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Robotic Ventral Hernia Repair: Indications and Outcomes

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Abstract

Purpose of Review The landscape of abdominal wall hernia repair has seen significant evolution with the advent of robotic-assisted techniques. This review explores the indications and outcomes of robotic ventral hernia repair (RVHR), highlighting its advantages over conventional approaches.

Recent Findings Comparative studies reveal a notable reduction in surgical site infection rates with RVHR compared to open repair, although findings regarding laparoscopic versus robotic approaches are inconclusive. Operative time tends to be longer in robotic procedures, influenced by factors such as surgeon learning curve and technique complexity. Length of stay is significantly shorter in RVHR compared to open repair, with comparable outcomes to laparoscopic approaches. Readmission and reoperation rates do not significantly differ between robotic and other techniques, while recurrence rates vary across studies. Cost analysis demonstrates higher hospital costs associated with RVHR, albeit with potential cost offsets in post-discharge care.

Summary RVHR presents distinct advantages in minimally invasive hernia repair, offering improved outcomes and enhanced surgical capabilities. Continued research and participation in hernia registries are crucial for advancing patient care and optimizing surgical outcomes in ventral hernia repair.

Keywords Robotic ventral hernia · Outcomes · Ventral hernia · Incisional hernia · Robotic hernia

Introduction

There are over 400,000 surgical procedures performed annually in the US for abdominal wall hernias, which carries significant implications for patient health, functional capacity, and quality of life, as well as health economics. While traditional open repair methods have been extensively employed, the evolution of surgical technology has ushered in minimally invasive techniques that have shown to improve post-operative pain, length of stay, and patient satisfaction [1, 2] Among these advancements, the integration of robotic systems stands out, offering a multitude of technical enhancements such as improved magnification, visibility, dexterity, and maneuverability [3–8]. The introduction of robotic surgery has notably increased the prevalence of abdominal hernia repairs conducted via minimally invasive means [3, 9–11]. However, the clinical efficacy of robotic hernia repair in comparison to laparoscopic or open surgery remains a topic of contention.

This article delves into the indications and outcomes of robotic ventral hernia repair, elucidating its advantages and potential benefits over conventional approaches. Robotic surgery stands as a beacon of advancement in the domain of ventral hernia repair, offering a multitude of compelling advantages. First, robotic procedures epitomize the essence of minimally invasive techniques, characterized by small incisions that minimize trauma to surrounding tissues. This approach not only alleviates postoperative discomfort but also expedites patient recovery, presenting a stark contrast to the prolonged recovery associated with traditional open surgery. Moreover, the robotic system equips surgeons to navigate through complex suturing and reconstruction tasks with heightened ease, thereby enhancing the reproducibility of the repair and reducing the likelihood of complications.

Second, it endows surgeons with an unprecedented level of precision and dexterity, enabling them to perform intricate maneuvers within the confined space of the abdominal

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wall with remarkable accuracy. This precision is further augmented by the system's high-definition 3D visualization capabilities, which provide surgeons with a comprehensive view of the surgical site. Such clarity facilitates meticulous dissection and reconstruction of the abdominal wall, ensuring optimal outcomes for patients.

Lastly, robotic surgery champions improved ergonomics, mitigating the physical strain on surgeons during prolonged procedures. By offering a comfortable and ergonomic operating environment, robotic surgery potentially enables surgeons to maintain peak performance throughout the entirety of the procedure. While approximately 20–27% of ventral hernias are repaired laparoscopically, the challenge continues to lie in closing large defects laparoscopically [12]. This not only leads to mesh eventration through the hernia defect and patient reported heightened acute and chronic pain, but also an increased risk of recurrence [13, 14]. Additionally, the well-documented risks associated with intraperitoneal meshes [15] have prompted surgeons to explore more complex surgical approaches, such as the retromuscular approach, which is difficult in the laparoscopic approach and more often requires an open approach.

One of the most esteemed hernia registries globally is The Danish Hernia Registry, which has profoundly shaped hernia management through its extensive research publications, evidence-based practices, quality enhancement endeavors, guideline formulation, and influential contributions to healthcare policy. Serving as a comprehensive repository of hernia surgery data, patient outcomes, and complication records, it fosters research breakthroughs and in-depth analysis within the field. The registry's insights have not only pioneered evidence-based protocols but also elevated the standard of care, consequently informing pivotal healthcare policies in Denmark. Its pivotal role in optimizing hernia treatment outcomes and propelling healthcare delivery underscores its significance in advancing medical care nationally. Moreover, the American Hernia Society has also initiated its own registry, marking a significant expansion in hernia research and treatment advancements over the past decade.

Indications

Before proceeding with any elective hernia procedure, it is customary to conduct a comprehensive history and physical examination as well as address modifiable risk factors such as diabetes mellitus, obesity, and smoking. However, for robotic hernia surgery, it is essential to also obtain cross sectional imaging with computed tomography because imaging is conducted to ascertain whether there is prior mesh or associated fluid collections, assess multiple concurrent fascial defects, or specify or specify the contents of hernia and the extent and nature of adhesions (such as omentum or bowel). Similar to laparoscopic repair, patients deemed suitable for robotic ventral hernia repair must be medically fit to tolerate the required pneumoperitoneum. The European Hernia Society Classification for ventral and incisional hernias stands as one of the most widely utilized classifications globally. In this context, we will delineate the indications for robotic ventral and incisional hernia repair based on etiology and size.

Primary Ventral Hernia

Small Size Primary Ventral Hernia (< 2 cm)

For small size primary ventral hernias (width < 2 cm), the robotic system offers an effective repair option. Both the Intraperitoneal Onlay Mesh (IPOM) and Transabdominal Preperitoneal (TAPP) techniques have been extensively documented in the literature about safety, effectiveness, and reproducibility.

a. In IPOM procedures, the hernia defect can be closed using barbed sutures, offering a reliable alternative to tacker fixation. This technique also enables the secure suturing of the coated mesh with a consistent and reproducible method.
b. TAPP procedures afford the opportunity to elevate a peritoneal flap, effectively close the hernia defect and the peritoneal flap, and secure uncoated mesh fixation using sutures. This comprehensive approach enhances the durability and integrity of the repair.

Medium Size Primary Ventral Hernia (Width 2–4 cm)

For medium-sized primary ventral hernias (width 2–4 cm), the robotic system presents a viable repair option. Both the IPOM and TAPP techniques have been extensively documented in the literature for their safety and effectiveness. Additionally, the retromuscular (RM) approach may be considered for hernias approaching the upper size limit.

a. In IPOM procedures, the medium size hernia defect can be closed using barbed sutures, in addition to mesh fixation providing a dependable alternative to tackers.
b. TAPP procedures offer the opportunity to elevate a peritoneal flap, effectively closing the hernia defect and the peritoneal flap, and securing uncoated mesh fixation using sutures. However, TAPP might pose challenges in the upper limits of medium size hernias as it requires a larger flap, which can be technically demanding and less reproducible, especially during the early learning curve.

c. RM procedures, whether totally extraperitoneal (TEP) or transabdominal (TA) approaches, may be suitable for larger hernias. The robotic platform facilitates difficult angles in raising the retromuscular flaps on both sides, closing any gaps in the posterior layer, and especially in primary closure of the upper limits of medium size hernia defects. Additionally, it aids in mesh placement and suture fixation, enhancing the overall repair process.

