from the posterior rectus sheath ⁴⁶
p-OACS	Subcutaneous adipose tissue is dissected from the anterior rectus sheath to beyond linea semilunaris at two distinct sites above and below the umbilicus. These two sites are then joined to create a tunnel over external oblique. The release of external oblique is completed as per the original OACS ⁴⁷
e-CST	Balloon dissection is used to create a space between external oblique and the subcutaneous adipose tissue. Two further working ports are inserted into this space to incise external oblique and then free it from internal oblique ⁴⁸
mi-CST	Optical port entry is used to insert a port deep to external oblique. The space between external oblique and internal oblique is developed by carbon dioxide insufflation. Working ports are then inserted and the procedure is completed as per e-CST ⁴⁹
TAR	Retrorectus space is developed to linea semilunaris. The posterior rectus sheath is incised medial to linea semilunaris to reach transversus abdominis. Transversus abdominis is incised along its length to reach the potential space between transversus fascia posteriorly and transversus abdominis anteriorly. This space is developed laterally ⁵⁰

Abbreviations: e-CST, endoscopic anterior component separation; mi-CST, minimally invasive anterior component separation; OACS, open anterior component separation; p-OACS, perforator sparing open anterior component separation; TAR, transversus abdominis release.

combined to achieve a significant reduction in the ratio of the volume of hernia sac to that of the abdominal cavity.⁵⁶ These techniques have been evaluated in a systematic review.⁵⁷ All three are safe and may be used in combination with CSTs. However, there is insufficient evidence for them to be recommended at present by the IEHS.³

In cases where tissue loss will lead to inadequate coverage of the repair, plastic surgical input may be required for split-skin graft or flap reconstruction.⁵⁸ In cases with unstable skin coverage, flap closure appears superior to mesh alone.⁵⁹ This will require interdisciplinary work with the plastic surgery team.

Technical Considerations in Open Ventral Hernia Repair

Primary Ventral Hernia Repair

The EHS/AHS guidelines recommend that mesh should be used for all primary VHRs, regardless of size.¹ A 2018 RCT found reduced recurrence rate when mesh was used to repair umbilical hernias as small as 1 cm.⁶⁰ A Danish cohort study also found reduced recurrence rates for primary VHs <2cm when mesh was used.⁶¹ These findings were confirmed in meta-analysis.⁶²

Subgroup analysis suggests that these findings hold for defects <1cm.⁶² However, the EHS/AHS guidelines advise that suture repair alone may be considered for these small hernias.¹ If a suture repair is performed, slowly absorbable or nonabsorbable sutures should be used,¹ although two large Danish population studies found no difference in outcome dependent on suture type.^{61,63}

The mesh-defect overlap should be 2 cm for defect < 1 cm and 3 cm for defect 1 to 4 cm.¹ However, the data regarding this is conflicting. A systematic review and case series found that for open repairs there was no significant association between degree of overlap and recurrence.^{64,65} By contrast, a

cohort study found overlap < 1cm to be associated with increased recurrence and in two RCTs (albeit designed to evaluate separate issues), overlap of 3 cm was associated with reduced recurrence.^{34,60}

There is insufficient evidence to guide a particular technique for mesh fixation, although if the decision is made to fix the mesh, nonabsorbable sutures are advised. With regard to defect closure over the mesh, the guidelines recommend closure although again acknowledge that the evidence is weak.¹

Incisional Hernia Repair

The higher recurrence rate associated with incisional VHR⁸ supports the advice that all incisional hernias should be repaired with mesh.⁶⁶ Expert consensus supports sublay repair.⁷

Open versus Laparoscopic Ventral Hernia Repair

The laparoscopic approach should be considered for hernia defects > 4 cm, in addition to patients with defects 1 to 4 cm that are at increased risk of wound infection (e.g., obesity) and for patients with multiple defects.^{1,3}

The SAGES guidelines advise the factors listed in ► **Table 6** as relative contraindications to the laparoscopic approach.⁵

A Cochrane review⁶⁷ demonstrated reduced surgical site infection with the laparoscopic approach, with no difference in recurrence rate. The laparoscopic technique was associated with a higher risk of bowel injury, although this event was rare with a total of 7 enterotomies in 642 cases (5 laparoscopic, 2 open). Limited to primary umbilical hernias, a meta-analysis of 16,549 patients found the laparoscopic approach to be associated with reduced wound infection, recurrence, and length of stay, although longer operating time.⁶⁸ The limitations of VHR data discussed in the introduction apply.

Table 6 Relative contraindications to laparoscopic repair of ventral hernia, as per SAGES guidance⁵

Significant adhesions
Recurrence hernia
Defect > 10 cm
Unusual location (e.g., subxiphoid, suprapubic)
Loss of domain
Presence of skin graft
Small defect: sac size ratio
Presence of enterocutaneous fistula
Required removal of large mesh

Abbreviations: IEHS, International Endohernia Society; SAGES, Society of Gastro-intestinal Endoscopic Surgeons.
IEHS advises a greater defect size of > 15 cm as a relative contraindication.³

An advantage of the laparoscopic technique is that any nearby additional hernia defects are visible at the time of the first operation and can be repaired using the same mesh, avoiding the overlooked additional hernia as a cause of “recurrence.” On the other hand, the lack of an abdominoplasty component with the laparoscopic technique can result in a less favorable cosmetic outcome for larger hernias. The risks of intraperitoneal mesh placement have been described previously.

