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Review Article

# Bilateral transversus abdominis release: Complex hernia repair without sacrificing quality of life

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ABSTRACT

*Background:* Transversus Abdominis Release (TAR) during ventral hernia repair (VHR) allows for further lateral dissection by dividing the transversus abdominis muscles (TAM). The implications of division of the TAM on clinical and patient-reported outcomes has not be extensively studied.
*Methods:* Adult patients undergoing retrorectus (RR) VHR with biosynthetic mesh with or without bilateral TAR were retrospectively identified. Post-operative and patient-reported outcomes (PROs) were collected.
*Results:* Of 50 patients, 24 underwent TAR and 26 had RR repair alone. Median defect sizes were 449 $cm^2$ and 208 $cm^2$, respectively ($p < 0.001$). Rates of SSO and SSI were similar ($p > 0.05$). One TAR patient (4.2%) and four RR patients (15.4%) recurred ($p = 0.26$), with median follow up of 24 and 38 months. PROs improved significantly in both groups ($p < 0.05$).
*Conclusion:* Despite more complex abdominal wall reconstruction on larger defects, TAR has minimal major adverse events, low recurrence rates, and does not negatively affect PROs.


## Introduction

Ventral hernia (VH) is a common yet complex problem, and methods to enable durable repair are constantly evolving. Nearly 3 decades ago, Rives and Stoppa detailed a technique for ventral hernia repair (VHR) that involved placing a sublay piece of mesh between the rectus muscle and the posterior rectus sheath.[1] Unfortunately, in order to preserve the segmental innervation of the rectus muscle, dissection and fascial release is limited, making this procedure less successful for large hernia defects.[2] Open anterior component separation (ACS) herniorrhaphy was initially described by Ramirez et al. as a means to bridge the fascial gap in larger hernias by separating and releasing the external oblique muscle and fascia.[3,4] The need for creation of large skin flaps with ACS, however, has been associated with significant wound morbidity.[5,6] To overcome the limitations and morbidity of traditional retrorectus repair (RR) and ACS, respectively, posterior component separation (PCS) with transversus abdominis release (TAR) was developed and introduced by Novitsky et al., in 2012.[7]

TAR is a relatively novel abdominal wall repair technique that allows for a further lateral dissection by dividing the posterior lamella of the internal oblique and the transversus abdominus muscle (TAM). This creates a pre-peritoneal plane above the transversalis fascia for mesh placement, while avoiding an extensive subcutaneous dissection and the creation of large skin flaps.[7–10] Several studies have demonstrated favorable outcomes with low two-year hernia recurrence rates and acceptable wound complication rates.[2,5,8,11–13] However, despite its theoretical

*Abbreviations:* Transversus abdominus Release, (TAR); Transversus abdominus muscles, (TAM); Patient reported outcomes measure, (PROMs); Retromuscular repair, (RMR); Poly-4-hydroxybutyrate, (P4HB); Surgical site occurrences, (SSO); Surgical site infections, (SSI); Abdominal Hernia Questionnaires, (AHQ); Hernia-Related Quality of Life Surveys, (HerQLes); Quality of Life, (QoL); Ventral hernia, (VH); Anterior component separation, (ACS); Posterior component separation, (PCS); Ventral hernia repair, (VHR); Electronic medical record, (EMR); REDCap, (Research Electronic Data Capture); Surgical site occurrences/infections requiring procedural intervention, (SSOpi); Enterocutaneous, (EC); Venous thromboembolism, (VTE); Computed Tomography, (CT); American Society of Anesthesiology, (ASA); Ventral Hernia Working Group, (VHWG); Standard deviations, (SD).

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advantages over ACS, TAR is a complex, technically challenging operation, and has been associated with severe complications when performed incorrectly or unnecessarily.[9] In addition, while restoration of the linea alba alone has been associated with improved abdominal wall functionality,[14,15] division of the TAM, which plays a role in abdominal wall core stability, and the subsequent implications of this on patient reported quality of life (QoL), has not been extensively studied. Given TARs rather recent development and popularization within the hernia community, data that focuses on both postoperative clinical and patient reported outcomes (PROs) is limited.