Large Size Primary Ventral Hernia (Width > 4 cm)

For Large-sized primary ventral hernias (width > 4 cm), the robotic system presents a viable repair option. But certain difficulties might challenge specific approaches.

a. In IPOM procedures, the large size hernia defect can be closed using barbed sutures, in addition to mesh fixation providing a dependable alternative to tackers. Often surgeons are faced with limitations related to space that might require additional port placements and redocking.
b. TAPP procedures are considered quite challenging for larger hernias with concerns about reproducibility due to the need to raise a large peritoneal flap. In certain cases, such as sub-xiphoid, or suprapubic where there is abundance of fat it might be feasible and reproducible in addition to lateral hernias.
c. RM procedures, whether totally extraperitoneal (TEP) or transabdominal (TA) approaches, are suitable for large hernias. The robotic platform facilitates difficult angles in raising the retromuscular flaps on both sides, closing any gaps in the posterior layer, and especially in primary closure of the upper limits of medium size hernia defects. Additionally, it aids in mesh placement and suture fixation, enhancing the overall repair process. In certain cases, where there is a loss of the posterior layer.

Primary Incisional Hernia

W1 Incisional Hernia (Width < 4 cm)

W1 hernias may be repaired via IPOM, TAPP, and RM. Incisional hernia might impact the ability to raise preperitoneal flap influencing the ability to perform TAPP due to scar tissue and loss of preperitoneal fat. Longer incisional hernias might favor the RM approach especially in the settings of numerous hernias along the incision.

W2 Incisional Hernia (Width 4-10 cm)

W2 hernias may be repaired either with RM or IPOM. Often such a large size prohibits the possibility to raise preperitoneal flaps as described in TAPP. In other cases, might encounter large gaps in the posterior layer necessitating the additional posterior component separation. Having a longer diameter as well adds more difficulty in regards the IPOM for fixation where in RM approach enables the utilization of the entire retromuscular envelope.

W3 Incisional Hernia (Width > 10 cm)

W3 hernias often repaired with robotic RM or TAR approach either TA or TEP and it is considered the most thought after robotic approach. Reconstructing the midline and reinforcing the visceral sac with large mesh in the extra-peritoneal space. Often lysis of adhesions is an additional step that prolongs the procedure in larger hernias.

Complex Incisional Hernia

Determining the precise proportion of incisional hernia repairs classified as complex poses a challenge. According to the Danish Ventral Hernia Database, approximately 15% of all repairs involved patients with incisional hernias exceeding 15 cm in size [16]. The extensively referenced modified Ventral Hernia Working Group (mVHWG) classification organizes hernia patients into distinct grades based on wound cleanliness and associated risk factors: grade 1 for clean wounds with minimal complication risks, grade 2 for clean wounds with concurrent co-morbidities or past infections, and grade 3 for clean contaminated to dirty wounds [17].

Recognizing the mVHWG's limitations regarding hernia size considerations, the 2018 Dutch guideline on Incisional Hernias recommended transitioning to the Hernia Patient Wound (HPW) classification [18]. This classification, similar to TNM staging, aims to predict postoperative outcomes solely relying on preoperative characteristics. Hernia width (H) is graded as 1 (0–9.9 cm), 2 (10–19.9 cm), or 3 (> 20.0 cm), while patient (P) comorbidities are recorded as absent (0) or present (1) in instances of a BMI > 35 kg/m^2, current nicotine use, diabetes, or immunosuppression. Wound (W) or surgical field cleanliness is assessed as clean (0) or contaminated (1). In addressing complex hernias, HPW stage II–IV Robotic TAR emerges as the primary repair method, often sought after by experienced hernia surgeons [19].

Diastasis Recti

The European Hernia society classified it based on the width of muscle separation, postpregnancy status, and whether there is a concomitant hernia (Type: T1 after pregnancy, T2 with adiposity. Distance as Inter-rectus distance: D1 = 2–3 cm, D2 = 3–5 cm, D3 = > 5 cm. Concomitant Hernia; H0 without, H1 present). In non-obese cases with symptomatic diastasis recti and ventral hernia numerous approaches may be considered. IPOM and TAPP are possible options where the linea alba is plicated with monofilament long lasting absorbable barbed suture with any concomitant ventral hernia in addition to placement of large mesh. Other approach in wider diastasis such as D3, retromuscular TEP with placement of large uncoated mesh covering the entire dissected retromuscular space in addition to repair of the concomitant primary ventral hernia.

Botox Injection

In specific cases involving complex abdominal wall hernias characterized by conditions such as loss of domain due to muscle retraction and extensive defects exceeding 20 cm in width, the strategic incorporation of onabotulinum toxin A (Botox®) has proven successful in enhancing pre-operative planning. This involves employing Botox as a chemical component relaxation technique, inducing paralysis and elongation of lateral abdominal wall muscles by a median of 4 cm.

The procedure entails the administration of 200–300 units of Botox, appropriately diluted in 30 ml of saline, through six targeted injections. These injections are meticulously delivered into both the external and internal oblique muscles at three distinct sites bilaterally, all performed under direct visualization with ultrasound guidance. Typically, patients undergo follow-up within four weeks, during which a repeat CT-scan is conducted to review the hernia volume, and they are subsequently scheduled for definitive robotic hernia repair.

Patients with a history of recurrent incisional hernias face an elevated risk of subsequent failures, underscoring the critical importance of meticulous operative planning. While cross-sectional imaging is valuable for complex repairs, it assumes paramount significance in delineating the existing anatomy in patients with prior failed repairs. Securing operative notes and records of previous interventions beforehand is imperative. Surgical considerations and the localization of prior mesh placements vary based on previous repair approaches. The removal of previously implanted mesh remains a contentious issue. In cases of prior Intraperitoneal Onlay Mesh (IPOM), the mesh often adheres firmly to the peritoneum, posing challenges in separation without risking multiple tears in the posterior flap or compromising posterior reapproximation. Preserving the integrity of the posterior flap is paramount. If feasible, excising prior mesh without compromising flap closure may be pursued; however, if excision jeopardizes flap closure, it should be avoided. Midline mesh excision should ensure unimpeded closure of the anterior midline. Failures in Transversus Abdominis Release (TAR) or retrorectus repairs frequently stem from inadequate mesh coverage or insufficient overlap. This deficiency typically results from inadequate flap dissection. For larger hernias, extending the posterior flap creation to encompass the subxiphoid area and pubic tubercle—commonly underexposed—is recommended. Additionally, generous lateral dissection in the preperitoneal space facilitates proper reinforcement of the visceral sac. Recurrences following complex abdominal wall reconstruction present limited options for repair, often necessitating an Intraperitoneal mesh placement. Understanding the nuances of recurrent incisional hernias is pivotal in tailoring effective surgical strategies.

Robotic Ventral Hernia Techniques

The goal of ventral hernia repair is to provide an excellent and durable repair with low recurrence rate by restoring the function of the abdominal musculature through re-creation and reinforcement of the visceral sac, as well as restoration of the linea alba without bridging of fascia and using mesh as reinforcement. Here a brief overview of the most common robotic ventral hernia approaches within the different layers of the abdominal wall.

Robotic IPOM

The IPOM approach boasts numerous advantages due to its technical simplicity and reproducibility. It emerges as a viable option for ventral hernia repair, especially in cases where prior operations have disrupted anatomical planes, rendering alternative approaches challenging. Patients are positioned supine with arms extended on the operating table under general anesthesia. We prefer accessing the abdomen using a Veress needle inserted at Palmer's point, followed by directed trocar insertion.