Technical Considerations in Laparoscopic Ventral Hernia Repair

The most widely performed laparoscopic technique is the intraperitoneal onlay mesh (IPOM) repair: an intraperitoneal antiadhesion barrier-coated synthetic mesh is placed to cover the defect, recreating the abdominal wall.^{1,3}

The association between degree of overlap and recurrence is more established for laparoscopic repair than open. Mesh overlap of >5cm was found to be associated with reduced recurrence rate.⁶⁴ This approach is advocated by EHS/AHS.¹ A further study found mesh: defect area ratio to be the greatest predictor of recurrence; a mesh: defect ratio of ≥ 16 significantly improves recurrence.⁶⁹ The IEHS guidelines recommend this threshold as the determinant of mesh size selection.³

In addition, the SAGES guidelines highlight that recurrence is reduced where the mesh is fixed lateral to the rectus abdominis.⁵ This also reduces the risk of injury to the epigastric vessels.

Various mesh fixation techniques for IPOM exist. The results of key studies are summarized in ►Table 7; no single technique emerges as clearly superior.

The EHS/AHS guidelines advise mesh fixation with either nonabsorbable sutures or tacks.¹ The IEHS guidelines advise either suture fixation or a double-crowned tack technique.³ The SAGES guidelines do not give specific advice regarding mesh fixation.⁵

Similarly, the data regarding the benefit of closing the fascia defect in laparoscopic VHR (a technique termed “IPOM-plus”) is conflicting. These are summarized in ►Table 8.

The EHS/AHS and IEHS guidelines advise closure of the fascia defect where possible,^{1,3} using nonabsorbable sutures.³ The SAGES guidelines recommend defect closure at the surgeon's discretion.⁵

Although the standard laparoscopic technique remains IPOM repair $\pm$ fascia defect closure, the potential adhesion-related complications of an intra-peritoneal mesh have prompted EHS/AHS to advocate for sublay mesh placement.¹

Enhanced-view totally extraperitoneal repair⁸⁰ is a novel technique that allows laparoscopic preperitoneal retromuscular mesh repair. The initial port incision is used to enter the rectus sheath away from the hernia. The retrorectus space is developed using balloon dissection. Working ports are inserted into this space. The left and right retrorectus spaces are joined and the dissection is continued toward the hernia sac. Sharp dissection is used to drop the hernia sac into the abdomen. The fascia defect is closed and a mesh placed in the dissected retrorectus space. A case series of 79 patients demonstrated the feasibility of this approach with one recurrence after mean follow-up of 332 days.⁸⁰ A second case series of 11 procedures demonstrated that this approach can favor the placement of large meshes with no major complication or recurrence after 7 months.⁸¹ However, the data is not yet sufficient to be able to draw firm conclusions.¹

Robotic Ventral Hernia Repair

Although preperitoneal mesh placement is achievable laparoscopically, this may be facilitated using robotic assistance.^{1,3,79} Several robotic VHR techniques exist (►Table 9).

The majority of the evidence regarding robotic VHR derives from case series. No studies to date have sufficient size or follow-up to accurately assess recurrence rates, long-term complications, or to suggest the superiority of one technique over another.^{1,3} However, the methods appear promising.³ Important studies assessing robotic VHR techniques are described in ►Table 10.

A limitation with robotic surgery is cost.⁸⁵ The cost of equipment (initial purchase and maintenance/disposables) often exceeds \$2 million.³ Further studies into the long-term implications of robotic surgery are required to facilitate cost-benefit analysis.³

Management of Emergent and Contaminated Cases

The EHS/AHS and WSES guidelines advise that synthetic mesh repair should be used for incarcerated VHs without strangulation.^{1,6} In this setting, an RCT comparing mesh to suture repair for incarcerated paraumbilical hernias demonstrated that mesh was associated with reduced recurrence with no increase in wound infection.⁸⁶

Table 7 Summary of key studies evaluating different techniques of laparoscopic mesh fixation in ventral hernia repair

