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ORIGINAL ARTICLE

Transversus abdominis release with biosynthetic mesh for large ventral hernia repair: a 5-year analysis of clinical outcomes and quality of life

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Abstract

Introduction Transversus abdominis release (TAR) may provide an optimal plane for mesh placement for large ventral hernias requiring medial myofascial flap advancement. Long-term outcomes of TAR for large ventral hernia repair (VHR) remains under-studied. This study aims to assess longitudinal clinical outcomes and quality of life (QoL) following large VHR with TAR and resorbable biosynthetic mesh.

Methods Retrospective review of clinical outcomes and prospective QoL was performed for patients undergoing VHR with poly-4-hydroxybutyrate mesh and TAR from 2016 to 2021. Patients with ≤ 24 months of follow-up, defects ≤ 150 cm^2, and parastomal hernias were excluded. Cost-related data was collected for each patient's hospital course. QoL was compared using paired Wilcoxon signed-rank tests.

Results Twenty-nine patients met inclusion criteria. Median age and BMI were 61 years (53.2–68.1 years) and 31.4 kg/m^2 (26.1–35.3 kg/m^2). Average hernia defect was 390cm^2 ± 152.9 cm^2. All patients underwent previous abdominal surgery and were primarily Ventral Hernia Working Group 2 (58.6%). Two hernia recurrences (6.9%) occurred over the median follow-up period of 63.1 months (IQR 43.7–71.3 months), with no cases of mesh infection or explantation. Delayed healing and seroma occurred in 27 and 10.3% of patients, respectively. QoL analysis identified a significant improvement in postoperative QoL ($p < 0.005$), that continued throughout the 5-year follow-up period, with a 41% overall improvement. Cost analysis identified the hospital revenue generated was approximately equal to the direct costs of patient care. Higher costs were associated with ASA class and length of stay ($p < 0.05$).

Conclusion Large VHR with resorbable biosynthetic mesh and TAR can be performed safely, with a low recurrence and complication rate, acceptable hospital costs, and significant improvement in disease-specific QoL at long-term follow-up.

Keywords Transverse abdominis release · Large ventral hernia · Biosynthetic mesh · Quality of life · Longitudinal outcomes

Abbreviation

AHQ	Abdominal Hernia-Questionnaire
HerQLes	Hernia-Related Quality of Life Survey
QoL	Quality of Life
TAR	Transversus Abdominis Release
VHR	Ventral Hernia Repair
VHWG	Ventral Hernia Working Group

C. A. Messa IV and C. Amro contributed equally to this work.

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CDC	Center for Disease Control
SSI	Surgical Site Infection
ACS	Anterior Component Separation
ASA	American Society of Anesthesiology
SSO	Surgical Site Occurrences
PRO	Patient Reported Outcome
IQR	Interquartile Range
VH	Ventral Hernia
EOM	External Oblique Muscle
REDCap	Research Electronic Data Capture

Introduction

Large ventral hernias (VH), categorized as defects larger than 150 cm^2, are a persistent surgical health issue with diverse clinical risk factors and challenging epidemiology [1, 2]. The evolution of complex abdominal wall reconstruction has developed rapidly and focuses on the principle of tissue-based reconstruction often with myofascial advancement and prosthetic reinforcement [3–5]. Popularized by Ramirez et al. in 1990, anatomical restoration and components separation has evolved in recent decades, including the division of the external oblique muscle (EOM) and subsequent creation of large lipocutaneous flaps for midline abdominal wall advancement [6, 7]. Since then, the anterior component separation (ACS) technique has been associated with relatively high rates of wound morbidity and short-term surgical site occurrences [7]. Rives-Stoppa retrorectus repair provides an alternative for moderate sized defects with efficacious outcomes and low morbidity, however the technique presents its own individual limitations [8]. Major disadvantages include limiting myofascial advancement as lateral dissection in this plane is restricted by the boundaries of linea semilunaris, innervation to the rectus muscle, and preventing the placement of prosthetic mesh for larger defects without reliable overlap [6].

Transversus abdominis release (TAR), proposed by Novitsky et al. [3, 8] addresses many of the shortcomings seen in ACS and retrorectus repairs. In this posterior component separation technique, lateral dissection of the posterior lamella of the internal oblique and fibers of the transversus abdominis creates a large, well-vascularized, preperitoneal plane permitting wide retromuscular mesh placement [8, 9]. This approach often obviates the need for skin flaps, preserves rectus innervation, and affords reliable myofascial advancement. Various studies demonstrate TAR to have lower recurrence rates and surgical site occurrences compared to ACS [5, 9, 10]. While published outcomes of TAR are favorable for complex ventral hernia patients, there is a paucity of data on either long-term clinical or quality of life (QoL) outcomes, specifically in large ventral hernias. Furthermore, controversy surrounding mesh selection with TAR remains prominent, especially regarding the use of resorbable biosynthetic mesh for sustainable long-term outcomes following large VHR.

Many clinical challenges exist in this complex patient population which can often make the choice of repair technique difficult, including extensive previous abdominal surgery, prior failed repairs, and complex comorbid conditions. The ultimate measure of success of hernia repair is to provide a lasting, durable, repair with a low hernia recurrence rate and avoidance of long-term complications. Nevertheless, there remains a significant knowledge gap regarding long-term clinical and QoL outcomes following complex VHR with TAR. The purpose of this study is to provide a thorough assessment of both clinical and patient-reported outcomes in patients who have undergone large VHR with TAR.

