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Loss of domain in complex ventral hernia: Volumetric assessment, prehabilitation, and algorithm-based surgical management

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Abstract

BACKGROUND: Loss of domain (LOD) in complex ventral hernia (CVH) poses a major surgical challenge due to volumetric imbalance between the hernia sac and abdominal cavity, risking intra-abdominal hypertension and abdominal compartment syndrome. Management strategies remain heterogeneous.

MATERIALS AND METHODS: This narrative review followed the Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews framework. A systematic search of PubMed, Embase, and Scopus identified studies published up to January 2026 using terms including "loss of domain," "complex ventral hernia," "Tanaka index,""Sabbagh ratio," "CT volumetry," "botulinum toxin,""progressive pneumoperitoneum," "component separation," "Fasciotens," and "robotic abdominal wall reconstruction." Two authors independently screened the titles and abstracts. The included studies comprised consensus statements, systematic reviews, meta-analyses, and cohort studies with ≥ 20 patients. Case reports, editorials, and non-English studies were excluded. Findings were synthesized descriptively.

RESULTS: Computed tomography volumetry is the diagnostic gold standard for quantifying LOD. A Tanaka index > 25% and Sabbagh ratio > 20% identify patients at high risk for tensioned closure. Prehabilitation—including smoking cessation, glycemic control, and weight optimization—reduces surgical site morbidity. Botulinum toxin A (BTA) increases lateral abdominal wall compliance by approximately 4 cm per side, while progressive preoperative pneumoperitoneum (PPP) expands the abdominal cavity volume by up to 53%. Combined BTA and PPP achieve high primary fascial closure rates in massive defects. Transversus abdominis release provides durable retromuscular reconstruction with lower recurrence than anterior component separation. Emerging adjuncts such as Fasciotens and prolonged CO_2 insufflation offer additional muscle lengthening of up to 25%.

CONCLUSION: CVH with LOD requires objective volumetric assessment and a tailored, algorithm-based approach integrating prehabilitation, domain-expanding techniques, and neurovascular-preserving reconstruction to improve the outcomes and reduce recurrence.

Keywords:

Abdominal wall reconstruction, botulinum toxin, complex ventral hernia, Fasciotens, loss of domain, progressive pneumoperitoneum, transversus abdominis release

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Introduction

Ventral hernia is a broad term that comprises all anterolateral abdominal wall fascial defects.[1] The prevalence of abdominal wall hernias is approximately 1.7% across all age groups, increasing to 4% among individuals aged 45 and older, indicating that this condition is relatively common. Globally, an estimated 20 million

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patients are treated for hernias each year, making it a frequent issue that surgeons encounter around the world.[2]

The European Hernia Society classification provides a simple, practical, and reproducible method to classify primary abdominal wall and incisional hernias.[3] A primary ventral hernia is defined as a spontaneous herniation of intra-abdominal contents through a defect in the abdominal wall that is not related to a scar from surgery or trauma. These include incisional, umbilical, epigastric, and spigelian hernias. They can also be categorized by their location on the abdominal wall. An epigastric hernia occurs from the xiphoid process to the umbilicus, an umbilical hernia occurs at the umbilicus, and a hypogastric hernia occurs below the umbilicus. An incisional hernia is described as an abdominal wall defect that may or may not present with a bulge at a postoperative scar.

Additionally, primary hernias that have undergone one or more prior surgeries are also classified as incisional hernias. Incisional hernias are a common long-term complication following abdominal surgeries. The incidence of incisional hernias varies, ranging from 2% to 20%.[4,5] Overall, the incidence of incisional hernias is slightly higher after midline laparotomy incisions (10%) compared to transverse muscle-splitting incisions (5%), and it is less than 1% following laparoscopic repairs.[5] Ventral hernias can present with or without symptoms. They typically manifest as a swelling in the abdomen, which may be accompanied by pain. In some cases, they can lead to serious complications, such as strangulation, incarceration, and obstruction.

The management of ventral hernias has undergone a significant transformation over the past decade. The global incidence of ventral hernia repairs is on the rise, attributed to an increase in intra-abdominal surgical procedures, an aging population, and higher rates of obesity, diabetes mellitus, smoking, and malnutrition.[6-9] While simple ventral hernias are defined anatomically by a fascial defect, they can often be effectively treated using straightforward suture or mesh techniques. Complex ventral hernia (CVH) repair in the form of abdominal wall reconstruction (AWR) is increasingly being recognized as its own surgical subspecialty, and it has been demonstrated that a multidisciplinary team meeting comprising the surgeon, internist, anesthetist, respiratory physiotherapist, and nutritionist, with the goal of standardizing CVH management, is key to improving the outcomes.[10]

This narrative review synthesizes contemporary evidence on CVHs with loss of domain (LOD) and was conducted in accordance with Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews guidance. A literature search was performed using PubMed, Embase, and Scopus for studies published up to January 2026. The search terms included "loss of domain," "complex ventral hernia," "Tanaka Index," "Sabbagh ratio," "CT volumetry," "botulinum toxin," "progressive pneumoperitoneum," "component separation," "Fasciotens," and "robotic abdominal wall reconstruction." Reference lists of relevant articles were manually screened to identify additional studies. Two authors independently screened titles and abstracts; and discrepancies were resolved by discussion. The inclusion criteria encompassed consensus statements, systematic reviews, meta-analyses, and prospective or retrospective clinical series with ≥ 20 patients. Case reports, editorials, and non-English-language publications without available translations were excluded. Given the heterogeneity in definitions and outcome measures, the findings were synthesized descriptively rather than through quantitative meta-analysis.