Trocar positioning is crucial to allow for full range of motion and anterior abdominal wall suturing. Typically, three trocars are utilized: the camera, in combination with a Maryland bipolar dissector, and the monopolar scissors. Their placement is determined based on the extent of the hernia defect, anticipation of the mesh outline, and anatomical factors potentially hindering free movement of robotic arms during the procedure. To minimize mechanical interference, trocars are spaced at least 6 cm apart. The camera trocar is positioned away from the surgical target to achieve optimal surgical view, ideally 8 cm away from the anticipated mesh edge.

Adhesiolysis may be required for adequate exposure of the hernia defect, with careful tissue handling due to the loss of haptic feedback in robotic surgery. Defects with a diameter of less than 10 cm are usually amenable to primary closure. Intraperitoneal pressure is often reduced to 6 mm Hg. For primary closure of the hernia defect, we employ a long-lasting absorbable barbed suture, following the same guidelines used for laparotomy closure. A tissue-separating mesh is placed in the intraperitoneal onlay position, ensuring a proper overlap in all directions. Mesh fixation to the abdominal wall is achieved using circumferential suture fixation, typically with absorbable suture (2–0) placed around the mesh in a running fashion (Fig. 1).

After completing mesh fixation, the patient-side cart is undocked, trocars removed, and pneumoperitoneum released.

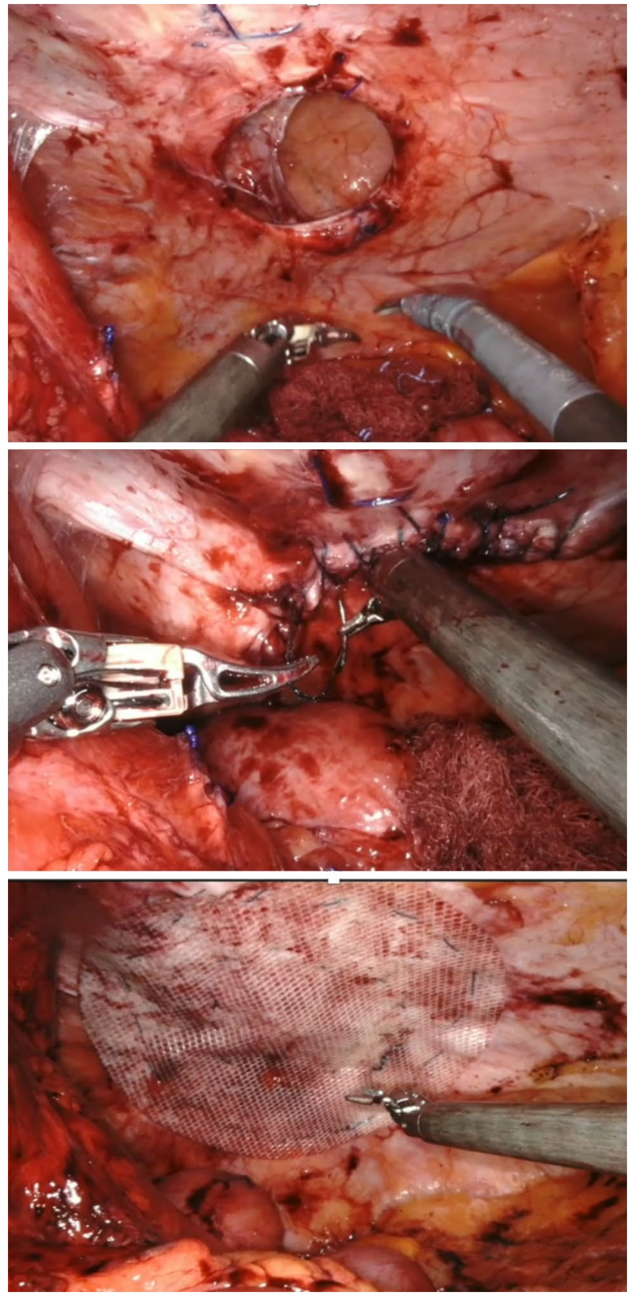

Fig. 1 Robotic IPOM approach for recurrent incisional hernia. Demonstrating hernia defect and lysis of adhesions with proper space for the mesh overlap, followed by defect closure with barbed sutures, coated mesh placement, with running absorbable sutures

Robotic TAPP

The TAPP repair involves positioning the mesh within a pocket created between the posterior rectus fascia and the peritoneum. This technique ensures coverage of the mesh by the peritoneal lining, safeguarding the viscera from direct contact. Notably, it eliminates the necessity for specialty coated meshes. The patient preparation, positioning, initial access, trocar placement, and adhesiolysis closely mirror the procedures described earlier.

Utilizing monopolar scissors and a bipolar Maryland dissector, the peritoneum is grasped and cut on the side ipsilateral to the trocars, creating the preperitoneal space. Any tears in the peritoneum during flap dissection are repaired using interrupted absorbable sutures at the conclusion of the case. The preperitoneal dissection extends circumferentially around the hernia defect, ensuring adequate overlap.

Closure of the hernia defect employs a barbed suture, following the technique described in the IPOM approach, with measurements confirmed by a ruler. Once the noncoated mesh is introduced into the abdominal cavity through a trocar, it is unfolded in the preperitoneal space, flush with the surrounding tissue. Subsequently, it is secured circumferentially to the posterior fascia using a barbed absorbable suture. After achieving adequate mesh fixation and controlling any bleeding, attention shifts to the closure of the peritoneal flap, for which a rapidly absorbable barbed suture may be employed. Ensuring the peritoneal flap adequately covers the mesh at the conclusion of the procedure is crucial to protect the viscera from direct exposure.

Robotic RM

The RM repair, originally described by Rives-Stoppa, gained popularity due to its underlay repair technique, reinforcing the repair with abdominal pressure while excluding the mesh from the abdominal cavity, thus protecting the viscera. For the enhanced-view totally extraperitoneal (eTEP) approach, the RM space is accessed directly, avoiding abdominal cavity entry. Ports are placed between the posterior rectus sheath and the rectus muscle, using an optical view port initially to establish pneumoperitoneum and entry into the working space.

The midline is approached as the ipsilateral RM space is opened to create a pedicled flap. At the medial border of the rectus, the posterior rectus sheath is incised a cm or more away from linea alba, entering the preperitoneal space as the midline is crossed to the contralateral side. Once the contralateral rectus muscle's medial border is noted, the RM space is re-entered, and the flap is completed on the contralateral side (Fig. 2). The hernia is reduced, and the defect is then closed using an absorbable barbed suture in a shoelace fashion (Figs. 3, 4). An uncoated mesh is introduced to occupy the RM pocket.

During dissection, it is crucial to meticulously identify and preserve the neuromuscular bundles and inferior epigastric vessels to prevent inadvertent injuries. Additionally, a thorough examination of the posterior layer towards the conclusion of the surgery is vital to prevent further disruption, which could potentially result in internal herniation and small bowel obstruction.

Robotic TAR

The primary goal of TAR is to extend the dissection plane beyond the confines of the rectus sheath to allow for larger mesh placement, thereby enabling increased posterior fascial advancement to reinforce the visceral sac (Fig. 5). However, a notable drawback is the potential risk of injury to the neurovascular bundles and to linea semilunaris. Upon establishing pneumoperitoneum, three of six trocars are laterally placed along the anterior axillary line.