Methods

A retrospective analysis of prospectively collected data was performed for patients undergoing VHR with transversus abdominis release (TAR) from January 2016 to May 2021 by a single surgeon. All adult patients (≥ 18 years of age) that underwent single-staged VHR with resorbable biosynthetic mesh and TAR were included in the study. Patients with ventral hernias smaller than 150 cm^2, less than 2 years of follow-up, synthetic or hybrid mesh reinforcement, and those undergoing parastomal hernia repair were excluded from analysis (Fig. 1). QoL was assessed prospectively as a standard of care and measured through patient reported outcomes (PRO), collected at pre-operative and post-operative periods. This study was reviewed and approved by the Institutional Review Board at the University of Pennsylvania (Protocol #851883). Consent was obtained for all post-operative PROs. Clinical follow-up was completed retrospectively through an evaluation of the electronic medical record and all clinical outcomes were determined based on physical exam findings.

The utilization of TAR was determined intraoperatively by the senior author, based on each individual patient's clinical presentation. In the present study, the need for TAR was indicated due to the large hernia defect size (≥ 150 cm^2) and the need for medialization of the posterior rectus sheath to mitigate the tension on the repair. The senior author aims for at least 10 cm of overlap in every direction, allowing for the TAR technique to act as an extension of the retromuscular repair, beyond the lateral border of the rectus complex without compromising vasculature or innervation to the abdominal wall. The senior author's operative approach to TAR has been previously described [5, 11]. Mesh selection was chosen on a case-by-case basis, based on the discretion of our senior author. Overall, for any clean-contaminated,

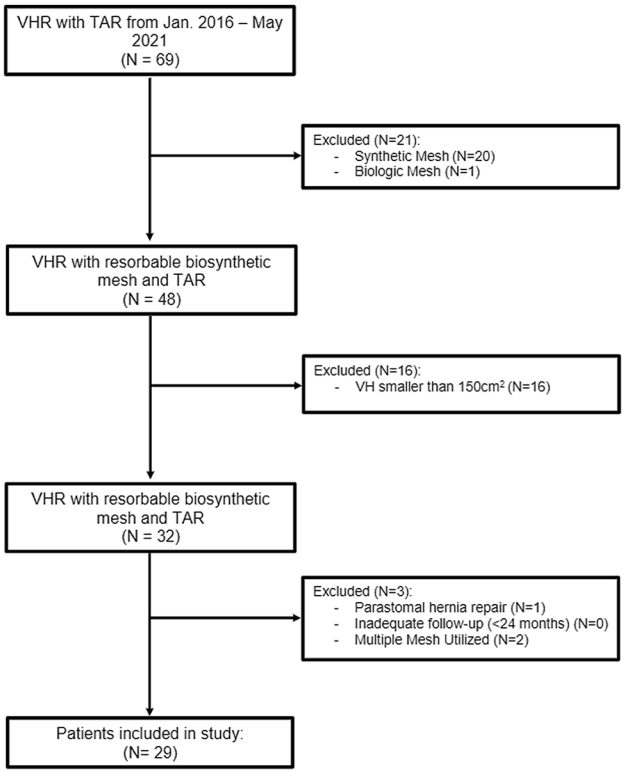

Fig. 1 Flow diagram for study participants following exclusion criteria

contaminated, or infected cases, resorbable biosynthetic mesh is preferred to reduce the risk of mesh infection and surgical site occurrences (SSO). Additionally, the senior author utilizes biosynthetic mesh in selected clean cases where a TAR is required, namely comorbid patients who are undergoing extensive intra-abdominal surgery, who are at an increased risk of post-operative complications.

Outcomes

Patient demographics, hernia characteristics and post-operative clinical outcomes were collected for all patients and retrospectively reviewed. Demographic information included age, gender, body mass index (BMI), and comorbidities, such as history of smoking, diabetes mellitus, hypertension, and previous open abdominal surgery. Post-operative follow-up was collected by month and determined for each patient individually. Hernia characteristics included defect size (cm^2), number of prior repairs, Center of Disease Control (CDC) wound classification, and ventral hernia working group (VHWG). Perioperative data included American Society of Anesthesiology (ASA) class, mesh type, plane of mesh placement, and operative time. Hernia defect size was measured intraoperatively, based on hernia width and length (cm^2).

Primary outcomes consisted of hernia recurrence and short-term SSO including surgical site infection (SSI), seroma, delayed healing, wound dehiscence, surgical site occurrences requiring procedural interventions (SSOPI), mesh infection and mesh explantation. Hernia recurrence was defined as a palpable fascial defect (on supine or standing) and confirmed by computed tomographic (CT) imaging [8, 12]. Any patient with a described or clinically present bulge was evaluated with a CT scan and confirmed accordingly. Secondary outcomes consisted of post-operative QoL. Long-term post-operative outcomes, beyond 60 days, such as Emergency Department (ED) visits, readmissions, and reoperations were also examined.

Quality of life

QoL was evaluated prospectively through pre- and post-operative completion of the Hernia-Related Quality-of-Life survey (HerQLes) and Abdominal Hernia-Questionnaire (AHQ) [13, 14]. Throughout the study period, our group transitioned from use of the HerQLes to sole administration of the AHQ. Thus, we developed a novel calibration tool to create a combined, composite QoL score to allow for long-term QoL analysis. All HerQLes surveys collected during the study period were subsequently converted to AHQ. The calibration technique has been previously described in a recent publication [15]. QoL was assessed at the pre-operative visit and prospectively at post-operative intervals of 0–3, 3–6, 6–12, 12–18, 18–24 months, 3, 4, and 5 years. Patients completed the instrument during scheduled follow-up visits or were contacted through telephone or email for patients that have not followed-up within 6 months. Extended QoL follow-up was collected through virtual or telephone administration of the AHQ among patients who were beyond 24 months of VHR with TAR and who were unable to follow-up in clinic. Patients were contacted through email or telephone in accordance with each post-operative time interval beyond 24 months if they could not follow-up in clinic. Any change in QoL assessed through the AHQ or HerQLes was not interpreted as an exclusion of a hernia recurrence. Clinical follow-up followed traditional methodology of a physical exam of the abdomen and was completed separately from QoL follow-up. Hernia recurrence was identified solely by physical exam and confirmed by CT imaging. No clinical characteristics or outcomes were determined through the completion of the AHQ. All data extracted from the electronic medical record, including QoL questionnaire results, was managed in a secure, institutionally verified, databased REDCap (Research Electronic Data Capture) [16, 17].