LOD: Pathophysiology and Clinical Implications

Recently, an international Delphi consensus of expert surgeons established a standardized definition of CVHs with LOD. According to this definition, a CVH is considered large enough that simple reduction of its contents and primary fascial closure cannot be achieved without the use of additional reconstructive techniques. Additionally, such a hernia poses a significant risk of complications due to increased intra-abdominal pressure, which may lead to intra-abdominal hypertension (IAH) or abdominal compartment syndrome.[11] CVHs have a negative impact on the quality of life, often resulting in immobility, chronic pain, discomfort, and cosmetic concerns.[12] Despite this, there is currently no standardized surgical approach for their repair, and the recurrence rates after 5 years remain notably high at 23.8%.[13]

The major issue in managing CVH is the concept of LOD. LOD is not merely a static anatomical term; it represents a dynamic pathophysiological condition. When viscera protrude consistently through a significant fascial defect, they lose their "right of domicile" within the peritoneal cavity. Over time, the hernia sac expands and effectively transforms into a "second abdominal cavity."[14] This chronic herniation of intra-abdominal contents triggers a series of anatomical and physiological disturbances.

Anatomically, the abdominal wall is organized in distinct layers. The paired rectus abdominis muscles occupy the central compartment, flanked laterally by three muscle layers, the external oblique, internal oblique,

and transversus abdominis, which converge at the linea alba via their aponeuroses. In the setting of significant midline or paramedian hernia defects that lead to LOD, the rectus muscles lose their medial fascial anchorage at the linea alba. Consequently, the lateral muscle stack, the external oblique, internal oblique, and transversus abdominis, also loses its medial tension vector, causing all components to retract laterally, shorten, and undergo progressive atrophy and fatty degeneration. It is important to note that hernias leading to LOD are not restricted to the midline; defects may arise at any location on the anterior or lateral abdominal wall, and the pattern of muscular retraction and noncompliance depends on both defect location and chronicity. This structural remodeling results in the remaining abdominal wall becoming non-compliant and rigid.[15,16]

Physiologically, the pressure equilibrium between the abdominal cavity and the hernia sac affects respiratory mechanics. When normal intra-abdominal pressure (IAP) is disrupted, the diaphragm becomes flattened and shortened due to a lack of support. As a result, the respiratory muscles must adapt to a lower-pressure environment.[14,17] If the contents of the hernia sac are forcibly reduced without proper preparation, there is a risk of abdominal compartment syndrome. This condition is characterized by cephalad displacement of the diaphragm, which compromises lung compliance, reduces venous return, and increases afterload, creating a potentially fatal cascade of respiratory failure, renal failure, and hemodynamic collapse.[17,18]

Several techniques have been identified to prevent severe complications associated with abdominal surgeries. Some of these techniques focus on reducing the abdominal content, such as omentectomy and visceral resection.[19,20] In contrast, others aim to increase the abdominal cavity volume (ACV). These include preoperative injections of botulinum toxin, progressive preoperative pneumoperitoneum (PPP), perioperative component separation techniques (CST), and mechanical tissue expanders such as Fasciotens. However, it has been reported that standardized techniques can be associated with significant complications in up to 30% of patients.[21-30]

This review seeks to standardize the approach to treating these patients by integrating recent consensus guidelines, volumetric data, and standardized surgical strategies.

Defining the Problem: The Volumetric Revolution

Despite the clinical significance of LOD, a standardized definition remains elusive, which complicates the comparison of outcomes across different studies. Recently, an International Delphi Consensus involving 20 expert surgeons concluded that there is currently no single written or volumetric definition that adequately addresses all clinical scenarios.[11] However, it was agreed that LOD is a pathophysiological continuum rather than a binary state.[11] Historically, LOD has been defined by linear dimensions (e.g., a defect width greater than 10–15 cm) or by the subjective "spot-test," which assesses the inability to reduce the contents of the defect.

However, these linear definitions do not adequately account for patient morphometric variability, and it is important to distinguish between two related but conceptually distinct measurements: the hernia *defect diameter* (expressed in cm, representing the width of the fascial opening) and the hernia sac volume (HSV) (expressed in cm^3, representing the total volume of herniated content). A large defect diameter does not necessarily equate to a large sac volume, and vice versa. The true physiological burden of LOD is best captured by the volumetric relationship between the hernia sac and the total peritoneal cavity. In this context, a 10-cm defect with a large HSV in a lean patient (body mass index [BMI]: 20 kg/m^2) represents a greater relative LOD and, therefore, a proportionally larger volumetric mismatch than the same defect diameter in a patient with a BMI of 40 kg/m^2, where the total peritoneal and ACV is substantially larger, potentially accommodating greater content without the same degree of tension upon reduction. Furthermore, in obese patients, visceral fat itself constitutes a significant proportion of intra-abdominal content; weight loss prior to surgery directly reduces the volume of intra-abdominal contents that must be re-accommodated, thereby improving the LOD ratio and facilitating tension-free closure. This distinction underscores why volumetric, rather than linear, assessment is essential for surgical planning.[31]

Volumetric Definitions: The Current Gold Standard

Historically, physical examination has been the standard method for diagnosing ventral hernias in clinical practice and research. However, with advancements in imaging techniques and their widespread availability, relying solely on physical examination is considered inadequate.[32] Research indicates that physical examinations can miss up to 23% of ventral hernias that are visible on radiological imaging. Furthermore, assessments made by surgeons alone are less effective than routine abdominal computed tomography (CT) scans for diagnosing ventral hernias.[33] Underdiagnosing or misreporting these hernias can lead to inappropriate management decisions and inaccurate benchmarks for surgical outcomes. The purpose of preoperative imaging is to determine the size of the ventral hernia, identify its

contents, assess the quality of the abdominal muscles, and recognize any complications that may affect the repair process.