Exposure of the defect progresses as previously described, and retromuscular dissection commences from the contralateral medial edge of the rectus sheath. This dissection is then extended laterally to the semilunar line, superiorly to the central tendon of the diaphragm, and inferiorly to expose the pubic tubercle. As the dissection nears the lateral border of the rectus sheath, the transversus abdominis fascia and muscle are encountered, and the muscle insertion is divided just medial to the rectus sheath border, thereby gaining entry to the preperitoneal plane while preserving the neurovascular bundles (Figs. 6, 7). Authors typically initiate release of the transversus fascia at the caudal aspect, just lateral to the arcuate line, facilitating the correct identification of the appropriate plane.

Continuing the dissection cephalad, division of the posterior lamella of the internal oblique aponeurosis exposes the medial fibers of the transversus abdominis muscle on the posterior rectus sheath, which are similarly released. The preperitoneal dissection is then extended laterally to approximately the midaxillary line, completing the mobilization of the posterior rectus sheath.

Following the measurement of the posterior flap dimensions for mesh selection, the mesh is shaped to cover the entire length of the dissected pocket, rolled along its longitudinal axis, and introduced into the abdominal cavity.

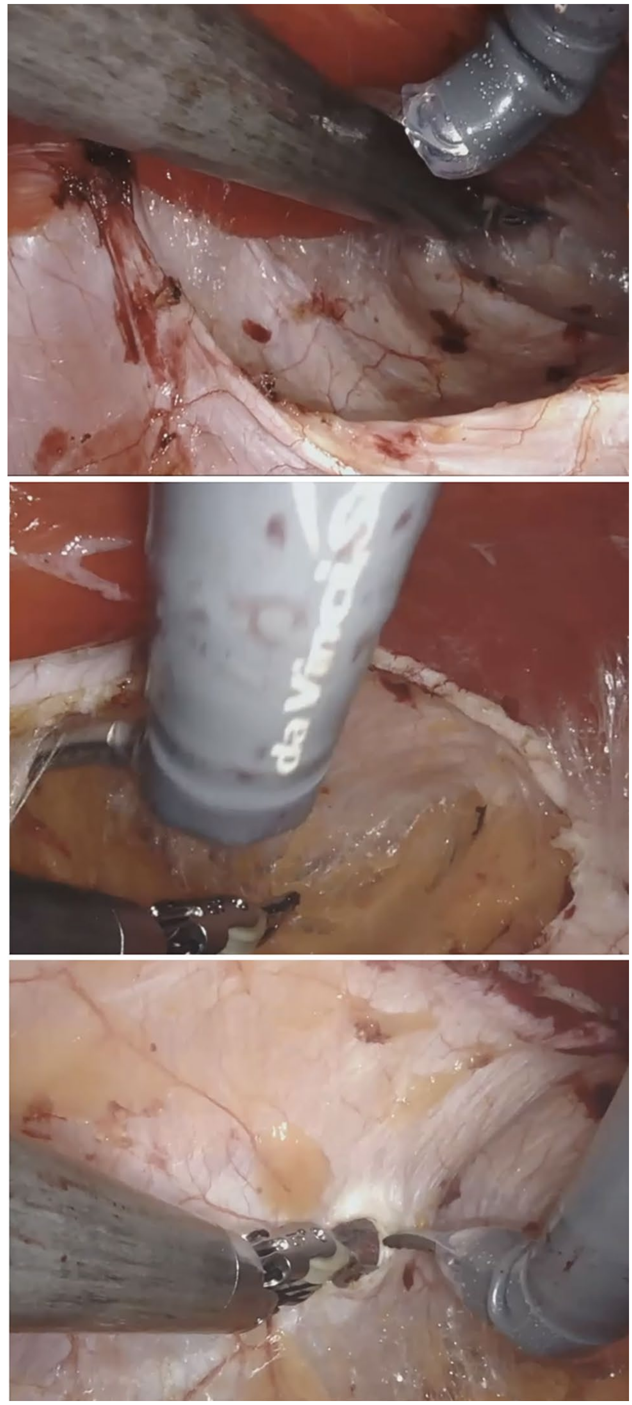

Fig. 2 The retromuscular space created via eTEP approach by delineating the rectus muscle superiorly and posterior rectus sheath inferiorly. Followed by dividing the medial edge of the posterior rectus sheath. Followed by crossing over in the preperitoneal then incising the contralateral medial edge of the posterior rectus sheath in order to enter the contralateral retromusclar space

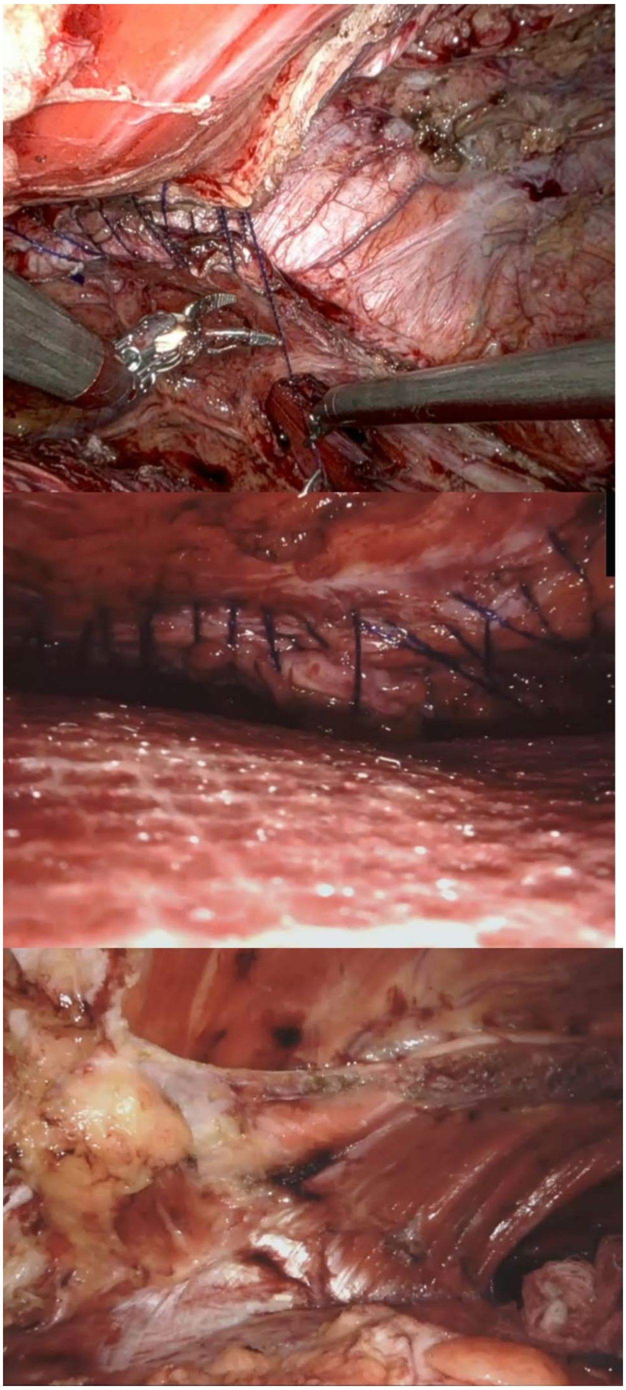

Fig. 3 Images demonstrating the complete cephalad dissection after TAR with the focus on the central tendon view, followed by the recurrent incisional hernia defect closure with barbed sutures, mesh reinforcement with uncoated 40 × 30 cm Syneco-Pre™ (Gore, DE)

Subsequently, three trocars are directly inserted into the contralateral anterior axillary line. The robot is then redocked, and the dissection of the opposite retromuscular flap and TAR are performed as previously described.