Cost data

Cost-related data was collected for each patient's index hospital course, along with subsequent emergency department visits, re-admissions, and reoperations. Total cost was collected from the Department of Finance at the Hospital of the University of Pennsylvania and only reflect costs to the University Health System. Profit margin was calculated using reimbursement data subtracted from aggregate costs. Values were normalized to U.S. dollars in 2020 using the U.S. Bureau of Labor Statistics Consumer Price Index.

Statistical analysis

Before analysis, a normality test was conducted that indicated non-normally distributed (nonparametric) data. Pre- and post-operative PRO scores were compared as continuous variables using Wilcoxon signed rank tests. Continuous variables were described as means and interquartile ranges (IQRs). Risk-adjusted generalized linear models with gamma distribution and log link followed by post-estimation calculations of average marginal effects were used to obtain predicted mean differences in incremental costs with 95% CIs. Covariates included were identified a priori based on known confounding factors. Generalized linear models for cost analysis controlled for patient and operative factors. Statistical significance was set at $p < 0.05$. All analyses were performed using R 4.2.0 (R Foundation for Statistical Computing, Vienna, Austria) and STATA MP release 17.0 (Statacorp, College Station, TX).

Results

Demographics

Sixty-nine patients underwent VHR with TAR and were reviewed for study inclusion. Twenty-nine patients met inclusion criteria and were analyzed (Fig. 1). Inclusion criteria included defects larger than 150 cm^2, at least 2-year of follow-up, excluding parastomal repairs. Median age and BMI of our cohort was 61 years (IQR 53.2–68.1 years) and 31.4 kg/m^2 (IQR 26.1–35.3 kg/m^2), respectively (Table 1). Most of our cohort was male (62.1%) and presented with a history of previous hernia repair (55.2%). All patients in our study previously underwent open abdominal surgery. Many patients presented with associated comorbidities such as hypertension (51.7%), diabetes mellitus (20.7%), and were current or former smokers (41.3%).

Table 1 Demographics for all patients undergoing VHR with bilateral TAR

	N (%) or Median (IQR)
Number of patients	29
Age at operation	61.1 (53.2–68.1)
BMI (kg/m^2)	31.4 (26.1–35.3)
Gender (M)	18 (62.1%)
Race	
Caucasian/White	20 (69.0%)
African American/Black	8 (27.6%)
Other	1 (3.4%)
Hypertension	15 (51.7%)
Diabetes mellitus	6 (20.7%)
Peripheral vascular disease	5 (17.2%)
COPD	3 (10.3%)
Smoking history	
Current	5 (17.2%)
Former	7 (24.1%)
Never	17 (58.6%)
Previous open abdominal surgery	29 (100%)
Previous hernia repairs	16 (55.2%)
Previous ostomy	7 (24.1%)

BMI Body mass index

Table 2 Pre-operative and peri-operative data for all patients

ASA status	
1	1 (3.4%)
2	12 (41.4%)
3	16 (55.2%)
VHWG	
1	7 (24.1%)
2	17 (58.6%)
3	4 (13.8%)
4	1 (3.4%)
Preoperative Wound Classification	
Clean	17 (58.6%)
Clean-contaminated	9 (31.0%)
Dirty/infected	3 (10.3%)

ASA American Society for Anesthesiology, *VHWG* Ventral hernia working group

Operative characteristics

Pre-operatively, the majority of wounds were classified as clean (58.6%), with a VHWG classification of 2 (58.6%) and an ASA class of 2 (41.4%) or 3 (55.2%) (Table 2). Hernia defects were primarily located in the midline ($n = 28$, 96.6%), with an overall mean defect size of 390 ± 152.9 cm^2 (Table 3). All patients had resorbable biosynthetic mesh, Poly-4-hydroxybutyrate [P4HB]—Phasix Mesh (C.R. Bard,

Table 3 Hernia characteristics for our cohort

Hernia location	
Midline	28 (96.6%)
Flank	1 (3.4%)
Length of hernia defect (cm)	20.5 (16–24)
Width of hernia defect (cm)	19 (14.8–25.5)
Mean defect size (cm^2)	390 ± 152.9
Component Separation	
Bilateral TAR	19 (65.5%)
Unilateral TAR	8 (27.6%)
Unilateral TAR and EOR	2 (6.9%)
Length of hernia repair (minutes)	219 (189–283)

All patients underwent retro-muscular mesh placement and TAR

EOR External Oblique Release (Anterior Component Separation)

Warwick, RI) placed in the retromuscular plane. Bilateral TAR was performed in 19 patients (65.5%), unilateral TAR was performed in 8 patients (27.6%) and unilateral TAR with concurrent external oblique release (ACS) was performed in 2 patients (6.9%).

Outcomes

Over a median follow-up period of 63.1 months (IQR 43.7–71.3 months), two hernia recurrences (6.9%) occurred, both of which were identified on clinical exam at 1.4 and 2.5 years of follow-up. Short-term (within 60 days) and long-term post-operative outcomes over the 5-year follow-up period are demonstrated in Table 4. Early post-operative outcomes included delayed healing and seroma which occurred in 27.6 and 10.3% of patients, respectively. There were no cases of wound dehiscence, hematoma, enterocutaneous fistula, post-operative bowel obstruction, mesh infection, or mesh explantation. SSOPI were exclusive to infection requiring surgical debridement ($n = 5$, 17.2%), and seroma drainage ($n = 1$, 3.4%). Total length of stay was a median of 5 days (IQR 3–7 days). Long-term post-operative outcomes of ED, readmission, and reoperation rate occurred in 20.7% ($n = 6$), 17.2% ($n = 5$) and 13.8% ($n = 4$) of our cohort, respectively, including the repair of one hernia recurrence. Of the ED visits, only four of the visits were attributed to post-surgical related concerns.

