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ORIGINAL ARTICLE

Decalogue of transversus abdominis release repair – technical details and lessons learnt

Dziesięć przykazań zabiegów hernioplastyki z uwolnieniem mięśnia poprzecznego brzucha – szczegóły techniczne i wnioski

Authors' Contribution:
A – Study Design
B – Data Collection
C – Statistical Analysis
D – Manuscript Preparation
E – Literature Search
F – Funds Collection

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ABSTRACT:

Introduction: Posterior component separation (PCS) via transversus abdominis release (TAR) technique overcomes the pitfalls of traditionally described repairs.

Aim: We evaluate the safety and efficacy of this approach and present the lessons we have learnt in our experience with a large series of complex ventral hernias. We also evaluate the importance of pre-operative optimisation and the value of a dedicated abdominal wall reconstruction (AWR) team in improving the surgical outcomes.

Material and methods: A retrospective review of all patients undergoing TAR at a specialised hernia centre in the 2016–2019 period was performed. Pertinent data collected included patient demographics, peri-operative details and post-operative complications. Primary outcome variables were surgical site occurrences (SSO) and hernia recurrence. A multivariate regression model was developed to determine significant predictors of SSO.

Results: In 92 consecutive patients, the mean age was 52 years with a mean body mass index of 27.9%. Major comorbidities included diabetes (41%), hypertension (23%), and chronic obstructive pulmonary disease (15%). The mean hernia defect was 13.2 cm and the average operative time was 232 minutes. Complete posterior sheath closure was achieved in 95.6% cases. There were 18 (19.5%) cases of SSO which were managed conservatively and no cases required mesh explanation. There were 2 (2.1%) recurrences which required a redo surgery. On multivariate analysis operative time (p value 0.047) was a significant predictor of SSO.

Conclusions: AWR using the TAR approach offers a robust repair with low overall morbidity. A holistic pre-operative optimisation strategy and a dedicated AWR team can further improve surgical outcomes.

KEYWORDS: abdominal wall reconstruction, posterior component separation, retromuscular repair, sublay, transversus abdominis release

STRESZCZENIE:

Wprowadzenie: Separacja komponentów tylnych (PCS) metodą uwolnienia mięśnia poprzecznego brzucha (TAR) pozwala na przezwyciężenie wad tradycyjnych podejść naprawczych opisywanych w literaturze.

Cel: W niniejszej pracy dokonujemy oceny bezpieczeństwa i skuteczności przedmiotowego podejścia, prezentując wnioski z własnego doświadczenia zdobytego w leczeniu dużej serii złożonych przepuklin brzusznych. Ponadto oceniamy rolę optymalizacji przedoperacyjnej i znaczenie dedykowanego zespołu rekonstrukcji powłok brzusznych (AWR) dla poprawy wyników leczenia operacyjnego.

Materiał i metody: Dokonano retrospektywnej oceny wszystkich pacjentów poddawanych zabiegowi TAR w specjalistycznym ośrodku leczenia przepuklin w latach 2016–2019. Gromadzone dane obejmowały: dane demograficzne, szczegółowe informacje o przebiegu leczenia w okresie okołooperacyjnym oraz informacje o powikłaniach pooperacyjnych. Pierwszorzędowymi zmiennymi wynikowymi były zdarzenia w miejscu operowanym (SSO) i nawroty przepukliny. W celu określenia znaczących czynników prognostycznych wystąpienia SSO opracowano model regresji wielorakiej.

Wyniki: W grupie 92 kolejnych pacjentów średnia wieku wyniosła 52 lata, zaś średni wskaźnik masy ciała – 27,9. Do głównych chorób współistniejących należały: cukrzyca (41%), nadciśnienie tętnicze (23%) i przewlekła obturacyjna choroba płuc (15%). Średni rozmiar defektu przepuklinowego wyniósł 13,2 cm, zaś średni czas pracy 232 minuty. Całkowite zamknięcie tylnej pochewki mięśnia prostego osiągnięto w 95,6% przypadków. Stwierdzono 18 (19,5%) przypadków SSO, w których zastosowano postępowanie zachowawcze; żadnym z przypadków nie była konieczna eksplantacja siatki. Doszło do 2 (2,1%) nawrotów przepukliny, wymagających operacji rewizyjnej. W przypadku analizy wielozmiennowej istotnym predyktorem SSO był czas operacji (wartość p = 0,047).