Reference	Type of study	Sample size	Intervention	Comparison	Mean follow-up (mo)	Outcome
Reynvoet et al 2014 ⁷⁰	Meta-analysis	4,300	Sutures + tacks	Tacks alone; sutures alone	29.1	No significant difference in recurrence (sutures + tacks 2.5% (1.3–3.7%); tacks 3.4% (2.4–4.5%); sutures 0.9% (0–1.7%) or pain between different techniques
Baker et al 2017 ⁷¹	Meta-analysis	6,553	Sutures	Absorbable tacks; absorbable tacks + sutures; permanent tacks; permanent tacks + sutures	22	The crude recurrence rates were as follows: absorbable tacks + sutures 0.7%; sutures 1.5%; permanent tacks + sutures 6.0%; permanent tacks 7.7%; absorbable tacks 17.5%. Statistical significance was not achieved in these differences
Brill and Turner 2011 ⁷²	Systematic review	8,465	Sutures ± tacks	Sutures alone; tacks alone	30.1	No significant difference in hernia recurrence or prolonged postoperative pain. Sutures associated with significantly higher SSI
Ahmed et al 2018 ⁷³	Meta-analysis	466	Tacks	Suture	16.1	No significant difference in postoperative pain at 4–6 weeks (MD: 0.18; 95% CI: –0.48–0.85), chronic pain (OR: 1.24 [0.65–2.38]) or recurrence (OR: 1.11 [0.34–3.62]), although operative time was significantly lower with tack fixation (MD: –19.25 [–27.98––10.51])
Sajid et al 2013 ⁷⁴	Meta-analysis	207	Tacks	Suture	10.6	No significant difference in recurrence (OR: 1.54 (0.38–6.27). Tacks associated with reduced operative time (MD: –23.65 [–31.06––16.25]) and 4–6 weeks postoperative pain (MD: –0.69 [–1.16––0.23])
Khan et al 2018 ⁷⁵	Meta-analysis	1,149	Absorbable tacks	Nonabsorbable tacks	30	No difference in recurrence (RD: 0.03 [–0.04–0.09]) or chronic pain (OR: 0.91 [0.62–1.33])
Eriksen et al 2011 ⁷⁶	RCT	40	Fibrin sealant	Titanium tacks	1	Fibrin sealant associated with reduced acute postoperative pain on days 0–2 ($p = 0.025$) and resumed normal activity earlier ($p = 0.027$)
Eriksen et al 2013 ⁷⁷	RCT	40	Fibrin sealant	Titanium tacks	12	Fibrin sealant associated with higher recurrence rates (26 vs. 6%, $p = 0.182$), although not statistically significant. No significant difference in pain at 1 year follow-up
Stirler et al 2017 ¹¹	Prospective cohort study	80	Absorbable tacks	Titanium tacks	60.5	Early postoperative pain was significantly lower with absorbable tacks at 6 ($p = 0.008$) and 12 weeks ($p = 0.008$), but not at 18 months ($p = 0.21$)

Abbreviations: CI confidence interval; MD, mean difference; OR, odds ratio; RCT, randomized controlled trial; RD, risk difference; SSI, surgical site infection.

Table 8 Summary of key studies evaluating fascia defect closure versus defect nonclosure during laparoscopic ventral hernia repair

Reference	Type of study	Sample size	Intervention	Comparison	Mean follow-up (mo)	Outcome
Nguyen et al 2014 ⁷⁸	Systematic review	393	Defect closure	Defect nonclosure	20	Defect closure results in reduced recurrence (0–5.7 vs. 4.8–16.7%) and seroma rates (5.6–11.4 vs. 4.3–27.8%)
Tandon et al 2016 ⁹	Meta-analysis	3,638	Defect closure	Defect nonclosure	34.8	Defect closure was associated with reduced adverse events (RR: 0.25, $p < 0.001$) and seroma (RR: 0.37, $p < 0.001$)
Gonzalez et al 2014 ⁷⁹	Retrospective cohort study	134	Defect closure	Defect nonclosure	19.4	Defect closure was associated with increased operative time ($p = 0.012$). There was no significant difference in complications ($p = 0.084$) or recurrence ($p = -0.095$)
Lambrecht et al 2015 ¹⁰	Combined prospective and retrospective cohort study	194	Defect closure	Defect nonclosure	32.5	Defect closure was associated in increased complication rate (OR: 3.42, 95% CI: 1.25–9.33), with no difference in seroma, pain at 2 months, pseudorecurrence or true recurrence

Abbreviations: CI, confidence interval; OR, odds ratio; RR, risk ratio.

Table 9 Novel robotic VHR techniques and their more traditional equivalents³

Robotic technique	Equivalent open/laparoscopic technique
Robotic IPOM	Laparoscopic intraperitoneal onlay mesh repair
Robotic TAPP	Laparoscopic transabdominal preperitoneal mesh repair
Robotic VHR ± robotic TAR	Open retrorectus mesh repair ± transversus abdominis release

Abbreviations: IPOM, intraperitoneal onlay mesh; TAPP, transabdominal preperitoneal; TAR, transversus abdominis release; VHR, ventral hernia repair.

In cases of intestinal ischemia without necrosis and bowel resection without gross enteric spillage, synthetic mesh repair can be performed without an increase in wound morbidity.⁶ The EHS/AHS guidelines state that this decision should be taken on a case-by-case basis.¹ Although not unanimous, the main studies in this field support the safety of synthetic mesh in this environment (► **Table 11**).

For the stable patient with bowel necrosis or gross enteric spillage during bowel resection, if the defect is < 3cm suture repair is advised. If the defect is too large for suture repair, WSES guidelines suggest consideration of biologic mesh if available. If not, biosynthetic mesh or planned delayed hernia repair are both viable options.⁶ However, the evidence

for use of biologic and biosynthetic mesh is weak, as described previously; this recommendation remains controversial.