Throughout the study period, 25 patients (86.2%) completed postoperative QoL assessment with a significant improvement in long-term postoperative QoL ($p = 0.002$) (Fig. 2). There were no significant differences in QoL among CDC wound classification, VHWG classification, history of smoking, or a history of ostomy ($p > 0.05$). Furthermore, there was no significant difference in QoL among patients who experienced SSO, SSOPI, readmissions, reoperations, and ED visits ($p > 0.05$). However, patients who had a previous VHR demonstrated a significantly greater improvement in QoL after VHR with TAR ($p < 0.05$). Long-term postoperative QoL improvement was continuously demonstrated at the 5-year follow up with an 80% response rate compared to prior post-operative assessments ($p > 0.05$). Patients achieved an average improvement of 41% at 5-year follow-up compared to preoperative QoL (Fig. 3).

Table 4 Post-operative outcomes including surgical site occurrences (SSO), surgical site occurrences requiring procedural interventions (SSOPI), Emergency Department visits, Reoperations, and Readmissions throughout the 5-year follow-up period

Follow up (months)	Median 63.1 (43.7–71.3)
Total length of stay	Median 5 (3–7)
Number of drains	2.3 ± 1.3
Mean days with drains	18.1 ± 12
Short-term post-operative outcomes	
Surgical site occurrences (SSO)	11 (37.9%)
Non-healing incisional wound	8 (27.6%)
Seroma	3 (10.3%)
Cellulitis	2 (6.9%)
Surgical site infection (SSI)	5 (17.2%)
SSOPI	6 (20.7%)
Infection	5 (17.2%)
Seroma drainage	1 (3.4%)
Long-term post-operative outcomes	
Hernia recurrence	2 (6.9%)
Readmission	5 (17.2%)
Emergency department visit	6 (20.7%)
Total reoperation	4 (13.8%)
Hernia recurrence repair	1 (3.4%)

There were no cases of wound dehiscence, hematoma, infected mesh, or mesh explanation

SSOPI Surgical site occurrences requiring procedural interventions

Cost analysis

Total direct cost for the index operation and any subsequent readmission or reoperation was collected for all patients. Cost analysis revealed the average total cost per repair was USD $30,017 (IQR $22,706–$34,720) while the average margin was an insignificant loss of USD −$1956 (IQR −$12,370, $7362) ($p > 0.05$) (Table 5). Risk-adjusted analysis revealed that higher index costs were associated with patient factors including ASA class ($6948.58 [$1102.42 to −$12,794.73], $p = 0.02$) and length of stay ($2145.30 [$1762.04–$2528.55], $p = 0.01$). Lower profit margins were associated with length of stay (−$1087.07/day [−($1530.54–$643.59)], $p = 0.01$), female patients (−$6919.86 [−(13,334.23–505.48)], $p = 0.03$) and those with history of smoking (−$7325.34 [−($10,971.12–$3679.55)], $p = 0.01$; Table 6).

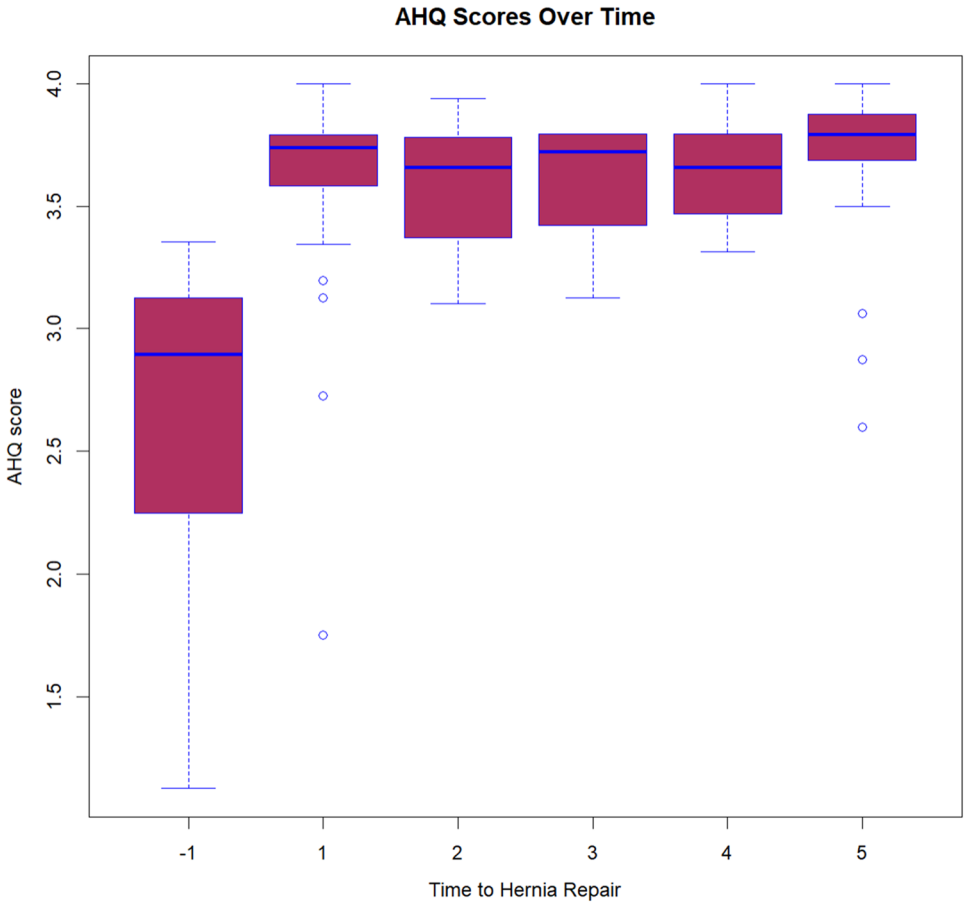

Fig. 2 Pre- and postoperative AHQ scores over the 5-year median follow-up period. ("−1" = pre-operative time-point)