The purpose of this study is to address this knowledge deficit by comparatively analyzing clinical outcomes and PROs between RR ventral hernia repair (VHR) with or without bilateral TAR using a biosynthetic mesh (Poly 4 hydroxybutyrate [P4HB], Phasix™, Bard, Inc.). We hypothesize that despite a more extensive abdominal wall reconstruction than the RR technique alone, TAR results in a safe and durable hernia repair with acceptable incidences of postoperative complications and recurrence rates, while improving patient QoL when performed in the appropriate patient by an experienced surgeon.

## Materials and methods

### *Population*

All adult patients (≥18 years old) undergoing a VHR with P4HB by a single plastic and reconstructive surgeon (JPF) at a large academic center between January 1st, 2015 and January 1st, 2020 were identified by retrospective review of physician operative logs. Patients were included if they had a RR VHR with or without the addition of a bilateral TAR. Patients were excluded if they had unilateral component separation, underwent an ACS, had more than one piece of mesh implanted, had a parastomal hernia, and/or had less than 12 months of clinical follow up. Additionally, patients without documented PROs metrics were excluded from our analysis. The Institutional Review Board at the University of Pennsylvania reviewed and approved this study. Due to its retrospective nature, waiver of informed consent was obtained.

### *Data collection & outcomes*

Data were extracted from the Electronic Medical Record (EMR) and managed in a secure electronic data capture tool, REDCap (Research Electronic Data Capture), hosted at The University of Pennsylvania Hospital.[16,17] Patient demographic information, hernia characteristics, and perioperative data were collected and analyzed. This included the modified Ventral Hernia Working Group (VHWG) classification,[18] American Society of Anesthesiology (ASA) physical status classification, and Center for Disease Control (CDC) surgical wound classification,[19] among others. Hernia defect size was measured intraoperatively and based on hernia width and length (cm$^2$). Primary outcomes were postoperative hernia recurrence and a composite of postoperative complications that included surgical site occurrences (SSO – surgical site infection (SSI), cellulitis, seroma, hematoma, delayed healing, wound dehiscence), surgical site occurrences requiring procedural intervention (SSOpi), mesh infection, enterocutaneous (EC) fistula, bowel obstruction, ileus, and venous thromboembolism (VTE). Hernia outcomes were classified according to previously published guidelines by DeBord et al.[20] Additionally, we assessed the frequency of Emergency Department visits, readmissions, and reoperations. Recurrence was assessed through review of the EMR. All recurrences were confirmed by physician physical examination and palpation of a fascial defect or by Computed Tomography (CT) scan. The secondary outcome was PROs as defined by overall pre and post-operative Abdominal Hernia Questionnaire (AHQ)[21] and the Hernia-Related Quality-of-Life Survey (HerQLes)[22] scores. These questionnaires are hernia specific instruments designed to assess post-operative PROs after hernia surgery. Surveys comprise questions related to patient reported pain, physical and mental function, self-esteem, body image, overall satisfaction with the provider-patient relationship, as well as perception of post-repair improvement, recovery process and surgical scar. Overall scores for both surveys are an average of all questions converted to a score out of 100. If patients had completed more than one post-operative AHQ or HerQLes, instruments completed at least 30 days after VHR were averaged and used for analysis.

### *Statistical analysis*

Descriptive statistics were used for patient characteristics including age, BMI, comorbidities, ASA class, modified VHWG, and postoperative outcomes. Continuous data were described as medians with interquartile ranges [IQR]. Comparative analysis of outcomes was completed using chi-square or Fischer's exact tests, as appropriate. Pre- and post-operative AHQ and HerQLes scores were compared as continuous variables using Wilcoxon signed rank tests. Statistical significance was set at $p < 0.05$ and all analyses were performed using STATA/IC 16.0 (StataCorp LLC; College Station, TX).