For the unstable patient, open wound management is advised to avoid abdominal compartment syndrome, with early defect closure following stabilization.⁶

A number of studies have demonstrated the feasibility of laparoscopy in the management of incarcerated VHs.^{90–92} A further study extended this to the strangulated setting for groin hernias⁹³; reduced wound infection rates were found in the laparoscopic group without an increase in recurrence. In the emergency setting, the WSES guidelines recommend that laparoscopy may be considered to treat an incarcerated

Table 10 Summary of key studies of robotic VHR

Reference	Type of study	Sample size	Intervention	Comparison	Outcome
Gonzalez et al 2014 ⁷⁹	Retrospective cohort study	134	Robotic IPOM-plus	Laparoscopic IPOM	Robotic IPOM-plus associated with nonsignificant reduction in recurrence ($p = 0.095$) and complications ($p = 0.084$), with a significant increase in operative time ($p = 0.012$) compared to laparoscopic IPOM
Kennedy et al 2018 ⁸²	Retrospective cohort study	63	Robotic TAPP	Robotic IPOM	Robotic TAPP associated with reduction in complications without significant difference in operative time compared to robotic IPOM
Carbonell et al 2018 ⁸³	Retrospective cohort study	333	Robotic RVHR	Open RVHR	Robotic RVHR associated with reduced length of stay ($p < 0.001$), although with a greater rate of surgical site occurrences (mainly seromas) ($p < 0.001$) compared to open repair
Bittner et al 2017 ⁸⁴	Retrospective cohort study	102	Robotic TAR	Open TAR	Robotic TAR associated with significant reduction in length of stay (6 days (5.9–8.3 vs. 3 days [3.2–4.3]) but increased operative time ($p < 0.01$) compared to open TAR

Abbreviations: IPOM, intraperitoneal onlay mesh; RVHR, retromuscular ventral hernia repair; TAPP, transabdominal preperitoneal; TAR, transversus abdominis release.

Table 11 Key studies assessing use of mesh in emergency VHR (excluding contaminated cases)

Reference	Type of study	Sample size	Intervention	Comparison	Outcome
Haskins et al 2016 ⁸⁷	Retrospective cohort study	2,449, emergency VHR	Mesh repair	Suture repair	Mesh repair was not associated with increased wound-related or additional 30-day morbidity or mortality
Nieuwenhuizen et al 2011 ⁸⁸	Retrospective cohort study	203, emergency groin and VHRs	Mesh repair	Suture repair	Mesh repair was not associated with increased wound complications relative to suture repair
Choi et al 2012 ⁸⁹	Retrospective cohort study	33,832, clean-contaminated and contaminated VHR (elective and emergency)	Mesh repair	Suture repair	Mesh repair was associated with increased complications relative to nonmesh repair in clean-contaminated cases (OR: 3.56 vs. 2.52)

Abbreviations: OR, odds ratio; VHR, ventral hernia repair.

hernia. However, if strangulation or the need for bowel resection is anticipated, the open approach is preferable.⁶

A further indication for laparoscopy in the emergency setting is to assess the viability of spontaneously reduced bowel during open repair via hernia sac laparoscopy. An RCT of 95 patients with inguinal hernias found hernioscopy reduced hospital stay and major complications.⁹⁴ This could be extended to VHs.

Conclusion

Although there has been a recent increase in research into VHR,⁴ there remain a number of issues that require well-designed RCTs to resolve. These include:

- Comparison of efficacy and safety of different CSTs and tissue expansion techniques.

- ii. Determination of optimal mesh fixation technique in laparoscopic VHR.
- iii. Assessment of benefit of fascial defect closure in laparoscopic VHR.
- iv. Comparison of novel laparoscopic and robotic techniques to standard IPOM.
- v. Assessment of biologic mesh versus suture repair in contaminated cases.

In addition to these trial topics, improvement in preoperative risk stratification and imaging assessment will improve patient selection.

This review highlights the complexity of VHR; novel techniques and materials develop rapidly, while supporting data struggles to keep pace. The available evidence to guide decision-making is often conflicting and relatively weak. Guidelines must rely heavily on expert consensus.

In this context, challenging cases benefit from discussion in a multidisciplinary setting including radiological, anesthetic, and surgical (both general and plastic surgery) teams. Discussion should focus on consideration of preoptimization, probability of postoperative respiratory impairment, the need for adjuncts to improve fascia coverage, and optimal surgical approach. Careful assessment in this environment helps to bridge the gap between currently available evidence and high-quality patient treatment.

Conflict of Interest Statement

The authors of this manuscript declare no conflicts of interest.