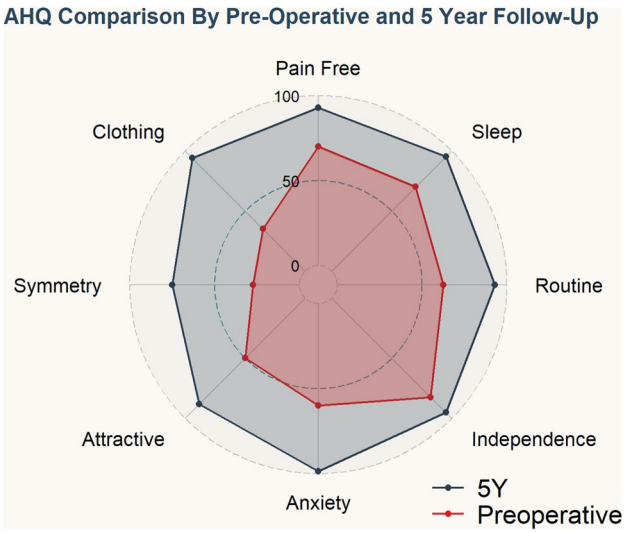

Fig. 3 AHQ comparison between pre-operative and 5 year post-operative follow-up. Clothing = Satisfaction of feeling normal in clothing, Symmetry = Abdominal Symmetry Satisfaction, Attractive = Satisfaction towards appearance without clothing, Anxiety = Anxiety relief, Independence = Comfortability with self–tasks, Routine = Comfortability with daily routines, Sleep = Satisfaction with sleep, Pain Free = Abdominal pain relief

Discussion

Despite medical and surgical advancements, incisional hernia remains a common problem following open abdominal surgery, causing a significant burden to both function and quality of life [18]. Modern abdominal wall reconstruction necessitates a combination of mesh reinforcement and tissue-based repairs to successfully achieve a hernia-free state. In this study of complex VHR, we identify the long-term efficacy of TAR as a reliable technique for abdominal wall reconstruction, through our low hernia recurrence rate over a 5-year median follow-up period, significant improvement in QoL, and acceptable rate of wound complications.

Although current literature has highlighted the benefits of TAR, few studies have assessed long-term outcomes of TAR for massive VHR. Since the introduction of TAR by Novitsky et al. [3], various studies have identified its utility to provide a reliable repair and mitigate hernia recurrence. Notably, recurrence rates range from 0 to 8% following TAR for VHR [5], which is comparable to the 6.9% presented in our study. Furthermore, current literature report surgical site occurrences in around 11–45% of cases, with major surgical interventions required in only 2–18% of patients with an adverse event. In the study herein, we report an SSO and

Table 5 Total cost including the index operation and admission, and any subsequent readmission or reoperations for each patient

Cost	$ USD
Index admission, median (IQR)	$30,017 ($22,706, $34,720) ($n=29$)
Emergency Department Visits, median (IQR)	$7727 ($1295, $9730) ($n=5$)
Readmissions, median (IQR)	$31,361 ($16,393, $40,076) ($n=4$)
Reoperations, median (IQR)	$52,981 ($23,055, $82,907) ($n=2$)
Index Margin (Payment-Dir Cost), median (IQR)	−$1956 (−$12,370, $7362) ($n=29$)
ED Margin (Payment-Dir Cost), median (IQR)	$444 (−$575, $1113) ($n=5$)
Readmissions Margin (Payment-Dir Cost), median (IQR)	−$5628.76 (−$13,730, $10,626) ($n=4$)
Reoperation Margin (Payment-Dir Cost), median (IQR)	−$1839 (−$23,818, $20,139) ($n=2$)

Outside hospital visits/readmissions were not included. Costs rounded to the nearest hundredth

IQR Interquartile range

Table 6 Risk-adjusted analysis of total direct cost for demographics pre-operative, and peri-operative characteristics

	Predicted mean cost of index admission	95% Confidence interval	*p*
Age	−$58.44	−$327.83 to $210.94	0.67
Female	$6248.28	−$1252.97 to $13,749.52	0.10
Race	$2439.48	−$382.99 to $5261.941	0.09
BMI	−$167.73	−$572.93 to $237.47	0.42
Defect size	$8.51	−$3.67 to $20.71	0.17
Number of previous hernia repairs	$428.65	−$1764.74 to $2622.03	0.70
Previous wound infection	$1607.10	−$4199.85 to 7414.06	0.59
ASA	$6948.58	$1102.42–$12,794.73	0.02
Previous ostomy	$3360.11	−$3047.47 to $9767.68	0.30
History of smoking	$1726.51	−$1346.57 to $4799.59	0.27
Public insurance (ref. private)	$5663.07	−$865.71 to $12,191.84	0.09
Length of stay (days)	$2145.30	$1762.04–$2528.55	0.01
	Predicted mean profit margin	95% Confidence interval	*p*
Age	−$191.44	−$485.80 to $102.93	0.20
Female	−$6919.86	−($13,334.23–$505.48)	0.03
Race	$3188.31	$121.81–$6254.82	0.04
BMI	$11.12	−$426.87 to $449.10	0.96
Defect Size	−$0.42	−$23.45 to $22.60	0.97
Number of previous hernia repairs	−$820.87	−$3042.37 to $1400.63	0.47
Previous wound infection	$12,666.94	−$1102.60 to $26,436.47	0.07
ASA	−$3148.38	−$10,752.98 to $4456.27	0.42
Previous ostomy	$1633.90	−$6072.41 to $9340.22	0.68
History of smoking	−$7325.34	−($10,971.12–3679.55)	0.01
Public insurance (ref. private)	−$2935.65	−$10,334.82 to $4463.52	0.44
Length of stay (days)	−$1087.07	−($1530.54–$643.59)	0.01