Modern management practices now rely on CT volumetry to enhance the understanding of CVH with LOD, aiding the formulation of effective surgical plans to achieve low recurrence rates and favorable functional outcomes. The evaluation of domain loss should be conducted prior to surgery.[18,24,34,35] This assessment involves measuring the ACV and incisional hernia volume or HSV from a preoperative CT scan to calculate the LOD ratio, defined as HSV/(HSV + ACV). A ratio exceeding 20% is generally considered to indicate a high risk of postoperative abdominal compartment syndrome, and patients may require the implementation of one or more techniques to increase ACV.[36-39]

Currently, two primary methods have been proposed to evaluate the LOD:

(1) The Tanaka index (TI): This is the fundamental metric for repairing CVH with LOD. It is calculated as the ratio of HSV to ACV. Both HSV and ACV are determined through CT scan measurements of the longitudinal, transverse, and anteroposterior diameters of each cavity. A TI greater than 25% is traditionally considered the threshold for LOD, which necessitates preoperative intervention. In the original series, patients below this threshold often underwent primary closure, whereas those above it required additional techniques, such as PPP.[38]
(2) The Sabbagh ratio: This ratio is often confused with the TI as it uses a different denominator. It expresses hernia volume as a proportion of the total peritoneal volume. A Sabbagh ratio exceeding 20% indicates a predictive factor for the inability to achieve primary fascial closure without tension. Other factors influencing tension-free fascial closure include age, BMI, and the width, length, and surface area of the hernia.[39] It is important for the operating surgeon to differentiate between these two ratios as a Sabbagh ratio of 20% indicates a larger relative hernia compared to a TI of 20%. The volumes are typically calculated by treating the hernia sac and abdominal cavity as geometric ellipsoids, based on the measurements of the longitudinal (CC), transverse (Lat), and anteroposterior diameters obtained from CT scans. Comparison of these indices is depicted in Figure 1.

Simplified Measurement Techniques

After the Delphi consensus meetings, the participants agreed on a volumetric definition of LOD as described by Sabbagh *et al*.[39] This definition specifies that LOD is the percentage of the total peritoneal content located outside the abdominal cavity.[39] It is important to note that the abdominal cavity includes only the intra-abdominal organs and excludes retroperitoneal and subperitoneal organs. There are different methods for measuring the ACV and HSV. Volumes can also be estimated using simple two-dimensional (2D) measurements. By measuring the height, width, and depth on CT imaging and applying the ellipsoid formula, the corresponding volumes can be calculated. Although this method is simple, straightforward, and quick, the shapes of the hernia sac and abdominal cavity are not always perfect ellipsoids. Consequently, this approach does not visualize the relationship between the intraperitoneal and retroperitoneal spaces, leading to questionable accuracy in determining the LOD. Volume rendering involves a set of techniques that create a three-dimensional (3D) visualization from a series of 2D images. 3D reconstructions are generated using specialized software that processes volumetric data from CT scans. One advantage of this method for assessing LOD is its ability to specifically select and calculate HSV and ACV, regardless of their shapes. While 3D volume

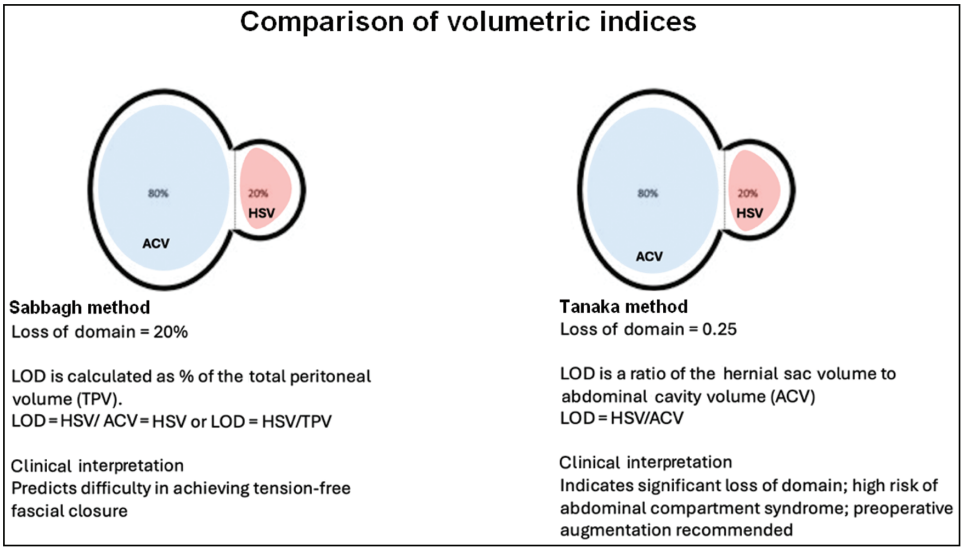


Figure 1: Comparison of volumetric indices. LOD, loss of domain; HSV, hernia sac volume; ACV, abdominal cavity volume

rendering (e.g., using 3D Slicer) is considered the gold standard for accurate volume assessment on CT, it is time-consuming.[40-42] It requires radiological expertise, which may not be available at all centers. Recent studies have introduced specific "surgeon-friendly" alternatives for volume assessment.

2D versus 3D correlation: Boermeester *et al*.[43] compared 2D linear measurements, using a simple ellipsoid formula based on the height, width, and depth measured by standard viewers, against 3D volumetry in a group of patients with incisional hernias with LOD. They found a strong correlation between the straightforward 2D measurements and the standardized 3D volume rendering. This validates the use of bedside calculations as a safe and quick alternative for surgical planning, eliminating the need for complex computer software required for 3D volumetry.[43]

The Reims-ratio (R-ratio): Al Sadairi *et al*.[44] proposed a novel standardized method for obtaining the LOD ratio, termed the "R-ratio." This ratio can be calculated in less than a minute by any surgeon with basic computer skills and does not require extensive radiological knowledge. It is a simple tool intended to assist in the proper evaluation of CVH with LOD, anticipate complications, and guide the preparation and surgical techniques needed for these complex patients, which may include botulinum toxin injection, preoperative pneumoperitoneum, and component separations.[44]