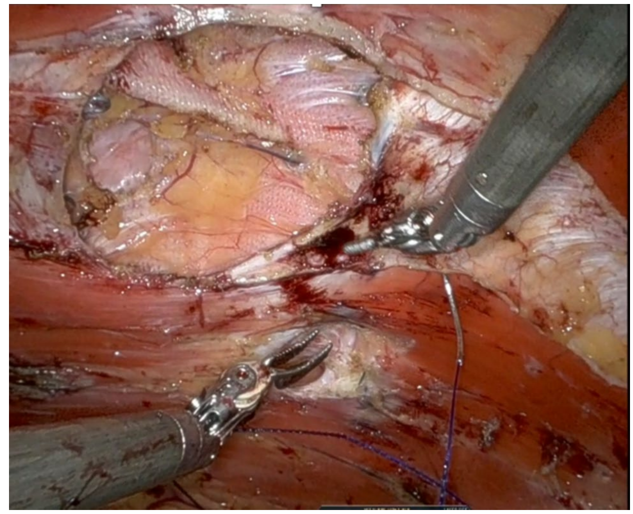

Fig. 4 Robotic Retromuscular Recurrent Incisional Hernia Repair demonstrating the view of a recurrent incisional hernia with mesh migrating within hernia defect, tackers within the hernia defect and previously placed permanent sutures

Upon completion of flap dissection, the initially placed trocars are brought into the preperitoneal space, and resulting defects are closed with absorbable suture. The midline posterior sheath is closed using a 2–0 absorbable barbed suture in a running fashion. The pneumoperitoneum level is then lowered to between 6 mmHg. The hernia defect is closed using a 0 absorbable barbed suture. All these closures are facilitated by reducing the level of pneumoperitoneum to 6 mmHg or less. The mesh is deployed and secured to the contralateral abdominal wall with absorbable sutures.

Hybrid Robotic Ventral Hernia Repair

The Hybrid approach has been embraced for the management of large and complex incisional ventral hernias, which pose challenges in terms of closing massive hernia defects and deploying mesh effectively. Additionally, it expedites operative times, particularly in lengthy procedures involving extensive enterolysis and mesh removal. This hybrid approach combines the precision of robotic dissection and component separation with the efficacy of open fascial defect closure and mesh deployment (Fig. 8). When compared with open repair, hybrid robotic ventral hernia repair has been shown to achieve

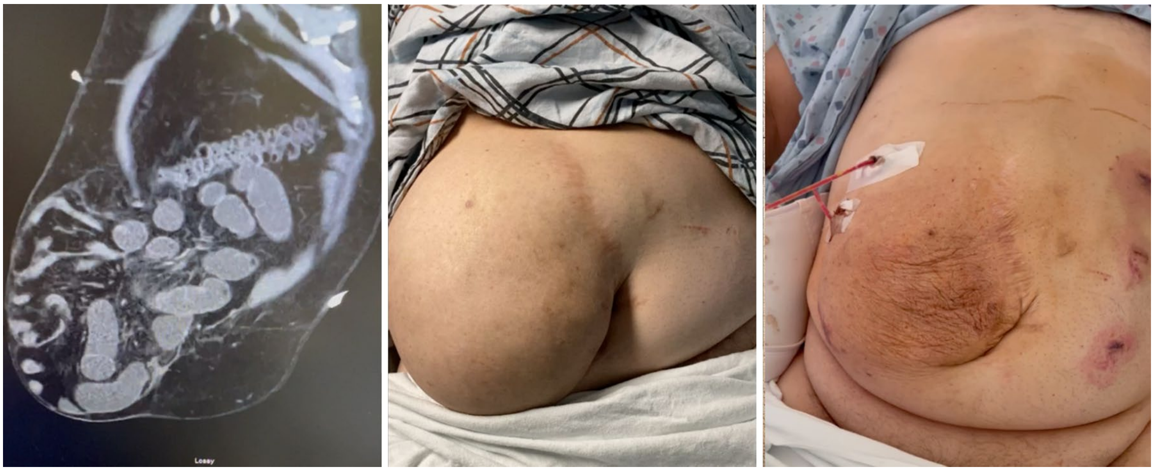

Fig. 5 Recurrent Incisional hernia in a obese patient with loss of domain. Images portraying the loss of domain and the amount of visceral contents outside the peritoneal cavity, followed by external view of preoperative abdominal view and immediate post robotic TAR

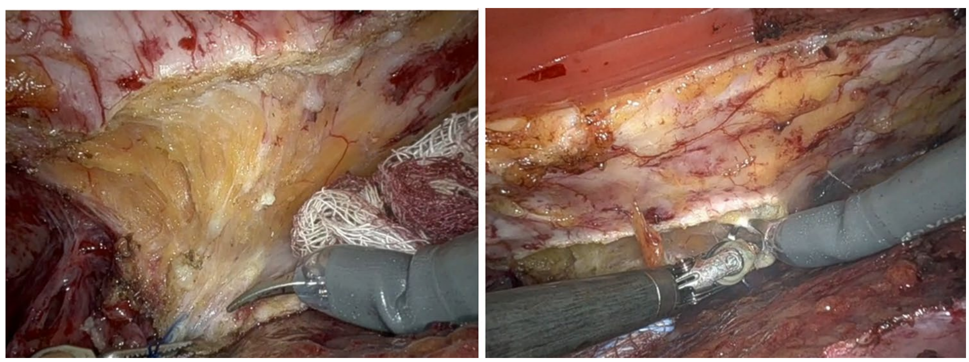

Fig. 6 Intra-operative images of robotic TAR for a large recurrent incisional hernia with absence of rectus muscle after Transversus Rectus Abdominal Muscle Flap

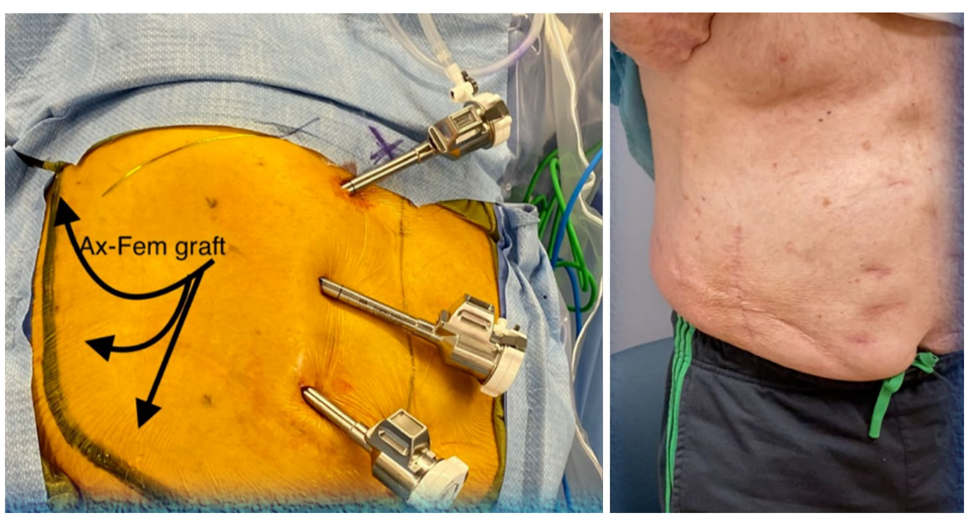

Fig. 7 Intra-operative and post-operative images of TEP TAR for Complex Lateral Incisional Hernia in the presence of Ax-Fem Bypass

Fig. 8 Complex Incisional Hernia (Pre and post operative images of Lateral incisional hernia width larger than 10 cm, close to a bony structure undergoing robotic hybrid TAR)

shorter length of hospital stay (LOS) with similar rates of complication and wound morbidity.