Wnioski: AWR z wykorzystaniem podejścia TAR pozwala na uzyskanie trwałej naprawy przepukliny przy niskim wskaźniku chorobowości ogólnej. Zastosowanie holistycznego podejścia ma na celu optymalizację przygotowania przedoperacyjnego oraz utworzenie dedykowanego zespołu AWR w celu dalszej poprawy wyników leczenia chirurgicznego.

SŁOWA KLUCZOWE: *posterior component separation*, rekonstrukcja powłok brzusznych, *sublay*, uwolnienie mięśnia poprzecznego brzucha, zamięśniowa plastyka przepukliny

ABBREVIATIONS

ACS – anterior component separation
AWR – abdominal wall reconstruction
BMI – body mass index
COPD – chronic obstructive pulmonary disease
CT – computed tomography
DM – diabetes mellitus
EHS – European Hernia Society
EO – external oblique
ERAS – enhanced recovery after surgery
HWPP – heavy weight polypropylene
IHD – hypertension and ischemic heart disease
IO – internal oblique
PCS – posterior component separation
PEG – polyethylene glycol
PFT – pulmonary function tests
PRS – posterior rectus sheath
RA – rectus abdominis
RS – Rives-Stoppa
SSI – surgical site infection
SSO – surgical site occurrence
TA – transversus abdominis
TAP – transversus abdominis plane
TAR – transversus abdominis release
VAC – vacuum-assisted closure

INTRODUCTION

Complex ventral hernias still continue a significant technical challenge to surgeons due to the high peri-operative morbidity and recurrence rates. The ideal surgical approach remains to be elucidated. Myofascial advancement leading to closure of a hernia defect with autologous tissue is often described as the most physiological reconstruction of ventral hernias [1]. Ramirez et al. [2] popularised the anterior component separation (ACS) technique wherein external oblique (EO) aponeurosis is incised to allow for significant medialisation of the rectus muscles. Although widely used, requirement of skin flaps and the absence of a space for mesh reinforcement resulting in a recurrence rate of up to 30% and wound infection rate of 26–42% are major drawbacks of this technique [3–5]. The Rives-Stoppa (RS) repair emerged as an effective repair with well proven results and a low overall morbidity [6, 7]. It is limited laterally by the linea semilunaris and is therefore inadequate for larger defects.

In 2012, Novitsky et al. [8] described a novel approach to the posterior component separation (PCS) technique. Essentially this is an extension of the retromuscular RS repair resulting in creation of a wide space between the transversus abdominis muscle (TA) and fascia transversalis/peritoneum. This technique allows for creation of a well vascularised plane for prosthetic reinforcement while separating the mesh from intra-abdominal contents. It also avoids the wound morbidity associated with skin flaps. These advantages and promising results of this approach prompted us to implement the procedure in our routine practice.

The goal of this study is to present our preoperative optimisation strategy, technical operative details of the procedure and our long-term results. Our recommendation to create an abdominal wall reconstruction (AWR) team and minimise the operative time may further improve the efficacy and safety of this procedure.

METHODS

A prospectively maintained database of all patients undergoing PCS via the transversus abdominis release (TAR) approach at a tertiary care center catering to a population of 10 million was reviewed after approval from the Institutional Ethics Committee.

All patients admitted in the 2016–2019 period having a hernia defect of 8 cm and above on a pre-operative computed tomography (CT) were included in the review. Patients with a history of acute pancreatitis, retroperitoneal surgery or previously failed retromuscular hernia repair were excluded from the study. Patients who were unfit for general anaesthesia or who had a bleeding diastasis were also excluded.