Preoperative Optimization: The "Prehabilitation" Phase

Successful surgical repair begins months before the actual procedure. Due to the risks and costs associated with postoperative complications following repair of CVH with LOD, there is a growing consensus that preoperative optimization may be more crucial than the surgical technique itself. However, it is the combination of both that is likely to yield the best outcomes.[45] The concept of prehabilitation can be divided into two distinct pillars. The first pillar focuses on managing comorbidities to minimize existing conditions such as advanced age, frailty, smoking, obesity, diabetes, and underlying liver disease. These conditions are associated with adverse early and late postoperative outcomes. Modifiable risk factors like obesity, diabetes, or smoking are associated with an increased likelihood of experiencing wound complications within 30 days of surgery. Notably, patients with more than one comorbidity have an increased risk of wound morbidity and may require subsequent procedural interventions.[46] The second pillar involves abdominal wall prehabilitation, which employs preoperative strategies to ensure a tension-free midline closure and the technical feasibility of the repair.

The idea of prehabilitation turns the waiting period into an active preparation phase.[47] While research on systemic prehabilitation shows mixed results, there is strong, consistent evidence supporting the use of abdominal wall adjuncts (such as botulinum toxin A [BTA] and PPP). Expert consensus clearly favors aggressive optimization.[48] Delphi consensus guidelines suggest a standardized approach to managing modifiable risk factors. There is strong agreement on the importance of recommending weight loss through medical management or weight loss surgery for patients with a BMI over 35 kg/m^2, smoking cessation, blood sugar control for people with diabetes mellitus, exercise prehabilitation for individuals with poor exercise tolerance, treatment of malnutrition, and providing access to biological and other adjunct materials when appropriate.[49]

Metabolic and Lifestyle Optimization

Smoking cessation: Smoking is a significant modifiable risk factor in hernia repair. It contributes to tissue hypoxia, impaired collagen synthesis, and increased postoperative recurrence rates. Current smokers experience higher rates of wound, respiratory, and infectious complications, along with increased long-term healthcare costs. Evidence indicates that a minimum preoperative cessation period of 4 weeks can reduce postoperative complications from 41% to 21%.[50-52]

Glycemic control: Perioperative hyperglycemia is a well-established risk factor for prolonged hospital stays and a higher incidence of surgical site occurrences (SSOs) in CVH repairs.[53,54] While expert guidelines suggest postponing elective surgeries for patients with an glycated hemoglobin A1c (HbA1c) level greater than 8%, recent registry data question this threshold. The data show similar complication rates regardless of HbA1c levels when perioperative glucose is well managed. Despite this conflicting evidence, the 8% cutoff remains the accepted standard of care to ensure patient safety.[55,56]

Weight loss: Obesity increases the risk of recurrence and wound complications, especially in open hernia, though minimally invasive techniques seem to reduce these risks.[57] A BMI less than 35–40 kg/m^2 is generally targeted. Visceral fat volume is a more accurate predictor of complications than BMI. Postponing surgery to achieve lifestyle-based weight loss is often ineffective and can lead to significant hernia expansion.[58] As a result, a staged approach that includes bariatric surgery is widely favored to ensure sustainable optimization and durable repair. It is important to balance rapid weight loss with the risk of nutritional depletion.[59]

Frailty: Frailty, defined as diminished physiological reserve, is a strong predictor of postoperative morbidity

in ventral hernia repairs. Severe frailty notably increases the odds of complications and surgical site infections.[60] Radiographic assessment of sarcopenia (measuring the psoas muscle area on CT scans) has been proposed as a surrogate marker for frailty.[61]

BTA: Chemical Component Separation

BTA has revolutionized the management of CVH with LOD by altering abdominal wall compliance. BTA is a highly effective neurotoxin that inhibits acetylcholine release at the presynaptic neuromuscular junction. This inhibition results in the cessation of electrical activity in the target muscle, leading to a reversible flaccid paralysis. It is administered to the lateral abdominal wall musculature, comprising the external oblique, internal oblique, and transversus abdominis. The physiological action of BTA facilitates "chemical component separation," thereby reducing lateral retraction forces and significantly elongating the abdominal muscles. This helps achieve tension-free midline closure and may eliminate the need for more invasive mechanical CSTs. The clinical effects of BTA typically begin 3 days post-injection, reach a peak at 2 weeks, and last for 6–9 months.[15,62-64]

Studies have demonstrated that BTA application results in a mean lateral abdominal muscle elongation of approximately 4.11 cm per side, with various studies reporting elongation ranging from 2.8 to 4.2 cm per side.[21,63,65] Importantly, BTA does not increase the long-term risk of abdominal wall weakness or bulging as muscle function generally returns within 4 weeks. In the acute "open abdomen" setting (damage control laparotomy), BTA injection has achieved an 83% primary fascial closure rate, increasing to 89% when administered within 24 h of the initial procedure. In the elective repair of LOD hernias, the combination of BTA and PPP has facilitated defect closure in 98.2% of patients. Notably, the use of BTA significantly reduces the need for invasive mechanical releases. In a systematic review encompassing 217 patients, only 14.7% required transversus abdominis release (TAR), while 32.2% required anterior component separation (ACS).[21,66-68]

Ultrasound guidance is the standard technique for visualizing the three lateral muscle layers and ensuring precise infiltration. The toxin is injected directly into the external oblique, internal oblique, and transversus abdominis muscles to secure diffuse distribution throughout the muscle bellies. Electromyography may also be utilized to confirm denervation in previously operated fields.[22,63,69] In the context of elective repair, BTA is generally administered 4–6 weeks prior to surgery to achieve optimal muscle relaxation and elongation. When used in conjunction with PPP, BTA is given first, followed by the initiation of PPP approximately 2 weeks thereafter. In damage control situations, BTA should be administered as soon as the patient achieves hemodynamic stability, ideally within 24 h, to maximize closure success. Standard total doses typically range from 200 to 300 units (Botox®) or 500 units (Dysport®), diluted in normal saline (e.g., 300 units in 150 mL).[21,23,65]