References

- 1 Henriksen NA, Kaufmann R, Simons PM, et al. on behalf of the European Hernia Society and the Americas Hernia Society. EHS and AHS guidelines for treatment of primary ventral hernias in rare locations or special circumstances. *BJS Open* 2020 Apr;4(02): 342–353. Doi: 10.1002/bjs.5.50252, Epub 2020 Jan 9
- 2 Muysoms F, Campanelli G, Champault GG, et al. EuraHS: the development of an international online platform for registration and outcome measurement of ventral abdominal wall hernia repair. *Hernia* 2012;16(03):239–250
- 3 Bittner R, Bain K, Bansal VK, et al. Update of Guidelines for laparoscopic treatment of ventral and incisional abdominal wall hernias (International Endohernia Society (IEHS)): Part B. *Surg Endosc* 2019;33(11):3511–3549. Doi: 10.1007/s00464-019-06908-6, Epub 2019 Jul 10
- 4 Holihan JL, Nguyen DH, Flores-Gonzalez JR, et al. A systematic review of randomized controlled trials and reviews in the management of ventral hernias. *J Surg Res* 2016;204(02):311–318
- 5 Earle David, Scott Roth J, Saber Alan, Haggerty Steve, Bradley JF III, Fanelli Robert. SAGES guidelines for laparoscopic ventral hernia repair. *Surg Endosc*. Doi: 10.1007/s00464-016-5072-x
- 6 Birindelli A, Sartelli M, Di Saverio S, et al. 2017 update of the WSES guidelines for emergency repair of complicated abdominal wall hernias. *World J Emerg Surg* 2017;12:37
- 7 Liang MK, Holihan LJ, Itani K, et al. Ventral Hernia Management: Expert Consensus Guided by Systematic Review. *Ann Surg* 2017; 265(01):80–89. Doi: 10.1097/SLA.0000000000001701
- 8 Stabilini C, Cavallaro G, Dolce P, et al. Pooled data analysis of primary ventral (PVH) and incisional hernia (IH) repair is no more acceptable: results of a systematic review and metanalysis of current literature. *Hernia* 2019;23(05):831–845
- 9 Tandon A, Pathak S, Lyons NJ, Nunes QM, Daniels IR, Smart NJ. Meta-analysis of closure of the fascial defect during laparoscopic incisional and ventral hernia repair. *Br J Surg* 2016;103(12): 1598–1607
- 10 Lambrecht JR, Vaktiskjold A, Trondsen E, Øyen OM, Reiertsen O. Laparoscopic ventral hernia repair: outcomes in primary versus incisional hernias: no effect of defect closure. *Hernia* 2015;19 (03):479–486
- 11 Stirlor VMA, Nallayici EG, de Haas RJ, Raymakers JTFJ, Rakic S. Postoperative pain after laparoscopic repair of primary umbilical hernia: titanium tacks versus absorbable tacks: a prospective comparative cohort analysis of 80 patients with a long-term follow-up. *Surg Laparosc Endosc Percutan Tech* 2017;27(06): 424–427
- 12 Singhal V, Szeto P, VanderMeer TJ, Cagir B. Ventral hernia repair: outcomes change with long-term follow-up. *JSLS* 2012;16(03): 373–379
- 13 Kokotovic D, Sjølander H, Gögenur I, Helgstrand F. Watchful waiting as a treatment strategy for patients with a ventral hernia appears to be safe. *Hernia* 2016;20(02):281–287
- 14 Helgstrand F, Rosenberg J, Kehlet H, Bisgaard T. Outcomes after emergency versus elective ventral hernia repair: a prospective nationwide study. *World J Surg* 2013;37(10):2273–2279
- 15 Martindale RG, Deveney CW. Preoperative risk reduction: strategies to optimize outcomes. *Surg Clin North Am* 2013;93(05): 1041–1055
- 16 Liang MK, Bernardi K, Holihan JL, et al. Modifying risks in ventral hernia patients with prehabilitation: a randomized controlled trial. *Ann Surg* 2018;268(04):674–680
- 17 Borbély Y, Zerkowski J, Altmeier J, Eschenburg A, Kröll D, Nett P. Complex hernias with loss of domain in morbidly obese patients: role of laparoscopic sleeve gastrectomy in a multi-step approach. *Surg Obes Relat Dis* 2017;13(05):768–773
- 18 Augenstein VA, Colavita PD, Wormer BA, et al. CeDAR: Carolinas Equation for Determining Associated Risks. *JACS* 2015;221(04): S65–S66
- 19 Fligor JE, Lanier ST, Dumanian GA. Current risk stratification systems are not generalizable across surgical technique in midline ventral hernia repair. *Plast Reconstr Surg Glob Open* 2017;5 (03):e1206
- 20 Joseph WJ, Cuccolo NG, Baron ME, Chow I, Beers EH. Frailty predicts morbidity, complications, and mortality in patients undergoing complex abdominal wall reconstruction. *Hernia* 2020;24(02):235–243
- 21 Carbonell AM, Criss CN, Cobb WS, Novitsky YW, Rosen MJ. Outcomes of synthetic mesh in contaminated ventral hernia repairs. *J Am Coll Surg* 2013;217(06):991–998
- 22 Köckerling F, Alam NN, Antoniou SA, et al. What is the evidence for the use of biologic or biosynthetic meshes in abdominal wall reconstruction? *Hernia* 2018;22(02):249–269
- 23 Sahoo S, Haskins IN, Huang LC, et al. Early wound morbidity after open ventral hernia repair with biosynthetic or polypropylene mesh. *J Am Coll Surg* 2017;225(04):472–480.e1
- 24 Renard Y, de Mestier L, Henriques J, et al. Absorbable polyglactin vs. non-cross-linked porcine biological mesh for the surgical treatment of infected incisional hernia. *J Gastrointest Surg* 2020;24(02):435–443
- 25 Coccolini F, Agresta F, Bassi A, et al. Italian Biological Prosthesis Work-Group (IBPWG): proposal for a decisional model in using biological prosthesis. *World J Emerg Surg* 2012;7(01):34. Doi: 10.1186/1749-7922-7-34
- 26 Bondre IL, Holihan JL, Askenasy EP, et al. Ventral Hernia Outcomes Collaborative. Suture, synthetic, or biologic in contaminated ventral hernia repair. *J Surg Res* 2016;200(02):488–494