### *TAR patient selection and surgical technique*

In the senior surgeon's practice, TAR is typically utilized in patients with large defects, where too much tension would be applied to approximate the posterior sheath with a RR alone. Additionally, smaller chronic hernias can have significant rectus muscle retraction and atrophy and require TAR in order to bring the posterior sheath together without undue tension. Tension should be assessed after debridement of attenuated, scarred, or non-viable musculofascial tissue. Use of poor quality tissue in closure will prevent the abdominal wall from adequately resisting strain and lead to higher rates of recurrence. Clinical evaluation of tension involves placing Kocher clamps on either side of the fascia where the defect is largest and simulating closure by bringing the clamps together in the midline. Excess tension can often be subjectively determined by the operating surgeon using this technique. However, if closure is attempted and the suture "cheese wires" or slices through the tissue, this is an indication that the stress on the abdominal wall exceeds the strength of the suture closure. Additionally, rises in peak airway pressures >12 mmHg or plateau airway pressures >4.4 mmHg above baseline signify the fascial closure is under too much tension, and places patients at risk for respiratory complications in addition to repair failure and recurrence.[23] When component separation is indicated, utilizing TAR over ACS can be considered in patients with a recurrent hernia who have already undergone ACS repair, patients with a high risk of wound complications, as TAR avoids the creation of large skin flaps, and for hernias in close proximity to bony structures as the external oblique muscle mobilization is limited by fixed insertions.[9]

After midline laparotomy and careful adhesiolysis, the medial aspect of the rectus is identified followed by incision of the muscle and the posterior rectus sheath. The retrorectus plane is developed cranially towards the xyphoid, caudally towards the pubis, and laterally to the linea semilunaris muscle where the anterior and posterior rectus sheaths join at the posterior lamella of the internal oblique muscle. At this step, it is critical to identify and preserve perforating neurovascular bundles that innervate and supply the rectus to avoid postoperative abdominal wall muscle atrophy and weakness.[7] Next, starting in the upper abdomen, the anterior/posterior rectus sheath junction is divided in order to gain access to the TAM, and the TAM subsequently divided to enter a space above the transversalis fascia.[7] Using a combination of sharp and blunt dissection, the TAM is dissected from the peritoneum and transversalis fascia to create a large plane that is bordered laterally by the psoas and extends to the subxyphoid and Retzius' spaces.[10] The medialized posterior rectus sheath is then approximated in the midline and the mesh secured in a sublay position. 2–3 closed suction drains are place above the mesh pending defect size and patient risk factors.

## Results

This study identified 50 consecutive patients that met inclusion criteria, with 26 undergoing RR VHR alone, and 24 undergoing bilateral TAR at the time of VHR. Patient demographics and comorbidities were comparable across cohorts ($p > 0.05$). The majority of patients were female (RR 53.9% vs TAR 54.2%, $p = 0.98$), obese (BMI: 31.4 [24.4–38.0] kg/m$^2$ vs 29.7 [25.4–36.3] kg/m$^2$, $p = 0.90$), and white (68.0% vs 83.3%, $p = 0.28$). The remainder of patient demographics and comorbidities are shown in Table 1.

### Operative characteristics

Perioperative details can be found in Table 2. Patients were mostly ASA class 2 (RR 50.0% vs TAR 45.8%) or class 3 (50.0% vs 50.0%) ($p = 0.57$) and modified VHWG grade 2 (57.7% vs 58.3%, $p = 0.95$). Nearly all patients had ventral/midline incisional hernias (n = 46, 92%), and hernia defect size was significantly larger in the TAR cohort (RR 208 [104–339] cm$^2$ vs TAR 449 [384–480] cm$^2$, $p < 0.001$). While there were more concomitant abdominal procedures performed in the RR cohort (84.6% vs 54.2%, $p = 0.01$), the incidence of enterotomies, need for mesh removal at the time of surgery, and CDC wound classes were similar between groups (*all* $p > 0.05$).