BTA is consistently reported as safe, with no complications directly attributed to the toxin itself across numerous studies. Postoperative outcomes indicate low recurrence rates of 3%–5.9% and SSOs of 12%–26.2%. In acute settings, BTA modulates pain by inhibiting the release of substance P and calcitonin gene-related peptide, potentially reducing the need for narcotic analgesics.[15,65,68,70]

PPP

PPP effectively addresses the volume discrepancy that cannot be resolved by BTA. It is the sole modality that actively expands the ACV. PPP primarily operates as a "pneumatic tissue expander," elongating the abdominal wall muscles and enhancing the compliance of the abdominal cavity. This technique not only increases ACV but also elongates the abdominal muscles and elevates the diaphragm, which is critical for improving respiratory mechanics prior to the stresses of surgery. By gradually increasing the IAP over weeks, patients acclimatize to the pressure, thereby reducing the risk of postoperative respiratory failure. Furthermore, gradual insufflation promotes pneumatic adhesiolysis, aiding the non-traumatic separation of adhesions between the viscera and the hernia sac, thereby significantly facilitating surgical dissection.[22,71]

The standard protocol for this procedure typically involves establishing access at Palmer's point in the left hypochondrium, employing devices such as Veress needles or central venous catheters, often under ultrasound guidance to mitigate the risk of visceral injury. Ambient air is the preferred medium for insufflation due to its significantly slower absorption compared to carbon dioxide, which helps maintain stable pressure.[18,38,71,72] Treatment regimens usually comprise daily insufflations of 500–1000 mL (sometimes fractionated into two doses) over a duration of 7–21 days. The cumulative volumes may range from 10 to 15 L, depending on the size of the defect. This regimen achieves a 52% increase in ACV while incurring minimal complications. Monitoring during the procedure is predominantly clinical, relying on patient-reported symptoms such as pain or dyspnea instead of strict pressure thresholds.[18,72,73]

Evidence supports that PPP is an exceptionally effective intervention for CVH with LOD hernias, resulting in substantial increases in the ACV of 20%–53%.[71,73] This volumetric gain correlates with high rates of primary fascial closure (84%–94%) and is associated with relatively low recurrence rates in uncomplicated cases.[18,72] The procedure is regarded as safe, exhibiting a complication rate of 12%–18%, predominantly consisting of minor issues such as subcutaneous emphysema and shoulder pain, with severe morbidity rare. Recent studies strongly advocate the synergistic application of BTA alongside PPP to maximize domain gain and further reduce the risk of surgical-site complications.[22,71,73]

Synergistic Strategy: BTA + PPP

In cases of significant defects, monotherapy is frequently insufficient. There is compelling evidence supporting the efficacy of combining BTA and PPP. While BTA facilitates an increase in parietal compliance (stretch), PPP provides the necessary active expansion force. BTA essentially prepares the abdominal muscles for an extended stretch under pneumoperitoneal pressure. This combination has been demonstrated to achieve primary fascial closure in over 80% of "inoperable" defects, with low recurrence rates of 5.9%, thereby obviating the need for extensive bridging meshes, which are linked to higher recurrence and complication rates.[22,68]

Emerging Adjuncts: Fasciotens and Prolonged CO_2 Pneumoperitoneum in Minimally Invasive Surgery

Fasciotens

Fasciotens is a mechanical tissue expander designed to exert progressive, controlled tension on the fascial edges of the hernia defect, promoting gradual medialization of the abdominal wall. Unlike PPP, which works by expanding the intra-abdominal volume, Fasciotens acts directly on the fascial margins through an extracorporeal traction device anchored to the skin surface adjacent to the defect. This device applies incremental lateral-to-medial mechanical tension over a period of days to weeks prior to definitive repair, progressively elongating the myofascial units and reducing the effective defect width. Preliminary reports suggest that Fasciotens can achieve clinically meaningful reductions in defect size in patients with large incisional hernias, and it may be used as a standalone adjunct or in combination with BTA and PPP in the multimodal prehabilitation pathway. It is particularly advantageous in patients who are not candidates for pneumoperitoneum due to preexisting respiratory compromise or pleural adhesions. Further prospective data are needed to define its precise role within established management algorithms and to determine optimal patient selection criteria.

Prolonged CO_2 pneumoperitoneum in laparoscopic and robotic surgery

An additional domain-expanding effect has been described in the context of purely laparoscopic and robotic hernia repairs that utilize sustained CO_2 pneumoperitoneum. In these procedures, the maintenance of a continuous CO_2 pneumoperitoneum throughout the operative period, which may extend several hours for complex cases, exerts a progressive stretching effect on the lateral abdominal wall musculature analogous to PPP. Studies evaluating this phenomenon have reported abdominal muscle lengthening of approximately 25% during prolonged minimally invasive procedures, an effect attributed to the sustained mechanical distension of the peritoneal cavity under working pressures of 12–15 mm Hg. This intraoperative domain expansion may facilitate trocar-site fascial approximation and reduce tension at the repair site. While this effect is an inherent consequence of the minimally invasive approach rather than a separately applied adjunct, surgeons should be aware of its domain-expanding potential when selecting between open and minimally invasive platforms for complex LOD repairs. The clinical significance of this intraoperative muscle lengthening in terms of recurrence and postoperative complications warrants further prospective evaluation.

CSTs

When primary closure is impractical, CSTs become essential for recruiting the lateral abdominal wall.