The data collected consists of patient demographics such as age, sex, body mass index (BMI) and comorbidities, perioperative data such as the type of hernia as per the European Hernia Society (EHS) classification [9], previous hernia repairs, operative time, size of hernia defect, and intraoperative blood loss.

Post-operative data comprised of complications, duration of hospital stay and pulmonary function tests (PFT) 1 month after surgery. A follow up CT scan was done at 3 months to look for completeness of repair and residual collections. Patients were followed up at 2 weeks, 4 weeks, 3 months, 6 months and 1 year.

Primary outcome variables were surgical site occurrence (SSO) and hernia recurrence. An SSO was described as any surgical site infection (SSI), wound dehiscence or wound breakdown, seroma or hematoma formation [10]. SSIs were categorised into superficial, deep and organ space infections [11].

Data was analysed using SPSS 26.0 (Statistical Package for Social Sciences; IBM, Chicago, IL, USA). A chi square test was used for categorical variables and an independent t-test was used for numeric variables to ascertain their influence on SSOs. A multivariate regression model was then developed for the statistically significant variables to evaluate significant predictors of SSO.

TECHNICAL DETAILS

Pre-operative Care

The authors recommend preoperative CT imaging of the abdomen as it delineates the abdominal wall musculature, dimensions of the hernia defect, contents of the hernia, loss of domain, thickness of the oblique muscles, evidence of any underlying retroperitoneal abnormalities and plane of the previously placed mesh. PFTs are performed preoperatively in all patients.

Preoperative patient optimisation holds paramount importance for good surgical outcomes. There are reports of increased complications in patients who are active smokers, who are diabetics with poor glycemic control and who are obese or malnourished [12–16].

So cessation of smoking for 4 weeks, strict glycemic control with HbA1c levels of < 7 gm% and weight loss with a target BMI of do kolejnej linijki 30 kg/m^2 are ensured prior to elective repair.

We offer a holistic approach to all our patients with *anatomical optimisation* done with an abdominal corset designed 2 weeks prior to surgery, *physiological optimisation* by incentive spirometry with progressively tightening the corset to mimic post-operative increase in abdominal pressure, *nutritional optimisation* with high protein diet and *psychological optimisation* with preoperative counselling. Patients with colon as hernia content are given bowel preparation with polyethylene glycol (PEG) prior to surgery.

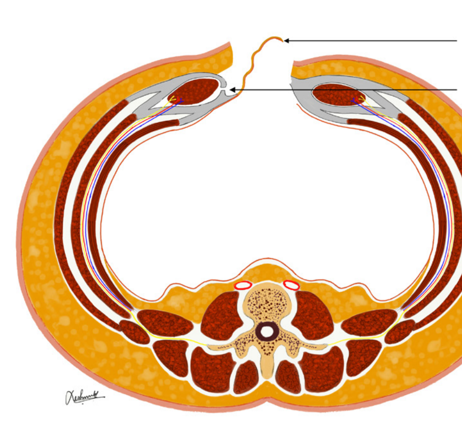

Fig. 1. Incision taken on the posterior rectus sheath (PRS) 5 mm from the medial edge of the rectus abdominis muscle. The hernial sac is kept continuous with the PRS.

SURGICAL TECHNIQUE

We propose a *Decalogue* of TAR.

The patient is operated on under general anaesthesia in supine position.

1. Adhesiolysis

A midline laparotomy with excision of the scar is performed. Entry into the abdomen is based on physical examination (from a virgin area of the abdomen) or CT scan review (where there is a clear pre-peritoneal fat present separating the abdominal wall and viscera). Care is taken where hernial sac is in close proximity to skin to prevent underlying visceral injury. The hernial sac is opened in the midline and depending on the case, it is preserved and kept continuous with the posterior rectus sheath (PRS). All adhesions to the undersurface of the anterior abdominal wall and the abdominal scar are dissected with minimal use of energy devices. Inter-bowel adhesiolysis is avoided.

2. Placement of the TAR towel

A large sterile wet towel is then placed intraperitoneally and is tucked laterally into the paracolic gutters, inferiorly into the pelvis, and superiorly under both domes of the diaphragm to protect the viscera during subsequent dissection.