Costs adjusted to $USD in 2020 using Consumer Price Index. Age, BMI, defect size, number of previous hernia repairs, and ASA treated as continuous variables

SSOPI rate of 37.9% ($n=11$) and 20.7% ($n=6$), respectively. A further look demonstrates that patients had an average 18-day duration of SSI's (superficial and deep), 5-day duration of seromas and cellulitis, and 87-day duration of delayed healing in which all patients ultimately achieved complete resolution. Our procedural interventions were exclusive to SSI intervention ($n=5$) and seroma drainage ($n=1$). Overall, post-operative outcomes remain comparable to current literature reports, despite the large hernia defect size in our complex patient population.

The evaluation of true outcomes in VHR not only relies on clinical outcomes but can be viewed through a

multi-dimensional approach to include patient-centric outcomes (QoL) and cost (Fig. 4). Our assessment of defects larger than 150 cm^2 contributes to the operative complexity and increases the potential for adverse outcomes. Ross et al. identified patients with massive hernias, defined as an area greater than 150 cm^2, were at an increased risk of wound complications, hematomas, and length of stay. Our assessment of long-term QoL following TAR showed a significant improvement throughout the 5-year follow-up period and a 41% overall improvement. Additionally, comparative analysis identified patients with a previous VHR resulted in a greater improvement in post-operative QoL, signifying an increased satisfaction for patients following TAR and their feeling of an improved outcome. In reference to cost, our analysis revealed no significant average margin gain or loss ($p > 0.05$) (Fig. 4). A risk-adjusted evaluation of total direct cost showed higher index cost associated with ASA classification and length of stay. Additionally, an analysis of profit margin identified a lower margin associated with length of stay, female patients, and patients with a history of smoking. While further cost comparison is needed, our data can identify a greater financial burden on the healthcare system when complex patients with large defects, smoking history, and a longer length of stay undergo VHR with TAR.

The benefits and utility of TAR with VHR are inherent in the procedures technical approach. Firstly, the ability to achieve retromusuclar mesh placement and a vascularized plane for mesh incorporation. Secondly, the ability to preserve underlying blood supply by eliminating the large undermining of skin flaps can decrease the risk of wound complications [4, 19]. Wound events remain a concern following posterior component separation, due to the layer of vascularized tissue separating the mesh from the bowel and subcutaneous tissue, commonly resulting in skin only complications. Conversely, flap loss, mesh exposure, and infection have a higher association with ACS or EOR [20]. Thus, there remains an inherent tradeoff between avoiding hernia recurrence and preventing wound morbidity when large ventral defects necessitate advanced technique for midline approximation. The utilization of resorbable biosynthetic mesh, evident throughout our population, has also proven to serve as an effective biomaterial for long-term prevention of recurrence and significantly reduce the risk of mesh related complications [21, 22]. In this series, our inclusion criteria of resorbable biosynthetic mesh only was determined to accurately assess the surgical technique of TAR with biosynthetic mesh and decrease the potential for confounding factors associated with other mesh types or patient selection. Moreover, the decision to use this biomaterial was based on its ability to provide short-term mechanical support and simultaneously mitigate bacterial burden [23, 24]. In the practice of our senior author, biosynthetic mesh is utilized in high risk, clean-contaminated, contaminated, or dirty cases, to reduce the risk of SSO and mesh infection. Lastly, we believe the ability to diminish the prosthetic mesh footprint in these complex cases can decrease the risk of post operative wound events, fistula formation, and mesh erosion.

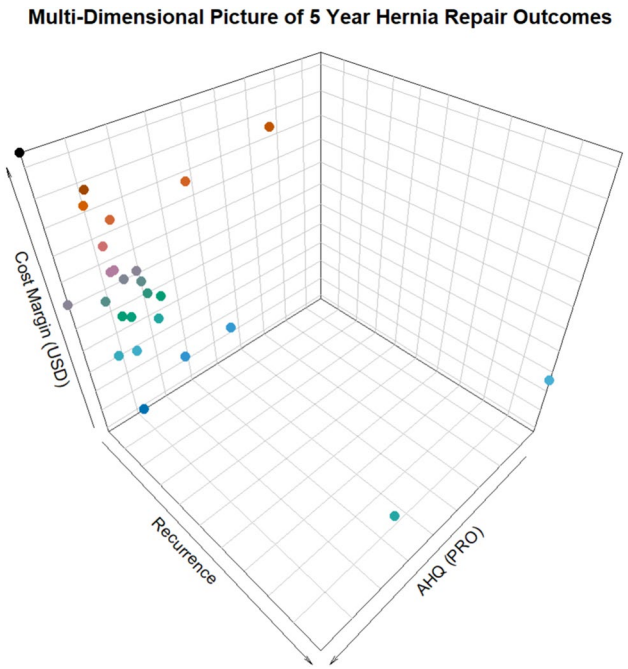

Fig. 4 Multi-dimensional picture of true outcomes including recurrence, cost, and patient reported outcomes. The *Z*-axis (Recurrence) arrow indicates either 'No Recurrence' at one end or 'Recurrence' at the other (binary value only), with no intermediary values. *X*-axis: AHQ (PRO). *Y*-axis: Cost Margin (USD)

Despite the plethora of literature regarding VHR overall, longitudinal outcomes up to or beyond five years are limited. A comprehensive review of the literature published within the past five years was performed for studies evaluating VHR with 5-year outcomes. Nineteen articles were identified after excluding articles with average follow-up less than five years or no reported outcomes at five years, and VHR without the use of mesh reinforcement (Table 7) [22, 25–42]. One study specifically examined QoL and clinical outcomes in patients who underwent TAR [41]. Although hernia recurrence often varies by repair technique, longitudinal studies have shown that recurrence continues beyond the first two years of follow-up and continues to increase up to 7 years post-operatively, further emphasizing the importance of longitudinal data to accurately assess outcomes following VHR [25, 26, 40, 41].