- 27 Lee L, Mata J, Landry T, et al. A systematic review of synthetic and biologic materials for abdominal wall reinforcement in contaminated fields. *Surg Endosc* 2014;28(09):2531–2546
- 28 Miserez M, Grass G, Weiss C, Stützer H, Sauerland S, Neugebauer EALAPIS Investigators. Closure of the LAPIS trial. *Br J Surg* 2010;97(10):1598
- 29 Buell JF, Sigmon D, Ducoin C, et al. Initial experience with biologic polymer scaffold (poly-4-hydroxybutyrate) in complex abdominal wall reconstruction. *Ann Surg* 2017;266(01):185–188
- 30 Montgomery A. The battle between biological and synthetic meshes in ventral hernia repair. *Hernia* 2013;17(01):3–11
- 31 Parker S, Halligan S, Liang KM, et al. International Classification of Abdominal Wall Planes (ICAP) to describe mesh insertion for ventral hernia repair. *Br J Surg* Feb;2020;107(03):209–217. Doi: 10.1002/bjs.11400, Epub 2019 Dec 25
- 32 Skolimowska-Rzewuska M, Mitura K. Essential anatomical landmarks in placement of an adequate size mesh for a successful ventral hernia repair. *Pol Przegl Chir* 2021;93(05):1–5
- 33 de Vries Reilingh TS, van Geldere D, Langenhorst B, et al. Repair of large midline incisional hernias with polypropylene mesh: comparison of three operative techniques. *Hernia* 2004;8(01):56–59
- 34 Ponten JEH, Leenders BJM, Leclercq WKG, et al. Mesh versus patch repair for epigastric and umbilical hernia (MORPHEUS Trial): one-year results of a randomized controlled trial. *World J Surg* 2018;42(05):1312–1320
- 35 Holihan JL, Bondre I, Askenasy EP, et al; Ventral Hernia Outcomes Collaborative (VHOC) Writing Group. Sublay versus underlay in open ventral hernia repair. *J Surg Res* 2016;202(01):26–32
- 36 Holihan JL, Hannon C, Goodenough C, et al. Ventral hernia repair: a meta-analysis of randomized controlled trials. *Surg Infect (Larchmt)* 2017;18(06):647–658
- 37 Patel PP, Love MW, Ewing JA, Warren JA, Cobb WS, Carbonell AM. Risks of subsequent abdominal operations after laparoscopic ventral hernia repair. *Surg Endosc* 2017;31(02):823–828
- 38 Aufenacker TJ, Koelemay MJ, Gouma DJ, Simons MP. Systematic review and meta-analysis of the effectiveness of antibiotic prophylaxis in prevention of wound infection after mesh repair of abdominal wall hernia. *Br J Surg* 2006;93(01):5–10
- 39 Abramov D, Jeroukhimov I, Yinnon AM, et al. Antibiotic prophylaxis in umbilical and incisional hernia repair: a prospective randomised study. *Eur J Surg* 1996;162(12):945–948, discussion 949
- 40 Tanaka EY, Yoo JH, Rodrigues AJ Jr, Utiyama EM, Birolini D, Rasslan S. A computerized tomography scan method for calculating the hernia sac and abdominal cavity volume in complex large incisional hernia with loss of domain. *Hernia* 2010;14(01):63–69
- 41 Blair LJ, Ross SW, Huntington CR, et al. Computed tomographic measurements predict component separation in ventral hernia repair. *J Surg Res* 2015;199(02):420–427
- 42 Winters H, Knaapen L, Buyne OR, et al. Pre-operative CT scan measurements for predicting complications in patients undergoing complex ventral hernia repair using the component separation technique. *Hernia* 2019;23(02):347–354
- 43 Kingsnorth AN, Sivarajasingham N, Wong S, Butler M. Open mesh repair of incisional hernias with significant loss of domain. *Ann R Coll Surg Engl* 2004;86(05):363–366
- 44 Sabbagh C, Dumont F, Robert B, Badaoui R, Verhaeghe P, Regimbeau JM. Peritoneal volume is predictive of tension-free fascia closure of large incisional hernias with loss of domain: a prospective study. *Hernia* 2011;15(05):559–565
- 45 Mitura K. Mew techniques in ventral hernia surgery – an evolution of minimally invasive hernia repairs. *Pol Journ Surg* 2020. Doi: 10.5604/01.3001.0014.1898
- 46 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(03):519–526