3. Creation of the Rives-Stoppa Plane

Diastasis of the recti can cause lateralisation of the rectus abdominis (RA) muscle. The medial edge of the RA is identified by palpation or by the twitching of its fibres to electrical stimuli. The PRS-peritoneum complex is then incised 5 mm from its medial edge typically at the level of the umbilicus (Fig. 1.). The retro-rectus plane is identified and the incision on the PRS-peritoneum complex is extended cranially and caudally along its entire length. The retro-rectus plane is developed towards the linea semilunaris by blunt dissection while the assistant retracts the RA muscle superiorly and away from the PRS. Any minor bleeding at this point is controlled with a bipolar electrosurgery unit. The neurovascular bundles (branches of the thoracoabdominal nerves and vessels which penetrate the lateral edge of PRS) are identified and preserved.

Below the arcuate line dissection is continued to develop the pre-peritoneal plane. Here, it is important to identify and preserve the deep inferior epigastric vessels which lie in the pre-transversalis plane along the posterolateral surface of the RA muscle. Inferiorly the space of Retzius is dissected to expose the pubis symphysis and the Cooper's ligaments. The round ligaments are identified in females and are divided to complete the dissection of the Rives-Stoppa plane.

4. Release of TA muscle

The posterior lamella of internal oblique (IO) aponeurosis is then incised 5 mm medially to the neurovascular bundles to expose the underlying TA muscle (Fig. 2.). This is usually done in the upper third of the abdomen ('top-down' approach) since the TA muscle is well defined. Its volume regresses in the inferior third where it is replaced by its aponeurotic component. However, depending on the case, a 'bottom-up' approach can also be used. There is substantial fat in the pre-peritoneal plane in the lower part of the abdomen which facilitates the creation of a retromuscular plane. This is the basis of the 'bottom-up' approach.

Once the TA muscle is identified, it is lifted with Lahey's forceps and its fibres are divided for a length of 4 inches with blend mode of mono-polar electrosurgery. This will allow us to develop the space between the TA muscle and transversalis fascia/peritoneum. This space is extended laterally toward the psoas muscle. Once this tunnelling is completed, the remaining fibres of the TA muscle can be identified with greater ease which are then cut along the entire length of the muscle (Fig. 2.).

5. Creation of the TAR Plane

The abdominal wall is retraced upwards with novel right angled retractors by the assistant, while the left hand of the surgeon applies counter traction over the fascia transversalis/peritoneum (Fig. 3.). An additional mop is placed over the fascia transversalis/peritoneum for further protection. With the help of a peanut dissector the TA muscle is lifted superiorly and away from the transversalis fascia/peritoneum. Laterally the dissection is extended up to the lateral border of the psoas muscle. Overzealous dissection with exposure of ureters is strictly avoided. The plane created can be extended cephalad to the costal margins and dorsal to the

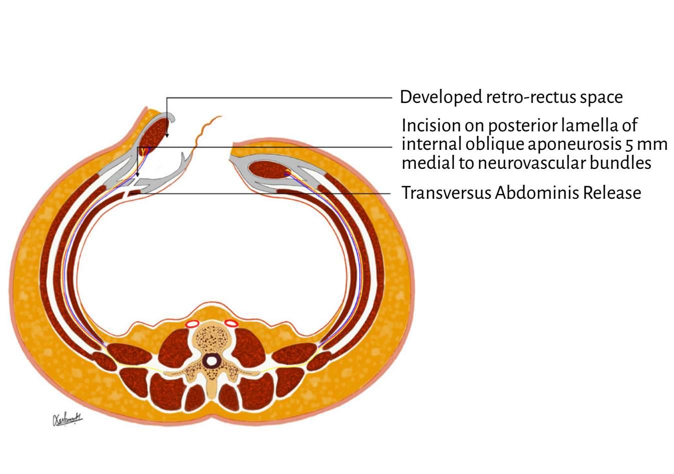

Fig. 2. The Rives-Stoppa plane is developed. Neurovascular bundles are identified and incision taken on the posterior lamella of internal oblique 5 mm medial to the neurovascular bundles to expose the transversus abdominis (TA) muscle. Incision taken on the TA muscle to enter the pretransversalis/preperitoneal plane.