ACS

Originally described by Ramirez *et al.*,[26] the open ACS (OACS) technique entails releasing the external oblique fascia to facilitate the medialization of the rectus fascia. This approach is particularly suited for myofascial advancement, allowing for lateral mobilization of approximately 5 cm in the upper abdomen and up to 10 cm in the lower abdomen. Although it effectively restores the linea alba, OACS is associated with significant wound morbidity because extensive subcutaneous undermining is required to expose the fascia. Systematic reviews reveal SSO rates for OACS between 20% and 35%, with wound morbidity and flap necrosis reported as high as 75%. Hernia recurrence rates from pooled analyses generally range from 9% to 13%. To address the high wound complication rates, endoscopic and perforator-sparing variations have been introduced, which have demonstrated a reduction in SSOs to approximately 20% while maintaining similar recurrence rates. In cases where the retrorectus plane is compromised by prior surgery or mesh infection, ACS remains a critical salvage procedure. The key modification is to preserve the periumbilical perforators to prevent skin flap necrosis.[26,29,74,75]

Posterior component separation (PCS)

PCS techniques expand dissection beyond the lateral borders of the rectus sheath, with the introduction of a novel approach, TAR. TAR involves incising the posterior rectus sheath and dividing the transversus abdominis muscle to access the space between this muscle and the transversalis fascia. A notable advantage of TAR is the preservation of the neurovasculature supplying the rectus abdominis, which is often damaged by other posterior techniques. TAR allows for significant medial advancement of the posterior fascia, estimated at 8–12 cm per side, thus creating a substantial retromuscular space capable of accommodating mesh sizes from 1200 to 4500 cm^2. Due to its ability to conserve neurovascular supply, TAR is now the preferred method for complex hernia repairs. Outcomes are promising, with pooled analyses indicating low hernia recurrence rates of 4%–5.7%. Despite some wound complications, the SSO rate is approximately 15%, comparable to or lower than that of open anterior techniques. Recent innovations include robotic-assisted TAR, which shows potential in minimizing hospital stays and systemic complications, with some studies reporting SSO rates as low as 3%.[27,28,30]

The sandwich technique

Often referred to as "Peritoneal Flap" hernioplasty, the sandwich technique is primarily utilized for the repair of large incisional hernias where complete restoration of the linea alba cannot be achieved with conventional methods. The sandwich technique enhances the abdominal domain by positioning a bridging mesh between the medialized rectus muscles and completely covering it with mobilized peritoneal flaps, effectively "sandwiching" the prosthesis. In some instances, an acellular dermal matrix is placed below the fascia, and a soft synthetic polypropylene mesh is placed above the fascia. Reported data indicate a recurrence rate of less than 13% over follow-up periods of 1–7 years. However, this technique is associated with a high rate of wound complications, reaching up to 68%. Additionally, because the technique relies on a bridging component rather than restoring the native linea alba, there are concerns regarding the potential for symptomatic bulging or late recurrence.[76-80]

Staged repair (serial excision)

The staged repair or serial excision serves as a salvage approach for cases of "frozen abdomen" or massive LOD, where even bridging poses a risk of abdominal compartment syndrome. This multistage strategy aims to achieve delayed primary closure in complex hernia defects. Initially, extensive adhesiolysis and bowel resection are performed, followed by suturing a Gore-Tex mesh to the fascial edges under moderate tension to promote gradual medialization of the abdominal wall. Sequential re-exploration typically occurs every 5–6 days, during which a central ellipse of the mesh, usually 3–4 cm in diameter, is excised, and the fascia edges are reapproximated to maintain tension. It is crucial to bluntly dissect lateral adhesions at each

Table 1: Comparison of surgical techniques for complex ventral hernia with loss of domain

Technique	Principle	Fascial closure	Advantages	Limitations/recurrence
Anterior component separation (ACS)	External oblique release to medialize rectus complex	Yes	Restores linea alba; effective myofascial advancement (5–10 cm/side); salvage option	High wound morbidity (20%–35% SSO); flap necrosis risk; recurrence 9%–13%
Posterior component separation—transversus abdominis release (TAR)	Posterior rectus sheath incision with division of the transversus abdominis	Yes	Wide retromuscular mesh space; preserves neurovascular supply; lower wound complications than ACS	Technically demanding; recurrence 4%–5.7%
Robotic TAR	Minimally invasive posterior component separation	Yes	Reduced length of stay; lower SSO rates in early studies	Increased operative time and cost; long-term recurrence data limited
Sandwich repair (peritoneal flap technique)	Bridging mesh covered by mobilized peritoneal flaps	Partial (bridging component)	Option when complete fascial closure not achievable	High wound complications (up to 68%); risk of bulging; recurrence < 13%
Staged repair (serial excision)	Gradual medialization using temporary mesh with sequential reduction	Delayed primary closure	Useful in frozen abdomen or massive LOD	Multiple procedures; prolonged hospitalization; limited recurrence data
Bridged mesh repair	Mesh spans defect without fascial approximation	No	Technically simple	Higher recurrence and bulging compared with closure techniques
Adjunct: BTA + PPP	Chemical component relaxation + progressive abdominal expansion	Facilitates definitive closure	Converts high TI defects to closable domain; primary closure > 80%	Requires preoperative planning; minor PPP-related morbidity; recurrence 3%–5.9% (with definitive repair)

BTA = botulinum toxin A, PPP = progressive preoperative pneumoperitoneum, SSO = surgical site occurrence, TI = Tanaka index