Outcomes

Surgical Site Infections

A wealth of evidence underscores the significant reduction in surgical site infection (SSI) rates observed in Robotic Ventral Hernia Repair (RVHR) compared to Open Ventral Hernia Repair (OVHR) [5, 20–29]. However, when comparing laparoscopic and robotic approaches, several studies have found no statistically significant difference in SSI rates [23, 30–37]. Although most articles report no variance in SSI rates between robotic and laparoscopic approaches, two studies have indicated a notably lower SSI rate in RVHR compared to Laparoscopic Ventral Hernia Repair (LVHR) [38, 39]. Notably, Gaskins et al. discovered that RVHR was associated with reduced SSI rates in obese patients with a history of current smoking or diabetes [20]. In the realm of abdominal wall reconstruction, OVHR remains the conventional approach for most surgeons. Due to ergonomic limitations in laparoscopy, there has been a dearth of comparative studies between robotic and laparoscopic Transversus Abdominis Release (TAR). While two studies reported an equal SSI rate [22, 40], three studies demonstrated a significantly lower SSI rate in robotic TAR compared to open TAR [24, 29, 41].

Bleeding

Patients undergoing robotic hernia surgery while on antithrombotic medications, such as anticoagulants and antiplatelets, pose a significant challenge for perioperative management due to the delicate balance between the risk of bleeding complications and thrombotic events. Our research has shed light on this issue, revealing that patients on antithrombotics face a heightened risk of bleeding-related events, notably postoperative hematomas, and encounter more severe complications and higher morbidity scores compared to those not on antithrombotics. Specifically, anticoagulants like warfarin and novel oral anticoagulants (NOACs) were found to be associated with an elevated risk of bleeding-related complications, while no such association was observed with antiplatelet therapy. Moreover, the combination of older age and anticoagulation therapy significantly amplifies the risk of postoperative bleeding and thromboembolic events. Encouragingly, antiplatelet therapy did not adversely affect postoperative outcomes. Additionally, our study did not identify any significant association between specific surgical techniques and bleeding-related events. These findings underscore the importance of tailored perioperative management strategies for patients on antithrombotic medications undergoing robotic hernia surgery [42].

Operative Time

A literature review reveals that operative time (OT) for robotic surgery exceeds that of open and laparoscopic approaches. This extended OT can be attributed to factors such as the surgeon's learning curve, operating room staff adapting to robotic surgery, and the time required for docking and undocking. Surgeons incorporating the robotic platform into their hernia practice should be cognizant of the associated learning curves for IPOM, TAPP, RM, and TAR [42–46].

On the other hand, the hybrid technique combines the precision of robotic dissection and component separation with the efficacy of open fascial defect closure and mesh deployment. In a study by Halka et al., comparing hybrid TAR versus robotic TAR (rTAR), among 25 patients in the hybrid TAR group, the mean defect width was 14.24 cm, with an average procedure time of 344 min. Conversely, in our study, the mean defect size was 15.9 cm and a mean LOS of 1.8 days [47].

Length of Stay

Additionally, research indicates that RVHR is linked to a significantly shorter Length of Stay (LOS) compared to OVHR [5, 21–29, 40], with no significant differences observed when compared to LVHR [23, 30–39]. Studies have also shown that robotic RM VHR results in a significantly shorter LOS compared to laparoscopic IPOM repair [36, 48, 49]. In the RM VHR technique, the mesh is placed in the retromuscular area without fascial fixation. Conversely, in the IPOM technique, the mesh is affixed to the fascia using a tacker, potentially contributing to pain leading to longer hospital LOS.

Readmissions and Re-operations

Data from various studies have shown no significant difference in 30-day readmission and reoperation rates for RVHR, LVHR, and OVHR [23, 30, 31, 34, 39]. In terms of recurrence rates, the literature reports an average follow-up period for RVHR ranging from 3 to 39.2 months, with recurrence rates within this timeframe varying from 0 to 12% [50–57]. To note, LVHR exhibits a reoperation rate ranging from 2 to 11% [30, 31, 34]. While six studies found no differences in recurrence rates between RVHR and LVHR [13, 33, 34, 36, 39, 58], one study indicated a lower recurrence in RVHR compared to LVHR [38], and another reported a lower recurrence rate for RVHR compared to OVHR [25].

In our study, the robotic group had longer operative times, possibly due to the nature of the repairs and the techniques used. Hospital LOS were affected by various factors, including comorbidities, surgical techniques, and hernia complexity. Data on MIS in both elective and emergent ventral hernia repair demonstrate decreased LOS compared to conventional open methods. However, our study did not find any difference in LOS between groups. Robotic repair, although associated with fewer overall complications, did not significantly differ in recurrence rates or LOS compared to open repair. Our study highlights the importance of procedure selection for EVHR patients based on surgeon experience, resource availability, and patient factors [26].

Cost

Additionally, most published studies demonstrated higher total hospital costs for RVHR compared to both LVHR and OVHR [25, 30, 35, 39, 59], while one study reported similar direct hospital costs for RVHR and LVHR [31]. Kudsi et al. found that increased hospital costs associated with RVHR were offset by reduced post-discharge costs compared to OVHR, resulting in no significant difference in total costs [25].

Other Fields

The role of robotic surgery in emergency hernia repair is not well-established, with safety information mostly extrapolated from elective literature. Despite encouraging results for laparoscopic surgery, its implementation in emergency ventral hernia repair (EVHR) lags behind open approaches. There is no consensus on the best approach for EVHR, and surgical options should be tailored on a case-by-case basis. One drawback of MIS is prolonged operative times compared to open surgery.

Although guidelines for laparoscopic hernia repair have incorporated recommendations for robotic repair, specific guidance for the obese population is lacking. Studies have evaluated the outcomes of RVHR in morbidly obese patients, demonstrating favorable perioperative and mid-term outcomes with low complication rates and minimal hernia recurrence. Additionally, the impact of obesity on postoperative outcomes in RVHR has been investigated, with findings suggesting that a BMI $\geq$ 35 does not significantly affect short-term outcomes [60].

Conclusion

In conclusion, robotic ventral hernia repair stands as a promising advancement in minimally invasive surgery, bringing forth distinct advantages tailored to specific patient populations that benefit from enhanced exposure as in an open repair and smaller incisions as in a laparoscopic repair. It is versatile in addressing a wide range of ventral hernias, which positions it as a valuable tool in the arsenal of hernia surgeons. Patients with highly significant unfavorable factors should seek treatment from experienced robotic hernia surgeons to optimize intra-operative and postoperative complication rates, as well as complication-related re-operation rates. We also encourage participation in the Hernia Registry as it presents a unique opportunity to gather data and benchmark against other historical modalities, fostering ongoing improvements in patient care and surgical outcomes. By embracing these principles and leveraging the capabilities of robotic surgery, we can continue to advance patient care in the realm of ventral hernia repair.

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Data Availability No datasets were generated or analysed during the current study.

Declarations

Conflict of interest Dr. Aghayeva and Dr. Neiman have no conflict of interest. Dr. Kudsi received funding from Gore and Intuitive outside this review paper.