### Outcomes

While TAR patients had significantly longer lengths of stay (RR 3 [3–5] days vs TAR 5 [3.5–7] days, $p = 0.04$), no other significant differences in postoperative outcomes were found between cohorts, as shown in Table 3. There were comparable rates of SSOs (RR 15.4% vs TAR 37.5%) which included surgical site infection (SSI), seroma, hematoma, delayed healing, and wound dehiscence (all $p > 0.05$). Six patients developed an SSOpi, 3 (11.5%) in the RR cohort and 3 (12.5%) in the TAR cohort, five of which were managed with percutaneous drainage or bedside wound debridement. No patients in either cohort developed a mesh infection requiring explanation, EC fistula, or VTE. After an average follow up of 24.1 [17.6–41.1] and 38 [34.9–47.7] months in the TAR and RR groups, respectively, hernia recurrence occurred in one TAR patient (4.2%), and four RR patients (15.4%) ($p = 0.26$). Of note, duration of follow-up was significantly longer for patients with RR repair ($p = 0.001$). However, of the patients who recurred in the RR cohort, all did so within 2 years of their index procedure, and time to recurrence was an average of 471 [251–679.5] days. The one patient with recurrence after TAR recurred 510 days after initial repair. Additionally, during this follow-up period there were no significant differences in rates of healthcare utilization measures such as postoperative ED visits, readmissions, or reoperations ($p = 0.44$, $p = 0.77$, and $p = 0.19$, respectively). All three re-operations in the RR cohort were repeat hernia repairs for recurrences. The re-operation in the TAR patient was for an SSI that required formal operative debridement.

Pooled pre and post-operative survey scores for the overall cohort, as well as for patients who specifically had RR repair alone or TAR, can be found in Table 4. Regardless of repair technique, scores improved significantly after VHR. For patients undergoing RR repair, pre to postoperative scores increased from 43.3 [28–56] to 80 [69–93] ($p = 0.001$) and 50.0 [38–75] to 86.3 [76–98] ($p = 0.03$) when utilizing each PROs measure. Similarly, for patients undergoing TAR, pre to postoperative scores increased from 53.3 [44–72] to 82 [56–96] ($p = 0.03$) and 20.8 [4.2–38] to 93.4 [88–98] ($p = 0.02$). These improvements are further graphically depicted in Figs. 1 and 2. Preoperative AHQ scores for patients undergoing TAR were significantly lower than preoperative AHQ scores for patients who had RR repair ($p < 0.05$), however the same was not true for preoperative HerQLes scores between the groups. Postoperative scores were statistically similar regardless of repair technique and/or PROs metric ($p > 0.05$).

**Table 1**
Patient Demographics

| Patient Demographics | RR (n = 26) | TAR (n = 24) | *P* |
|---|---|---|---|
| **Age, years, median [IQR]** | 57.7 [49.4–65.7] | 60.1 [46.4–64.9] | *0.93* |
| **Sex, female, n (%)** | 14 (53.9) | 13 (54.2) | *0.98* |
| **Body mass index, kg/m$^2$, median [IQR]** | 31.4 [24.4–38.0] | 29.7 [25.4–36.3] | *0.90* |
| **Race, n (%)** | | | *0.28* |
| **White** | 17 (68.0) | 20 (83.3) | |
| **Black/African-American** | 7 (28.0) | 3 (12.5) | |
| **Other Race** | 1 (4.0) | 0 (0.0) | |
| **Prior Abdominal Surgeries, median [IQR]** | 2 [1–4] | 2 [1–4] | *0.58* |
| **History of Ostomy, n (%)** | 5 (19.2) | 9 (37.5) | *0.15* |
| **Comorbidities, n (%)** | | | |
| **Current Smoker** | 2 (7.7) | 3 (12.5) | *0.65* |
| **Diabetes Mellitus** | 7 (26.9) | 4 (16.7) | *0.38* |
| **Chronic Obstructive Pulmonary Disease** | 1 (3.9) | 1 (4.2) | *0.95* |
| **Peripheral Vascular Disease** | 2 (7.7) | 4 (16.7) | *0.33* |
| **Hypertension** | 16 (61.5) | 9 (37.5) | *0.09* |
| **Inflammatory Bowel Disease** | 3 (11.5) | 4 (16.7) | *0.60* |
| **Preoperative Steroid Use** | 2 (7.7) | 2 (8.3) | *0.93* |
| **Immunosuppression** | 4 (15.4) | 4 (16.7) | *0.90* |

RR- Retrorectus.
TAR- Transversus Abdominis Release.