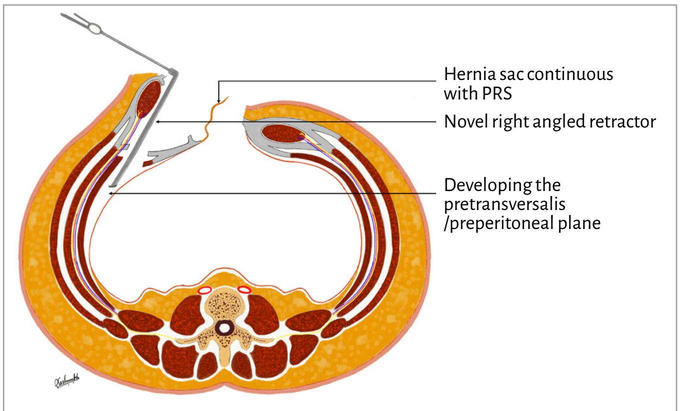

Fig. 3. The transversus abdominis muscle lifted up and away from the fascia transversalis using novel right angled retractors. The pretransversalis /preperitoneal plane developed laterally till the psoas muscle.

sternum in M1 and M2 hernias till central tendon of the diaphragm is visualised. Caudally the space of Retzius is developed in the midline and the space of Bogros is developed laterally.

All peritoneal button holes are sutured at this stage with an absorbable material. Larger defects are buttressed with omentum.

6. TAR on the other side with creation of retromuscular plane

A similar procedure is performed on the other side. The medial attachments of the arcuate line with the linea alba are taken down to create one confluent plane in the lower part of the abdomen. Creation of the retromuscular space and release of the TA muscles allows for significant medialization of the RA muscles (8–12 cm on each side) [8].

7. Closure of the PRS

The intra-peritoneally placed towel is removed gently to avoid peritoneal injury. The PRS is reapproximated in the midline with a running absorbable suture placed 5 mm apart (Fig. 4A.). When faced with difficulty in closure of PRS, two sets of teams start suturing the fascia – one from the cranial end and one from the caudal end with interrupted figure-of-8 sutures to progressively relieve the tension. If the PRS still cannot be closed or a closure is achieved at the cost of a rise in plateau pressures the defect is bridged with portions of the hernial sac or an absorbable mesh (Fig. 4B.).

Next, transversus abdominis plane (TAP) block is given by injecting liposomal bupivacaine into the intramuscular plane between the IO and TA muscles with an 18-gauge needle under direct visualisation [17, 18].

8. Placement of the mesh

Two 30 x 30 cm medium weight polypropylene meshes (MWPP) in home plate configuration [18] are then introduced in the retromuscular plane (Fig. 5. and 6.). The mesh is fixed laterally under physiological tension with two transabdominal sutures to prevent mesh migration and buckling of mesh during closure. Two closed suction drains are placed over the mesh to prevent seroma formation.

9. Closure of the anterior rectus sheath (ARS)

The ARS is then approximated using interrupted nylon sutures to recreate the linea alba ventral to the mesh (Fig. 5.). Allis forceps are used to assess virtual closure of ARS before the actual suturing of the anterior fascia. In instances where the ARS cannot be approximated completely, or there is excessive tension along the suture line, or there is a rise in the plateau pressure of > 5 mmHg, the ARS is closed partially and the residual defect is bridged with a heavy weight polypropylene (HWPP) mesh.

10. Subcutaneous tissue and skin closure

A flat drain is then placed in the subcutaneous plane to prevent seroma formation. Subcutaneous tissue is closed with an absorbable material and skin is closed using either staples or interrupted sutures. A well-fitting pre-operatively designed abdominal corset is applied immediately.