Throughout our review of the literature, hernia recurrence after a minimum of 5-year follow-up ranged between 2.8 and 32%. In our study herein, we contribute an acceptable recurrence rate of 6.9% following TAR in a complex patient population with large defects (Fig. 5). In comparison, a recent study by Zolin et al. examining TAR and VHR presented a

Table 7 Literature review of VHR studies published in the past 5-years with at least 5 years of follow-up

Reference	Year	Lap or open	Mesh	CST	Average length of F/u	Total # Pts	# Pts > 5 years f/u	Avg defect size	Mesh infection	Mesh explant	Recurrence at 5 years	Long-term PROs	Cost analysis
O'Dwyer PJ	2022	Both	Synthetic	–	104 mos (mean)	100	100	W: 6.2 cm	–	–	9.4%	None	None
Maspero M	2022	Lap	Synthetic	–	60 mos (median)	322	36	A: 60 cm^2	6%	6%	8%	None	None
Ayik N	2019	Open	Synthetic	–	70 mos (median)	163	163	A: 119 cm^2	–	–	3.7%	Yes (3 years)	None
Nielsen MF	2019	Open	Type n/s	–	75 mos (mean)	251	211	W: 9.2 cm	0%	0.4%	2.8%	None	None
Stodolski M	2018	Open	Type n/s	–	63 mos (median)	115	41	–	4.9%	4.9%	14.6%	None	None
Talwar AA	2022	Open	Biosyn	A & P	61.9 mos (median)	51	35	W: 16 cm A: 289cm^2	0%	0%	20%	Yes (5 years)	None
Roth JS	2022	Open	Biosyn	–	60 mos (n/s)	121	54	L: 14.7 cm W: 8.6 cm A: 108.2cm^2	–	3.3%	22%	Yes (5 years)	None
Gomez-Menchero J	2022	Lap	Synthetic	–	60 mos (n/s)	58	58	L: 8.83 cm W: 6.59 cm A: 66.72 cm^2	–	–	8.6%	None	None
Dhanani NH	2022	Both	Synthetic (85%) Biologic (15%)	Type n/s	60 mos (median)	213	132	Operative group L: 3.8 cm W: 3.0 cm A: 12.8 cm^2 Expectant group L: 3.5 cm W: 3.0 cm A: 12.0 cm^2	–	–	10%	Yes (5 years)	None
Yu JF	2022	Open	Synthetic	–	62.4 mos (mean)	49	49	A: 163 cm^2	–	–	14%	None	None
Bueno-Lledo	2021	Open	Synthetic	Ant	61.6 mos (median)	381	368	L: 24.4 cm W: 14.1 cm	2.3%	1.6%	8.9%	None	None
Asencio F	2021	Both	Synthetic	–	10 years (median)	85	58	Open W: 10.2 cm Lap W: 9.51 cm	6.15% (mesh complications)	–	21%	Yes (13.8 years)	None
Jolissaint JS	2020	Open	Type n/s (86%)	–	4.9 years (median)	630	–	W: 5.23 cm	–	–	24.3%	None	None

Table 7 (continued)

Reference	Year	Lap or open	Mesh	CST	Average length of F/u	Total # Pts	# Pts > 5 years f/u	Avg defect size	Mesh infection	Mesh explant	Recurrence at 5 years	Long-term PROs	Cost analysis
Maxwell DW	2019	Open	ADM	Ant	20.9 mos (median)	229	–	–	–	–	11.8%	None	None
Lavanchy JL	2019	Both	Synthetic	–	5.5 years (mean)	144	144	Open A: 29 cm^2 lap A: 25 cm^2	–	–	19.44%	None	None
Juvany M	2018	Open	Synthetic	–	64 mos (mean)	76	76	–	–	–	32%	Yes (5 years)	None
Rogmark P	2018	Open	Synthetic	–	87 mos (mean)	217	103	–	1.4%	0%	8.1%	Yes (7 years)	None
Zolin SJ	2022	Open	Synthetic	TAR	2 years (median)	1203	16	L: 23 cm W: 15 cm	–	0.7%	26%	Yes (5 years)	None
Asaad M	2022	Open	ADM	type n/s	34.4 mos (median)	725	162	L: 11.2 cm W: 13.9 cm A: 180 cm^2	1%	1%	17.3%	None	None

Initial search resulted in 3946 articles. After exclusion criteria, 19 studies were included. Use and type of mesh, average follow-up in months, total number of patients, and hernia recurrence is presented