**Table 2**
Perioperative Details

| Perioperative Details | RR (n = 26) | TAR (n = 24) | *P* |
|---|---|---|---|
| **ASA Class, n (%)** | | | *0.57* |
| **1** | 0 (0.0) | 1 (4.2) | |
| **2** | 13 (50.0) | 11 (45.8) | |
| **3** | 13 (50.0) | 12 (50.0) | |
| **VHWG, n (%)** | | | *0.95* |
| **1** | 4 (15.4) | 3 (12.5) | |
| **2** | 15 (57.7) | 14 (58.3) | |
| **3** | 7 (26.9) | 7 (29.2) | |
| **Hernia Location, n (%)** | | | *0.93* |
| **Midline (ventral/incisional)** | 24 (92.3) | 22 (91.7) | |
| **Paramedian** | 2 (7.7) | 2 (8.3) | |
| **Defect size, cm$^2$, median [IQR]** | 208 [104–339] | 449 [384–480] | ***<0.001*** |
| **Ostomy at Hernia Repair, n (%)** | 3 (11.5) | 3 (12.5) | *0.92* |
| **Concurrent Abdominal Procedure, n (%)** | 22 (84.6) | 13 (54.2) | ***0.02*** |
| **Enterotomy, n (%)** | 3 (11.5) | 6 (25.0) | *0.22* |
| **Previous Mesh Removed, n (%)** | 4 (15.4) | 7 (29.2) | *0.39* |
| **CDC Wound Class, n (%)** | | | *0.46* |
| **1** | 15 (57.7) | 11 (45.8) | |
| **2** | 9 (34.6) | 10 (41.7) | |
| **3** | 1 (3.8) | 0 (0.0) | |
| **4** | 1 (3.8) | 3 (12.5) | |
| **Operative time, minutes, median [IQR]** | 192 [127–239] | 208.5 [185.5–299.5] | *0.09* |

ASA- American Society of Anesthesiology.
VHWG- Ventral Hernia Working Group.
CDC- Center for Disease Control.

## Discussion

Over the past several decades there has been an evolution in the field of hernia surgery, fueled by an increase in hernia complexity and the need for new techniques to provide durable repair. The utilization of myofascial advancement techniques over traditional RR allows for midline fascial approximation despite the limitations of the rectus sheath width, providing large pre-peritoneal planes that facilitate increased mesh overlap. This is especially useful in large defects. The use of PCS with TAR, however, has been critiqued for the potential serious consequences in functionality of the abdominal wall associated with the release of the TAM.[24] While early studies have demonstrated promising clinical outcomes in terms of SSOs and recurrence[5,8,10,13] there have been few studies focused on patient reported outcomes (PROs) after hernia repair with TAR, as well as the differences in PROs and clinical outcomes between TAR and RR alone. We sought to answer this question as one of the first studies to comparatively examine clinical outcomes and PROs after these two hernia repair techniques. Despite a high incidence of SSOs, we echo previous literatures' low recurrence rates and low incidence of serious wound complications after TAR, as well as report important QoL improvement post repair. Overall, despite a more extensive abdominal wall construction, TAR outcomes were comparable to that of RR alone.