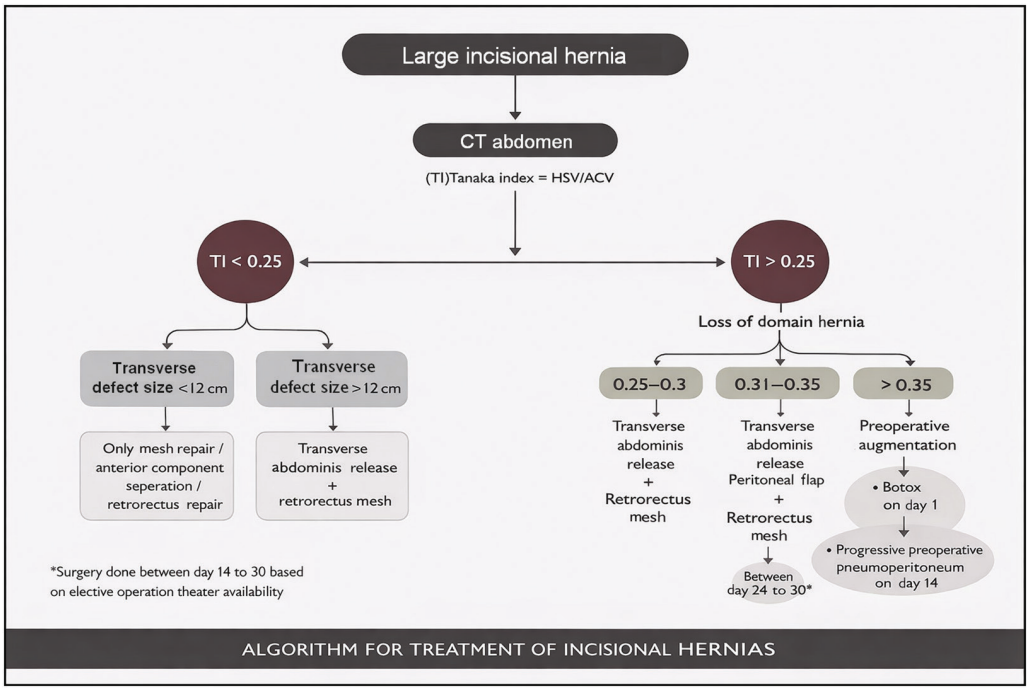


Figure 2: Algorithm for treatment of large incisional hernias

stage to preserve myofascial mobility for eventual advancement. This cycle continues until the mesh is reduced to approximately 3–4 cm in width. In the final stage, the remaining prosthetic mesh is excised, and either a standard or laparoscopic ACS is performed to facilitate fascial advancement. The repair is reinforced with an acellular dermal matrix placed as an underlay, allowing for primary midline fascial closure, with an additional onlay graft utilized if closure remains under tension.[26,81,82]

Comparison of all techniques is described in Table 1.

Algorithmic Surgical Management

The current consensus emphasizes a tailored approach rather than a "one-technique-fits-all" paradigm. The selection of the repair technique depends on the patient's physiological reserve and the volumetric characteristics of the hernia. Girieasen *et al.* introduced a stratified management algorithm utilizing the TI, which serves as an invaluable framework for clinical decision-making [Figure 2].[83,84]

TI < 10%: These defects, despite potentially having a large diameter, do not lead to significant volume loss. Standard approaches such as Rives–Stoppa retromuscular repair or TAR are generally adequate. It should be noted, however, that the defect width remains an important independent variable: defects ≤ 12 cm in this volumetric category may be amenable to ACS with mesh onlay reinforcement as the relatively small medialization distance required can be achieved with ACS alone without the risks associated with posterior plane dissection. This is the rationale for recommending onlay repair with ACS in this subset, and it reflects the specific anatomical and volumetric characteristics of the patient rather than defect size in isolation.

TI 10%–20%: These cases fall into a "grey zone." Although closure is often possible, it may occur under tension. The algorithm recommends considering BTA monotherapy to promote tension-free closure and minimize the extent of myofascial release required. For defects with a width >15 cm within this range, TAR should be considered as the first-line operative technique, and the threshold for adding BTA preoperatively should be low.

TI > 25%: These instances are categorized as "loss of domain." Attempting primary closure without adjunctive measures poses a substantial risk of abdominal compartment syndrome. A combined approach of BTA and PPP is imperative. Defects exceeding 15–20 cm in transverse diameter in this category will almost invariably require TAR as the definitive reconstructive technique, and in some cases, staged repair may be necessary. Surgical intervention should be postponed until the TI is reduced to < 20% for better outcomes.

The algorithm in Figure 2 represents an evidence-informed management framework developed by the authors based on the original stratified approach of Girieasen *et al.*,[84] incorporating modifications to address large defect diameters and emerging adjuncts.

It is intended as a clinical decision-support tool and not a prescriptive protocol, recognizing that individual patient factors including prior surgery, mesh infection, physiological reserve, and available institutional expertise must guide final surgical decision-making.

Postoperative Care and Enhanced Recovery After Surgery (ERAS)

The physiological challenges associated with CVH with LOD repair necessitate a specialized ERAS strategy to mitigate the risks of respiratory failure and hernia recurrence.

Abdominal core health quality collaborative recommendations for ventral hernia repair:[85]

(1) Fluid management: Employing a restrictive intraoperative fluid management protocol is essential. Excessive fluid administration can lead to bowel edema, elevated IAP, and increased tension on the fascial closure line. Goal-directed fluid therapy is recommended.
(2) Pain control: A multimodal analgesia approach is imperative to minimize opioid consumption as opioids are known to impair respiratory drive and gastrointestinal motility (ileus), both of which are deleterious in LOD patients. Regional anesthesia techniques, including TAP blocks or epidural analgesia, are strongly encouraged. Additionally, administering scheduled doses of acetaminophen, gabapentin, and nonsteroidal anti-inflammatory drugs (if renal function permits) can enhance pain management.
(3) Mobilization: Early mobilization within the first postoperative day is the most effective intervention to prevent complications such as atelectasis and pneumonia. Patients should be encouraged to sit in a chair during meals by postoperative day 1, promoting active recovery.
(4) IAP monitoring: Continuous monitoring of IAP via a bladder catheter is crucial for high-risk LOD patients during the initial 24–48 h. If the IAP exceeds 20 mm Hg, clinicians should consider sedation, muscular paralysis, and surgical decompression if there are signs of organ dysfunction. These recommendations underscore the importance of a comprehensive postoperative care pathway tailored for patients undergoing LOD repair to enhance recovery and prevent complications.[85,86]

Discussion

The management of CVH with LOD has undergone a major paradigm shift. Historically viewed as a static anatomical defect requiring simple closure, LOD is now understood as a dynamic pathophysiological state. Chronic visceral herniation leads to a non-compliant abdominal wall. Consequently, forcing the reduction of contents without addressing these structural changes results in IAH and abdominal compartment syndrome. This understanding has moved the field from mere fascial approximation to functional AWR, necessitating a multidisciplinary approach to reduce the historically high recurrence rates of nearly 24%.