- 47 Saulis AS, Dumanian GA. Periumbilical rectus abdominis perforator preservation significantly reduces superficial wound complications in “separation of parts” hernia repairs. *Plast Reconstr Surg* 2002;109(07):2275–2280, discussion 2281–2282
- 48 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(02):720–729, quiz 730
- 49 Dauser B, Ghaffari S, Ng C, Schmid T, Köhler G, Herbst F. Endoscopic anterior component separation: a novel technical approach. *Hernia* 2017;21(06):951–955
- 50 Novitsky YW, Elliott HL, Orenstein SB, Rosen MJ. Transversus abdominis muscle release: a novel approach to posterior component separation during complex abdominal wall reconstruction. *Am J Surg* 2012;204(05):709–716
- 51 Tong WM, Hope W, Overby DW, Hultman CS. Comparison of outcome after mesh-only repair, laparoscopic component separation, and open component separation. *Ann Plast Surg* 2011;66(05):551–556
- 52 Switzer NJ, Dykstra MA, Gill RS, et al. Endoscopic versus open component separation: systematic review and meta-analysis. *Surg Endosc* 2015;29(04):787–795
- 53 Hodgkinson JD, Leo CA, Maeda Y, et al. A meta-analysis comparing open anterior component separation with posterior component separation and transversus abdominis release in the repair of midline ventral hernias. *Hernia* 2018;22(04):617–626
- 54 Farooque F, Jacombs ASW, Roussos E, et al. Preoperative abdominal muscle elongation with botulinum toxin A for complex incisional ventral hernia repair. *ANZ J Surg* 2016;86(1-2):79–83
- 55 Mayagoitia JC, Suárez D, Arenas JC, Díaz de León V. Preoperative progressive pneumoperitoneum in patients with abdominal-wall hernias. *Hernia* 2006;10(03):213–217
- 56 Bueno-Lledó J, Carreño-Saenz O, Torregrosa-Gallud A, Pous-Serrano S. Preoperative botulinum toxin and progressive pneumoperitoneum in loss of domain hernias—our first 100 cases. *Front Surg* 2020;7:3. Doi: 10.3389/fsurg.2020.00003
- 57 Alam NN, Narang SK, Pathak S, Daniels IR, Smart NJ. Methods of abdominal wall expansion for repair of incisional herniae: a systematic review. *Hernia* 2016;20(02):191–199
- 58 Bath AS, Patnaik PK, Bhandari PS. Reconstruction of complex abdominal wall defects. *Med J Armed Forces India* 2007;63(02):123–126
- 59 Mathes SJ, Steinwald PM, Foster RD, Hoffman WY, Anthony JP. Complex abdominal wall reconstruction: a comparison of flap and mesh closure. *Ann Surg* 2000;232(04):586–596
- 60 Kaufmann R, Halm JA, Eker HH, et al. Mesh versus suture repair of umbilical hernia in adults: a randomised, double-blind, controlled, multicentre trial. *Lancet* 2018;391(10123):860–869
- 61 Christoffersen MW, Helgstrand F, Rosenberg J, Kehlet H, Bisgaard T. Lower reoperation rate for recurrence after mesh versus sutured elective repair in small umbilical and epigastric hernias. A nationwide register study. *World J Surg* 2013;37(11):2548–2552
- 62 Bisgaard T, Kaufmann R, Christoffersen MW, Strandfelt P, Gluud LL. Lower risk of recurrence after mesh repair versus non-mesh sutured repair in open umbilical hernia repair: a systematic review and meta-analysis of randomized controlled trials. *Scand J Surg* 2019;108(03):187–193
- 63 Christoffersen MW, Helgstrand F, Rosenberg J, Kehlet H, Strandfelt P, Bisgaard T. Long-term recurrence and chronic pain after repair for small umbilical or epigastric hernias: a regional cohort study. *Am J Surg* 2015;209(04):725–732
- 64 LeBlanc K. Proper mesh overlap is a key determinant in hernia recurrence following laparoscopic ventral and incisional hernia repair. *Hernia* 2016;20(01):85–99
- 65 Berrevoet F, Doerhoff C, Muysoms F, et al. A multicenter prospective study of patients undergoing open ventral hernia repair with intraperitoneal positioning using the monofilament polyester composite ventral patch: interim results of the PANACEA study. *Med Devices (Auckl)* 2017;10:81–88