Large hernias are well known to affect abdominal wall function due in part to a lateralization and subsequent atrophy of the rectus

**Table 3**
Postoperative Outcomes

| Postoperative Outcomes | RR (n = 26) | TAR (n = 24) | *P* |
|---|---|---|---|
| Length of Stay, days, median [IQR] | 3 [3–5] | 5 [3.5–7] | ***0.04*** |
| SSO, n (%) | 4 (15.4) | 9 (37.5) | *0.08* |
| SSI | 5 (19.2) | 5 (20.8) | *0.89* |
| Seroma | 1 (3.9) | 3 (12.5) | *0.26* |
| Hematoma | 0 (0.0) | 1 (4.2) | *0.29* |
| Delayed Healing | 3 (11.54) | 4 (16.7) | *0.60* |
| SSOpi, n (%) | 3 (11.54) | 3 (12.5) | *0.92* |
| Infected Mesh, n (%) | 0 (0.0) | 0 (0.0) | *> 0.99* |
| Enterocutaneous Fistula, n (%) | 0 (0.0) | 0 (0.0) | *> 0.99* |
| Post-operative Bowel Obstruction, n (%) | 1 (3.4) | 0 (0.0) | *0.33* |
| Venous Thromboembolism, n (%) | 0 (0.0) | 0 (0.0) | *> 0.99* |
| Ileus, n (%) | 0 (0.0) | 0 (0.0) | *> 0.99* |
| Readmit, n (%) | 4 (15.4) | 3 (12.5) | *0.77* |
| Reoperation, n (%) | 3 (11.54) | 1 (4.2) | *0.19* |
| Emergency Department Visits, n (%) | 1 (3.9) | 4 (16.7) | *0.44* |
| Postoperative follow-up, months, median [IQR] | 38.0 [34.9–47.7] | 24.1 [17.6–41.1] | ***0.001*** |
| Hernia Recurrence, n (%) | 4 (15.4) | 1 (4.2) | *0.26* |
| Days to Recurrence, median [IQR] | 474 [251–679.5] | 510 [n/a] | *> 0.99* |

**SSO**- Surgical Site Occurrence.
**SSI**- Surgical Site Infection.
**SSOpi**- Surgical Site Occurrence requiring procedural intervention.

**Table 4**
Patient Reported Outcomes

| Patient Reported Outcomes, median [IQR] | Pre-operative | Post-operative | *p* |
|---|---|---|---|
| **Overall** | | | |
| HerQLes | 44.1 [32–64]<br>N = 20 | 81 [65–93]<br>N = 25 | ***0.002*** |
| AHQ | 37.5 [17–46]<br>N = 18 | 91.7 [83–97]<br>N = 19 | ***0.001*** |
| **RR** | | | |
| HerQLes | 43.3 [28–56]<br>N = 13 | 80 [69–93]<br>N = 17 | ***0.001*** |
| AHQ | 50.0 [38–75]<br>N = 7 | 86.3 [76–98]<br>N = 8 | ***0.03*** |
| **TAR** | | | |
| HerQLes | 53.3 [44–72]<br>N = 7 | 82 [56–96]<br>N = 8 | ***0.03*** |
| AHQ | 20.8 [4.2–38]<br>N = 11 | 93.4 [88–99]<br>N = 11 | ***0.02*** |