A major barrier to consistent outcomes has been the lack of a standardized definition for LOD. Subjective "spot-tests" and linear dimensions fail to account for patient morphometry; a 10-cm fascial defect in a lean patient represents a far greater volumetric and physiological mismatch than the same defect diameter in a patient with a large abdominal cavity, particularly when HSV is considered independently of defect width. Preoperative CT volumetry has, therefore, become the diagnostic gold standard. The TI > 25% threshold signals the need for intervention, and the Sabbagh ratio > 20% predicts closure failure. While 3D volume rendering offers the highest accuracy, recent validation of surgeon-friendly 2D linear calculations provides a practical, time-efficient alternative for routine clinical use.

Successful repair is largely determined in the preoperative phase. Prehabilitation involves both systemic optimization and local tissue conditioning. Strict control of modifiable risk factors, especially smoking cessation and glycemic control, is mandatory to reduce SSOs. Locally, BTA has revolutionized management by inducing a chemical component separation, elongating the lateral muscle stack by approximately 4 cm per side. However, BTA addresses compliance rather than volume. For significant volumetric deficits, PPP remains the sole modality capable of actively expanding the abdominal cavity (by up to 53%) and conditioning the diaphragm. The synergistic combination of BTA and PPP has been shown to convert "inoperable" defects into closable domains, achieving primary fascial closure in over 80% of massive hernias. Emerging mechanical adjuncts, including Fasciotens and the domain-expanding effect of prolonged CO_2 pneumoperitoneum during minimally invasive repair (approximately 25% muscle lengthening), offer additional tools for surgeons managing these complex cases, though their precise positioning within management algorithms requires further prospective validation.

The operative strategy must be algorithmically tailored to the volumetric profile. While ACS effectively medializes the rectus abdominis complex, it is associated with high wound morbidity due to extensive subcutaneous dissection. TAR has emerged as the superior alternative for complex repairs. By accessing the retromuscular plane, TAR preserves the neurovascular bundles often sacrificed in anterior approaches and provides a substantial bed for wide mesh overlap. In scenarios where primary closure remains impossible even with adjuncts, staged serial excision offers a pathway to delayed closure, whereas bridging techniques should be reserved as a last resort due to higher complication and bulging rates.

Limitations

This review has several limitations that should be acknowledged. As a narrative review, it is subject to selection bias in the literature included. The heterogeneity in outcome definitions, patient populations, follow-up durations, and measurement methodologies across the included studies precludes quantitative pooling. The volumetric thresholds described (e.g., TI > 25%; Sabbagh ratio > 20%) are derived predominantly from single-center series and retrospective cohorts; prospective multicenter validation of these cutoffs is lacking. Furthermore, the long-term recurrence data beyond 5 years are sparse for many of the techniques discussed, including robotic TAR and combined BTA + PPP protocols. The proposed management algorithm, while evidence-informed, reflects expert opinion as much as high-level evidence, and no randomized controlled trials directly comparing the full spectrum of adjuncts and reconstructive techniques exist to date.

Future directions

While volumetric assessment is the cornerstone of LOD management, current manual methods are time-consuming and prone to interobserver variability. A significant area of future research lies in applying artificial intelligence (AI) to automate this process. Emerging AI models can now segment hernia sacs, abdominal cavities, and muscle variations from standard CT scans with accuracy surpassing that of human manual measurement. Future research must focus on integrating these AI tools into management algorithms to provide real-time, accurate preoperative planning for general surgeons. Furthermore, machine learning algorithms are currently being trained to identify optimal CT findings that can predict not only hernia size but also the specific likelihood of fascial non-closure and postoperative complications, allowing for truly personalized risk stratification.

The transition from open to robotic surgery represents the next technical leap. Early data indicate that robotic TAR significantly reduces the length of stay (median 3 days vs. 5 days) and lowers the rate of SSOs compared to open TAR. However, this comes at the cost of increased operative time and financial burden. There is a lack of high-quality cost-utility analyses to determine whether the savings from reduced hospital stays and wound care offset the upfront costs of the robotic platform. Future studies must address this economic question to justify widespread adoption. Prospective trials evaluating Fasciotens, standardized CO_2 pneumoperitoneum protocols in laparoscopic/robotic settings, and novel biologic mesh materials are also needed to expand the evidence base for emerging adjuncts.

Conclusion

The treatment of CVH with LOD has matured from a technical endeavor focused on mesh placement to a sophisticated science of physiological restoration. The evidence supports three definitive conclusions. First, objective volumetry must replace subjective estimation—the TI and Sabbagh ratio should be calculated from preoperative CT to accurately predict the risk of abdominal compartment syndrome and guide adjunct selection. Second, the synergistic application of BTA and PPP is non-negotiable for massive defects with significant LOD, and emerging adjuncts including Fasciotens and prolonged CO_2 pneumoperitoneum further expand the toolkit available to surgeons. Finally, surgical execution should prioritize neurovascular-preserving techniques like TAR, integrated within a strict ERAS protocol. As the field advances, the integration of AI-driven diagnostics and robotic platforms promises to further reduce morbidity. By adhering to standardized, volume-based algorithms and embracing emerging technologies, surgeons can significantly improve the functional quality of life for this complex patient population.

Author contributions

Both authors contributed equally to the conceptualization, literature review, and writing of this review article.

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Not applicable.

Declaration of patient consent

Not applicable.

Data availability statement

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Conflicts of interest

There are no conflicts of interest.

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