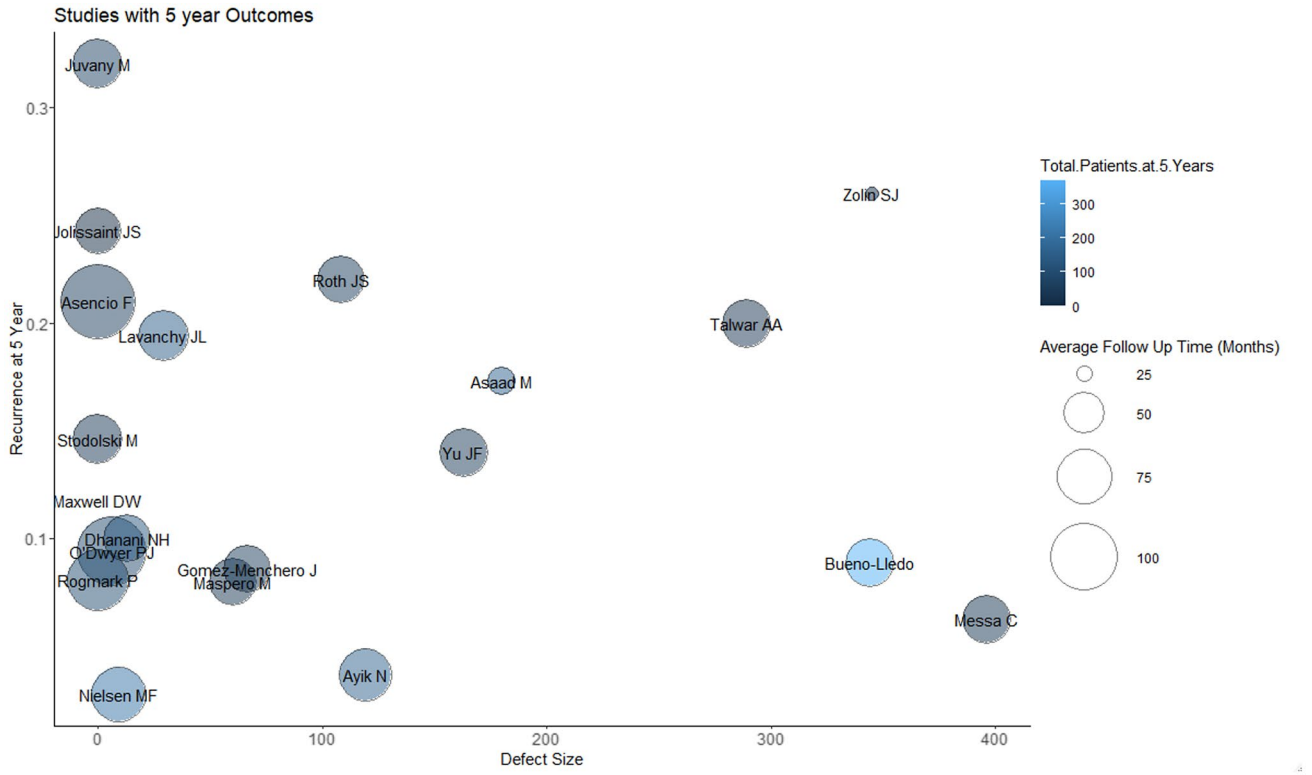

Fig. 5 Ventral hernia repair studies with at least 5 years follow-up stratified by recurrence rate, defect size, average follow-up time in months, and total number of patients with 5-year follow-up

composite hernia recurrence rate of 26% at 5 years, in which the authors identified recurrence using screening questionnaires, PROs, or clinical examination. However, with maximum specificity, their recurrence rate of 5% is comparable to recent literature [41]. Additionally, literature reports of both mesh explanation and mesh infection or mesh-related complications ranged from 0 to 6%. The use of resorbable biosynthetic mesh over the 5-year follow-up period also contributes valuable data to the current literature regarding the long-term viability and efficacy of resorbable mesh for VHR in the retromuscular plane with TAR.

Assessment of QoL remains a vital component to hernia outcomes research, where long-term analysis is required to accurately assess the benefits to a patient population plagued by the chronic cycle of hernia morbidity. While the number of long-term follow-up studies have increased in the past five years, there remains a significant knowledge gap pertaining to long-term QoL and clinical outcomes that must be filled. Talwar et al. reported most patients reported peak QoL five years after their index repair [39]. Furthermore, patients also reported improved QoL and pain scores regardless of hernia recurrence outcomes [39, 41]. Similarly, our study demonstrated significant and sustained improvement in QoL at the 5-year follow-up period, as well as a 41% average improvement relative to preoperative assessment. Long-term evaluation of patient-reported outcomes alongside long-term clinical outcomes is critical in assessing efficacy and safety of VHR techniques.

This study is not without limitations that are worth consideration. The retrospective nature of the study design and the lack of a comparison group present the potentiality of bias in study conclusions. Additionally, the size of our study population can limit the magnitude of our outcomes. Clinical outcomes were determined only by the findings of their last follow-up visit, which was an average of 5 years for all the patients in our cohort, thus presenting the potentiality of unaccounted recurrences or long-term events that were not collected. While the cost data presented can provide relevant information regarding associations of increased cost for VHR with TAR, further detailed financial evaluation is needed. Future studies assessing different mesh types and the use of other component separation techniques is needed to further delineate ideal outcomes in this population. Lastly, additional cost analyses are needed to thoroughly outline the cost implications of biosynthetic mesh and biomaterials, as well as transparency in evaluating the long-term financial impact of biosynthetic mesh with TAR.

Conclusion

In this long-term analysis, our study highlights the safety and efficacy of TAR with resorbable biosynthetic mesh for large VHR, with an optimal ratio of recurrence and mesh infection at acceptable overall costs. Furthermore, we identified significant improvements in disease specific quality of life and patient satisfaction that continued throughout the 5-year follow-up period. Complex patients with large ventral defects and previously failed repairs can be considered candidates for VHR with TAR for definitive abdominal wall reconstruction.

Data availability Data is available upon request.

Declarations

Conflict of interest Dr. John Fischer has received consulting payments from 3 M, AbbVie, BD, Baxter, Gore, and Integra Life Sciences. He has received research support from the National. Institutes of Health (NIH). Charles A. Messa IV, Chris Amro, Ellen F. Niu, Theodore E. Habarth-Morales, Ankoor A. Talwar, Sheri Thrippleton, and Robyn Broach have no financial or conflicts of interest or disclosures.

Ethics Approval This study was performed in line with the principles of the Declaration of Helsinki and approval was granted by the Institutional Review Board at the University of Pennsylvania (Protocol #851883) prior to the conduction of this study.

Human and animal rights' All procedures were performed with appropriate ethical standards, in accordance with national and institutional human rights standards.

Informed consent Due to the retrospective nature of our study, a waiver for informed consent was obtained.

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