Ethical Approval All procedures performed in the study involving human participants were following the ethical standards of the institutional and/or national research committee. The presented data within the scope of this study only involved a retrospective review of medical records. That allows for such reviews if the confidentiality of the patient's data and her identity are protected. Informed consent was obtained. The study protocol was approved by the Institutional Review Board.

Research Involved in Human and Animal Participants All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

References

1. LeBlanc KA, Booth WV. Laparoscopic repair of incisional abdominal hernias using expanded polytetrafluoroethylene: preliminary findings. Surg Laparosc Endosc. 1993;3(1):39–41.
2. Ramshaw BJ, Esartia P, Schwab J, et al. Comparison of laparoscopic and open ventral herniorrhaphy. Am Surg. 1999;65(9):827–31.
3. Kudsi OY, McCarty JC, Paluvoi N, Mabardy AS. Transition from laparoscopic totally extraperitoneal inguinal hernia repair to robotic transabdominal preperitoneal inguinal hernia repair: a retrospective review of a single surgeon's experience. World J Surg. 2017;41:2251–7.
4. Ye L, Childers CP, de Virgilio M. Clinical outcomes and cost of robotic ventral hernia repair: systematic review. BJS Open. 2021;5:zrab098.
5. Collins CE, Renshaw S, Huang LC. Robotic vs open approach for older adults undergoing retromuscular ventral hernia repair. Ann Surg. 2023;277(4):697–703.
6. Charles EJ, Mehaffey JH, Tache-Leon CA. Inguinal hernia repair: is there a benefit to using the robot? Surg Endosc. 2018;32:2131–6.
7. Kolachalam R, Dickens E, D'Amico L. Early outcomes of robotic-assisted inguinal hernia repair in obese patients: a multi-institutional, retrospective study. Surg Endosc. 2018;32:229–35.
8. Bittner Iv JG, Cesnik LW, Kirwan T. Correction to: patient perceptions of acute pain and activity disruption following inguinal hernia repair: a propensity-matched comparison of robotic-assisted, laparoscopic, and open approaches. J Robot Surg. 2019;13:191.
9. Sanchez A, Rodriguez O, Jara G. Robot-assisted surgery and incisional hernia: a comparative study of ergonomics in a training model. J Robot Surg. 2018;12:523–7.
10. Prabhu AS, Dickens EO, Copper CM. Laparoscopic vs robotic intraperitoneal mesh repair for incisional hernia: an Americas hernia society quality collaborative analysis. J Am Coll Surg. 2017;225:285–93.
11. Bittner JGT, Alrefai S, Vy M. Comparative analysis of open and robotic trans- versus abdominis release for ventral hernia repair. Surg Endosc. 2018;32:727–34.
12. Tsui C, Klein R, Garabrant M. Minimally invasive surgery: national trends in adoption and future directions for hospital strategy. Surg Endosc. 2013;27:2253–7.
13. Liang MK, Clapp M, Li LT. Patient satisfaction, chronic pain, and functional status following laparoscopic ventral hernia repair. World J Surg. 2013;37:530–7.
14. Booth JH, Garvey PB, Baumann DP. Primary fascial closure with mesh reinforcement is superior to bridged mesh repair for abdominal wall reconstruction. J Am Coll Surg. 2013;217:999–1009.
15. Miserez M, Lefering R, Famiglietti F. Synthetic versus biological mesh in laparoscopic and open ventral hernia repair (LAPSIS): results of a multinational, randomized, controlled, and double-blind. Trial Ann Surg. 2021;273(1):57–65.
16. Helgstrand F, Rosenberg J, Kehlet H, Jorgensen LN, Bisgaard T. Nationwide prospective study of outcomes after elective incisional hernia repair. J Am Coll Surg. 2013;216(2):217–28.
17. Kanters AE, Krpata DM, Blatnik JA, Novitsky YM, Rosen MJ. Modified hernia grading scale to stratify surgical site occurrence after open ventral hernia repairs. J Am Coll Surg. 2012;215(6):787–93.
18. Working group Incisional Hernias. National Guideline for Treatment of Incisional Ventral Hernias. https://richtlijnendatabasenl/richtlijn/littekenbreuken/startpagina_-_littekenbreukenhtml#algemeen. 2018.
19. Parker SG, Halligan S, Liang MK, Muysoms FE, Adrales GL, Boutall A, et al. Definitions for loss of domain: an international Delphi consensus of expert surgeons. World J Surg. 2020;44(4):1070–8.
20. GaskinsJ Huang LI, McPhail L, O'Connor S. Robotic approach for retromuscular ventral hernia repair may be associated with improved wound morbidity in high-risk patients: a propensity score analysis. Surg Endosc. 2023. https://doi.org/10.1007/s00464-023-10630-9. (**This article underscored the significance of employing a robotic approach for retromuscular ventral hernia repair, particularly in high-risk patients**).
21. Nguyen B, David B, Shiozaki T. Comparisons of abdominal wall reconstruction for ventral hernia repairs, open versus robotic. Sci Rep. 2021;11(1):8086.
22. Bittner JG 4th, Alrefai S, Vy M. Comparative analysis of open and robotic transversus abdominis release for ventral hernia repair. Surg Endosc. 2018;32(2):727–34.
23. LeBlanc KA, Gonzalez A, Dickens E, Prospective Hernia Study Group. Robotic-assisted, laparoscopic, and open incisional hernia repair: early outcomes from the prospective hernia study. Hernia. 2021;25(4):1071–82 (**Multicenter prospective observational study from 17 medical institutions within the United States evaluating robotic, laparoscopic and open incisional hernia repair and revealed short-term outcomes indicate that open, laparoscopic, and robotic-assisted approaches are effective surgical approaches to VIH repair; however, each repair technique may demonstrate advantages in terms of clinical**