- 66 Luijendijk RW, Hop WC, van den Tol MP, et al. A comparison of suture repair with mesh repair for incisional hernia. *N Engl J Med* 2000;343(06):392–398
- 67 Sauerland S, Walgenbach M, Habermalz B, Seiler CM, Miserez M. Laparoscopic versus open surgical techniques for ventral or incisional hernia repair. *Cochrane Database Syst Rev* 2011;(03):CD007781
- 68 Hajibandeh S, Hajibandeh S, Sreh A, Khan A, Subar D, Jones L. Laparoscopic versus open umbilical or paraumbilical hernia repair: a systematic review and meta-analysis. *Hernia* 2017;21(06):905–916
- 69 Hauters P, Desmet J, Gherardi D, Dewaele S, Poilvache H, Malvaux P. Assessment of predictive factors for recurrence in laparoscopic ventral hernia repair using a bridging technique. *Surg Endosc* 2017;31(09):3656–3663
- 70 Reynvoet E, Deschepper E, Rogiers X, Troisi R, Berrevoet F. Laparoscopic ventral hernia repair: is there an optimal mesh fixation technique? A systematic review. *Langenbecks Arch Surg* 2014;399(01):55–63
- 71 Baker JJ, Öberg S, Andresen K, Klausen WT, Rosenberg J, et al. Systematic review and network meta-analysis of methods of mesh fixation during laparoscopic ventral hernia repair. *Br J Surg* 2018 Jan;105(01):37–47. Doi: 10.1002/bjs.10720, Epub 2017 Dec 11
- 72 Brill JB, Turner PL. Long-term outcomes with transfascial sutures versus tacks in laparoscopic ventral hernia repair: a review. *Am Surg* 2011;77(04):458–465
- 73 Ahmed MA, Tawfic QA, Schlachta CM, Alkhamesi NA. Pain and surgical outcomes reporting after laparoscopic ventral hernia repair in relation to mesh fixation technique: a systematic review and meta-analysis of randomized clinical trials. *J Laparoendosc Adv Surg Tech A* 2018;28(11):1298–1315
- 74 Sajid MS, Parampalli U, McFall MR. A meta-analysis comparing tacker mesh fixation with suture mesh fixation in laparoscopic incisional and ventral hernia repair. *Hernia* 2013;17(02):159–166
- 75 Khan RMA, Bughio M, Ali B, Hajibandeh S, Hajibandeh S. Absorbable versus non-absorbable tacks for mesh fixation in laparoscopic ventral hernia repair: a systematic review and meta-analysis. *Int J Surg* 2018;53:184–192
- 76 Eriksen JR, Bisgaard T, Assaadzadeh S, Jorgensen LN, Rosenberg J. Randomized clinical trial of fibrin sealant versus titanium tacks for mesh fixation in laparoscopic umbilical hernia repair. *Br J Surg* 2011;98(11):1537–1545
- 77 Eriksen JR, Bisgaard T, Assaadzadeh S, Jorgensen LN, Rosenberg J. Fibrin sealant for mesh fixation in laparoscopic umbilical hernia repair: 1-year results of a randomized controlled double-blinded study. *Hernia* 2013;17(04):511–514
- 78 Nguyen DH, Nguyen MT, Askenasy EP, Kao LS, Liang MK. Primary fascial closure with laparoscopic ventral hernia repair: systematic review. *World J Surg* 2014;38(12):3097–3104
- 79 Gonzalez AM, Romero RJ, Seetharamaiah R, Gallas M, Lamoureux J, Rabaza JR. Laparoscopic ventral hernia repair with primary closure versus no primary closure of the defect: potential benefits of the robotic technology. *Int J Med Robot* 2015 Jun;11(02):120–125. Doi: 10.1002/rcs.1605 Epub 2014 Sep 18
- 80 Belyansky I, Daes J, Radu VG, et al. A novel approach using the enhanced-view totally extraperitoneal (eTEP) technique for laparoscopic retromuscular hernia repair. *Surg Endosc* 2018;32(03):1525–1532
- 81 Mitura K, Rzewuska A, Skolimowska-Rzewuska M, Romańczuk M, Kisielewski K, Wyrzykowska D. Laparoscopic enhanced-view totally extraperitoneal Rives-Stoppa repair (eTEP-RS) for ventral and incisional hernias – early operative outcomes and technical remarks on a novel retromuscular approach. *Wideochir Inne Tech Malo Inwazyjne* 2020;15(04):533–545
- 82 Kennedy M, Barrera K, Akelik A, et al. Robotic TAPP ventral hernia repair: early lessons learned at an inner city safety net hospital. *JLS* 2018;22(01):1–5
- 83 Carbonell AM, Warren JA, Prabhu AS, et al. Reducing length of stay using a robotic-assisted approach for retromuscular ventral hernia repair: a comparative analysis from the Americas Hernia Society Quality Collaborative. *Ann Surg* 2018;267(02):210–217
- 84 Bittner JG, Alrefai S, Vy M, Mabe M, Del Prado PAR, Clingempeel NL. Comparative analysis of open and robotic transversus abdominis release for ventral hernia repair. *Surg Endosc* 2017;16:179–188
- 85 Armijo P, Pratap A, Wang Y, Shostrom V, Oleynikov D. Robotic ventral hernia repair is not superior to laparoscopic: a national database review. *Surg Endosc* 2017;7:7–16
- 86 Abdel-Baki NA, Bessa SS, Abdel-Razek AH. Comparison of prosthetic mesh repair and tissue repair in the emergency management of incarcerated para-umbilical hernia: a prospective randomized study. *Hernia* 2007;11(02):163–167
- 87 Haskins IN, Amdur RL, Lin PP, Vaziri K. The use of mesh in emergent ventral hernia repair: effects on early patient morbidity and mortality. *J Gastrointest Surg* 2016;20(11):1899–1903
- 88 Nieuwenhuizen J, van Ramshorst GH, ten Brinke JG, et al. The use of mesh in acute hernia: frequency and outcome in 99 cases. *Hernia* 2011;15(03):297–300
- 89 Choi JJ, Palaniappa NC, Dallas KB, Rudich TB, Colon MJ, Divino CM. Use of mesh during ventral hernia repair in clean-contaminated and contaminated cases: outcomes of 33,832 cases. *Ann Surg* 2012;255(01):176–180
- 90 Landau O, Kyzer S. Emergent laparoscopic repair of incarcerated incisional and ventral hernia. *Surg Endosc* 2004;18(09):1374–1376
- 91 Shah RH, Sharma A, Khullar R, Soni V, Baijal M, Chowbey PK. Laparoscopic repair of incarcerated ventral abdominal wall hernias. *Hernia* 2008;12(05):457–463
- 92 Olmi S, Cesana G, Erba L, Croce E. Emergency laparoscopic treatment of acute incarcerated incisional hernia. *Hernia* 2009;13(06):605–608
- 93 Yang GPC, Chan CTY, Lai ECH, Chan OCY, Tang CN, Li MKW. Laparoscopic versus open repair for strangulated groin hernias: 188 cases over 4 years. *Asian J Endosc Surg* 2012;5(03):131–137
- 94 Sgourakis G, Radtke A, Sotiropoulos GC, et al. Assessment of strangulated content of the spontaneously reduced inguinal hernia via hernia sac laparoscopy: preliminary results of a prospective randomized study. *Surg Laparosc Endosc Percutan Tech* 2009;19(02):133–137