**HerQLes**- Hernia-Related Quality-of-Life Survey.
**AHQ**- Abdominal Hernia Questionnaire.

muscles.[25] Approximating the linea alba and the rectus sheath has become an important and well accepted tenant of ventral hernia repair in order to restore abdominal wall functionality. In studies looking specifically at rectus muscle function after VHR with approximation of the linea alba, dynamometers have demonstrated improvement by isokinetic and isometric measurements, as well as improvements in QoL.[14] However, in certain scenarios, a tension-free approximation of the linea alba can only be achieved with the addition of a myofascial release. A TAR is a relatively new surgical technique that achieves such release. The TAM is a lateral abdominal wall muscle that originates on the costal cartilages and thoracolumbar fascia. It provides core strength to the thorax and pelvis, assisting in trunk rotation as well as expiration and abdominal wall contraction.[26] Concern over division of the TAM causing donor morbidity has led to several studies that have tried to objectively answer this question. DeSilva et al. examined the pre and postoperative computed tomography (CT) scans of patients undergoing TAR with linea alba re-approximation. Post-operatively, TAR patients were found to have hypertrophy of the rectus abdominis, internal oblique, and external oblique muscles six months after repair, suggesting that TAR actually leads to improved anatomy of the abdominal wall as well as positive compensatory changes.[27] Similarly, Criss et al. tested core stability before and after repair and found that release of the TAM had no impact on core stability in the postoperative period. Additionally, hernia specific QoL was improved.[14] We are the second study to our knowledge to detail patient reported QoL improvement after TAR. All of our patients completed one of two hernia-specific PRO instruments that our group uses to assess QoL before and after hernia surgery. Patients had significant improvement from pre to postoperative scores utilizing both QoL metrics in the TAR and RR groups (*all* $p < 0.05$). With these QoL metrics available to us, we conclude that despite the extensive dissection, abdominal wall reconstruction, and muscle division required during a TAR, patients do not experience significant subjective functional deficits post operatively. Moreover, when we evaluated preoperative QoL scores, patients undergoing TAR had significantly lower baseline AHQ scores than those undergoing RR repair alone. This is interesting when we consider that TAR patients had on average, larger hernia defects. While the inclusion of two QoL metrics and relatively small sample size make it difficult to make any secondary conclusions regarding which factors in these patients were predictive of lower baseline QoL scores, this is certainly a finding that merits additional research.

Recurrence data in the literature surrounding TAR has been favorable. Maloney et al. and Novitsky et al. both analyzed >400