outcomes. Beside they found that operation time in the robotic vs open comparison is similar).
24. Dewulf M, Hiekkaranta JM, Mäkäräinen E. Open versus robotic-assisted laparoscopic posterior component separation in complex abdominal wall repair. BJS Open. 2022;6(3):zrac057.
25. Kudsi OY, Kaoukabani G, Bou-Ayash N. A comparison of clinical outcomes and costs between robotic and open ventral hernia repair. Am J Surg. 2023;226(1):87–92 (**In this study, it was shown that the costs were equally distributed in robotic and open ventral hernia repair groups. Their findings indicated that lower postoperative complications resulted in reduced post-discharge expenses, ultimately leading to comparable total costs between the two groups**).
26. Kudsi OY, Gokcal F, Bou-Ayash N, Chang K. Comparison of midterm outcomes between open and robotic emergent ventral hernia repair. Surg Innov. 2021;28(4):449–57.
27. Guzman-Pruneda FA, Huang LC, Collins C. Abdominal core quality of life after ventral hernia repair: a comparison of open versus robotic-assisted retromuscular techniques. Surg Endosc. 2021;35(1):241–8.
28. Carbonell AM, Warren JA, Prabhu AS. 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(2):210–7.
29. Abdu R, Vasyluk A, Reddy N. Hybrid robotic transversus abdominis release versus open: propensity-matched analysis of 30-day outcomes. Hernia. 2021;25(6):1491–7.
30. Olavarria OA, Bernardi K, Shah SK. Robotic versus laparoscopic ventral hernia repair: multicenter, blinded randomized controlled trial. BMJ. 2020;370: m2457.
31. Dhanani NH, Olavarria OA, Holihan JL. Robotic versus laparoscopic ventral hernia repair: two-year results from a prospective, multicenter, blinded randomized clinical trial. Ann Surg. 2023;278(2):161–5 (**This study was prospective, multicenter, blinded randomized clinical trial. They found that robotic ventral hernia repair demonstrated at least similar if not improved outcomes at 2 years compared with laparoscopy. There is potential benefit with robotic repair**).
32. Petro CC, Thomas JD, Tu C. Robotic vs laparoscopic ventral hernia repair with intraperitoneal mesh: 1-year exploratory outcomes of the PROVE-IT randomized clinical trial. J Am Coll Surg. 2022;234(6):1160–5.
33. Gonzalez AM, Romero RJ, Seetharamaiah R. 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;11(2):120–5.
34. Dhanani NH, Olavarria OA, Holihan JL. Robotic versus laparoscopic ventral hernia repair: one-year results from a prospective, multicenter, blinded randomized controlled trial. Ann Surg. 2021;273(6):1076–80.
35. Petro CC, Zolin S, Krpata D. Patient-reported outcomes of robotic vs laparoscopic ventral hernia repair with intraperitoneal mesh: the PROVE-IT randomized clinical trial. JAMA Surg. 2021;156(1):22–9.
36. Warren JA, Cobb WS, Ewing JA, Carbonell AC. Standard laparoscopic versus robotic retromuscular ventral hernia repair. Surg Endosc. 2017;31(1):324–32.
37. Chen YJ, Huynh D, Nguyen S. Outcomes of robot-assisted versus laparoscopic repair of small-sized ventral hernias. Surg Endosc. 2017;31(3):1275–9.
38. Walker PA, May AC, Mo J. Multicenter review of robotic versus laparoscopic ventral hernia repair: is there a role for robotics? Surg Endosc. 2018;32(4):1901–5.
39. Lu R, Addo A, Ewart Z. Comparative review of outcomes: laparoscopic and robotic enhanced-view totally extraperitoneal (eTEP) access retrorectus repairs. Surg Endosc. 2020;34(8):3597–605.
40. Halka JT, Vasyluk A, Demare A. Hybrid robotic-assisted transversus abdominis release versus open transversus abdominis release: a comparison of short-term outcomes. Hernia. 2019;23(1):37–42.
41. Dauser B, Hartig N, Elisabeth Vedadinejad M, Kirchner Florian Trummer, Herbst Friedrich. Robotic-assisted repair of complex ventral hernia: can it pay off? J Robot Surg. 2021;15(1):45–52.
42. Kudsi OY, Kaoukabani G, Bou-Ayash N, et al. Do blood thinners have an impact on the clinical outcomes of robotic ventral hernia repair. Am J Surg. 2023;226(2):213–7. https://doi.org/10.1016/j.amjsurg.2023.04.007.
43. Kudsi OY, Gokcal F, Bou-Ayash N, et al. Learning curve in robotic transabdominal preperitoneal (rTAPP) ventral hernia repair: a cumulative sum (CUSUM) analysis. Hernia. 2020. https://doi.org/10.1007/s10029-020-02228. (**Important study to show learning curve analysis in complicated procedure for ventral hernia repair**).
44. Kudsi OY, Gokcal F, Bou-Ayash N, et al. Learning curve in robotic primary ventral hernia repair utilizing intraperitoneal onlay mesh: a cumulative sum (CUSUM) analysis. Surg Laparosc Endosc Percutan Tech. 2020;31(3):346–55. https://doi.org/10.1097/SLE.0000000000000885.
45. Kudsi OY, Bou-Ayash N, Gokcal F, et al. Learning curve of robotic Rives-Stoppa ventral hernia repair. A cumulative sum (CUSUM). J Laparoendosc Adv Surg Tech A. 2021;31(7):756–64. https://doi.org/10.1089/lap.2020.0624.
46. Kudsi OY, Gokcal F, Bou-Ayash N, Crawford AS. Learning curve of robotic transversus abdominis release in ventral hernia repair: a cumulative sum (CUSUM) analysis. Surg Endosc. 2022;36(5):3480–8. https://doi.org/10.1007/s00464-021-08669-7. (**Important study to show learning curve analysis in very complicated procedure like TAR for ventral hernia repair**).
47. Kudsi OY, Bou-Ayash Chang K, N, et al. Hybrid robotic hernia repair for incisional hernias: perioperative and patient reported outcomes. J Laparoendosc Adv Surg Tech A. 2021;31(5):570–8. https://doi.org/10.1089/lap.2020.0657.
48. Christoffersen MW, Jørgensen LN, Jensen KK. Less postoperative pain and shorter length of stay after robot-assisted retrorectus hernia repair (rRetrorectus) compared with laparoscopic intraperitoneal onlay mesh repair (IPOM) for small or medium-sized ventral hernias. Surg Endosc. 2023;37:1053–9.
49. Zayan NE, Meara MP, Schwartz JS, Narula VK. A direct comparison of robotic and laparoscopic hernia repair: patient-reported outcomes and cost analysis. Hernia. 2019;23:1115–21.
50. Morrell ALG, Morrell AC, Cavazzola LT. Robotic assisted eTEP ventral hernia repair: Brazilian early experience. Hernia. 2021;25(3):765–74.
51. Sharbaugh ME, Patel PB, Zaman JA. Robotic ventral hernia repair: a safe and durable approach. Hernia. 2021;25(2):305–12 (**Good article that evaluate long term result of robotic ventral hernia repair and found that robotic ventral hernia repair was safe and durable with a low recurrence rate at a mean of 21 months**).
52. Kudsi OY, Kaoukabani G, Bou-Ayash N, Gokcal F. Robotic ventral hernia repair and concomitant procedures: mid-term outcomes and risk factors associated with postoperative complications. Surg Laparosc Endosc Percutan Tech. 2023;33(1):27–30.
53. Oviedo RJ, Robertson JC, Desai AS. Robotic ventral hernia repair and endoscopic component separation: outcomes. JSLS. 2017;21(3):e2017.00055.
54. Kudsi OY, Gokcal F. Lateral approach totally extraperitoneal (TEP) robotic retromuscular ventral hernia repair. Hernia. 2021;25(1):211–22.

55. Orthopoulos G, Kudsi OY. Feasibility of robotic-assisted transabdominal preperitoneal ventral hernia repair. J Laparoendosc Adv Surg Tech A. 2018;28(4):434–8.
56. Kudsi OY, Kaoukabani G, Bou-Ayash N. Quality of life and surgical outcomes of robotic retromuscular ventral hernia repair using a new hybrid mesh reinforcement. Hernia. 2022;26(3):881–8.
57. Olivier F, Abasbassi M, Geers J. Robotic retromuscular abdominal wall repair using an inverted TEP (iTEP) approach: surgical technique and short-term outcomes. Langenbecks Arch Surg. 2022;407(5):2177–86.
58. Petro CC, Maskal SM, Renton DB. Robotic enhanced-view totally extraperitoneal vs intraperitoneal onlay mesh evaluation: 1-year exploratory outcomes of the REVEAL randomized clinical trial. J Am Coll Surg. 2023;237(4):614–20.
59. Costa TN, Tustumi F, Ferros LSM. Robotic-assisted versus laparoscopic incisional hernia repair: differences in direct costs from a Brazilian public institute persoective. Arq Bras Cir Dig. 2023;35:e1714.
60. Kudsi OY, Gokcal F, Chang K. Propensity score matching analysis of short-term outcomes in robotic ventral hernia repair for patients with a body mass index above and below 35 kg/m^2. Hernia. 2021;25(1):115–23 (**This article was notable for assessing the significance of robotics in patients who are obese**).