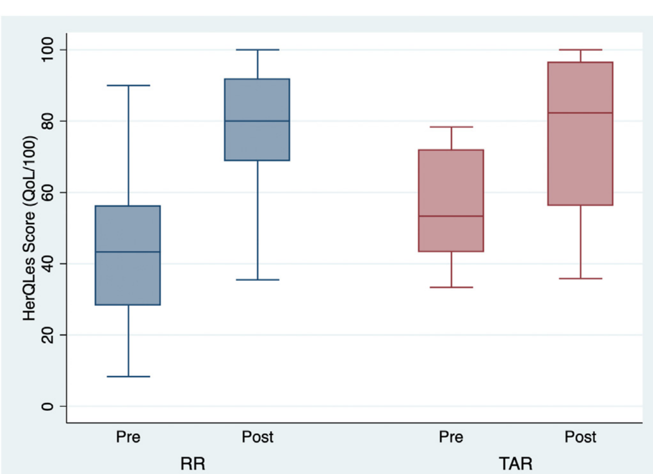


**Fig. 1.** Pre and post-operative Hernia Related Quality of Life survey scores by hernia repair technique.

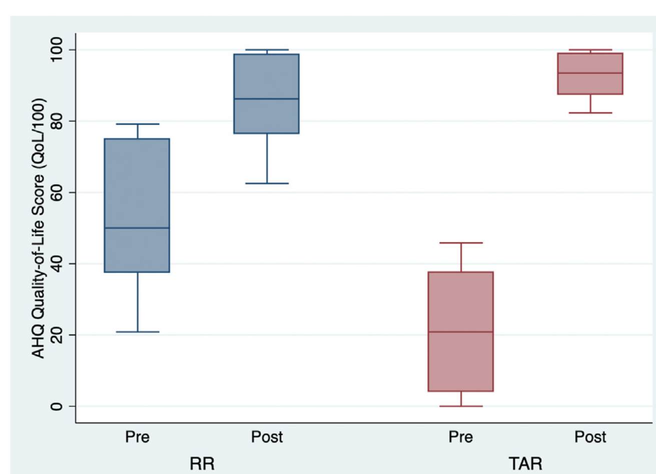


**Fig. 2.** Pre and post-operative Abdominal Hernia Questionnaire scores by hernia repair technique.

patients undergoing TAR, and reported recurrence rates of just 2.7% and 3.7% at 24 months, respectively.[5,8] However the use of mesh, mesh plane of placement, and/or mesh type has varied. We are one of the first studies to standardize mesh implant and plane of mesh use, and all patients included in this analysis had a single piece of RR biosynthetic P4HB used in their repair. The choice to utilize P4HB in this cohort study was twofold - (1) Our group has previously demonstrated promising outcomes with the use of this biosynthetic product in a diverse group of complex VHR patients,[28] and therefore (2) the most adequate sample size to conduct this retrospective, standardized, comparative review was with patients undergoing repair with P4HB. While an elaborate discussion of the properties of P4HB is beyond the scope of this paper, we echo promising rates of recurrence with just one patient in the TAR cohort (4.2%) who developed a hernia post repair. As P4HB is metabolized slowly, over the course of 12–18 months,[29–31] we felt it important to exclude any patients with less than 12 months of follow up in order to make more accurate conclusions on the incidence of hernia recurrence within this group of patients. When we consider the deleterious potential complications with synthetic mesh,[32,33] and the high cost and recurrence rates associated with biologic mesh,[34,35] the authors believe that these initial findings are positive. Nonetheless, we realize that a comparative analysis of biosynthetic mesh with other mesh products are indicated prior to making any definitive conclusions regarding mesh superiority.

In addition to recurrence rates, we analyzed and compared a composite of postoperative outcomes between RR and TAR. In a systematic review by Wegdam et al., 646 patients from 5 studies who underwent TAR were included in analysis and found to have a mean SSO of 15% after TAR.[36] In this study, our SSO rate was 37.5% in the TAR cohort and 15.4% in the RR cohort. A portion of both RR and TAR patients, however, had concomitant abdominal surgery (85%, 54%), enterotomies at the time of surgery (12%, 13%), and required previous mesh removal (15%, 29%). The surgical and medical complexity of this cohort likely increased their risk for postoperative wound events. When comparing RR to TAR, the authors acknowledge that the increased dissection and tissue plane manipulation required in a TAR likely predisposes patients to higher risks of post-operative wound events. This is perhaps why wound events were more frequent in the TAR group, further corroborated by the fact that TAR patients typically stayed in the hospital a day or two longer. However, it becomes important to assess how we measure success in our complex hernia repair patients. When we consider that only one patient required an operative debridement for an SSO, only one patient recurred, and QoL for all patients improved postoperatively– it challenges the hernia community to accept the risk of increased short term minor adverse effects, for the benefits of a safe and durable repair. We maintain that the overall patient and hospital burden associated with complications after TAR is low and we recommend its use as an adjunct to hernia repair in the appropriate patient population. Due to the high rates of SSOs in this cohort, we have continued to assess best practices for drain placement and now follow stricter criteria for drain removal in these patients.

Our study is not without limitations that must be addressed. Due to the strict inclusion criteria and attempts to standardize hernia repair techniques and mesh use, our sample size is relatively small. However, we felt these standardizations were important in order make accurate conclusions about our outcomes. Unfortunately, our efforts to make our cohort as homogenous as possible limits our ability to compare outcomes with this mesh with those of other mesh products. An important novelty of this paper is the inclusion of QoL data, and the comparative analysis of PROs after TAR and RR repair alone. Our group switched from the HerQLes to the AHQ in the middle of the study period. We have included both measures here, in order to most completely reflect our population's PROs data, but understand that using two different outcomes measures is not ideal. Lastly, follow up for our TAR cohort was significantly shorter than that of the RR group. This is a consequence of the senior surgeon utilizing TAR only later in his career. However, given the absorption properties of P4HB, and all of the recurrences in this study occurring within two years, we feel confident in making early conclusions about recurrence risks in these two cohorts. Certainly, additional longitudinal data is needed to assess the long term durability of these outcomes.

In conclusion, we have found that complex dissection and use of TAR on larger hernia defects may result in high rates of SSOs, but has overall low incidences of major adverse events and recurrence rates when we examined patients with >2 years of follow-up. Additionally, division of the TAM does not seem to affect PROs, as QoL improved regardless of repair technique.

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## Declaration of competing interest

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