Plateau pressures are monitored during the closure. A rise in plateau pressure of > 5mmHg necessitates keeping the patient intubated for 24 hours while any rise of > 10 mmHg requires mechanical ventilation with neuromuscular blockade in the early post-operative period to prevent abdominal compartment syndrome [19, 20].

Post-Operative Care

Use of narcotics is kept to a minimum since the TAP block provides for adequate analgesia in most patients. Acetaminophen is used to offer further analgesia. Deep vein thrombosis prophylaxis is initiated as per the current recommendations [21]. The patients are made to continue wearing the abdominal corset. Patients are advised bed rest for 48 hours. Diet is advanced according to the enhanced recovery after surgery (ERAS) protocol and patient is put on clear liquids on post-operative day 1 [18, 22, 23]. However transition to soft diet is progressed after complete resolution of post-operative ileus.

Drains are removed once the daily output is < 20 mL. Midline wound check is strictly avoided for 2 weeks till the inflammatory phase of wound healing is over unless there is soakage of the dressing.

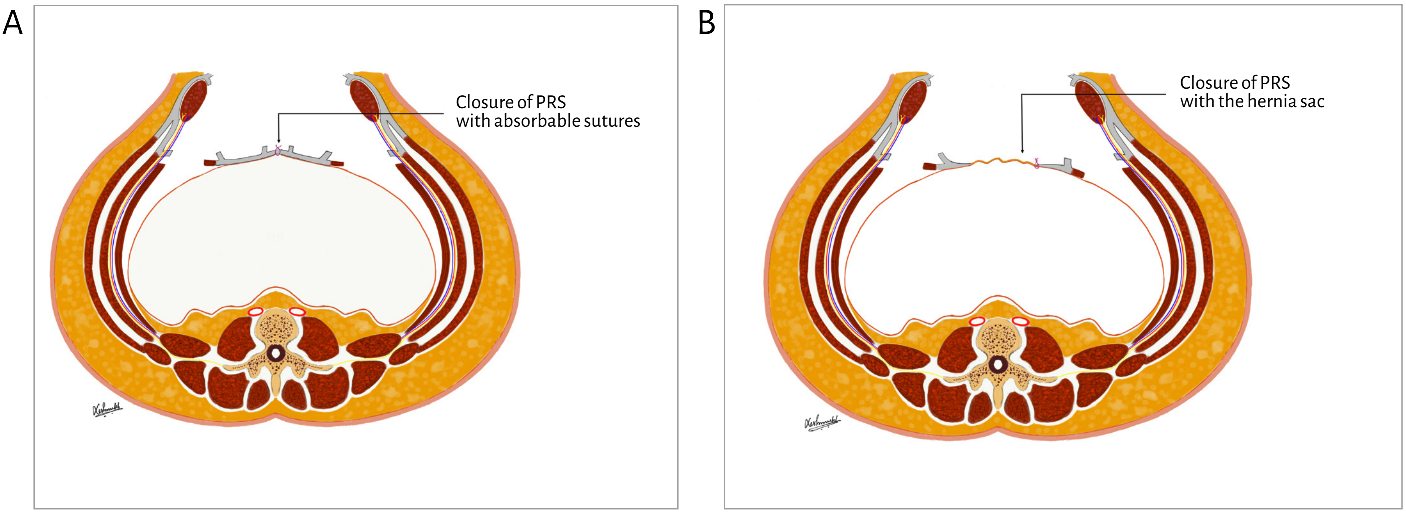

Fig. 4. (A) Complete closure of the posterior rectus sheath done with absorbable sutures after completion of bilateral transversus abdominis release; (B) in cases of incomplete approximation of the posterior rectus sheath (PRS), hernial sac kept continuous with the PRS is used to achieve closure.

Patients are followed up at 2 weeks, 4 weeks, 3 months, 6 months and at one year. A routine follow-up CT scan is performed to look for hernia recurrence and residual collections.

RESULTS

A total of 92 cases were included in the study. The results are summarised in Tab. I. More than half the cases were females. The median age in this cohort was 52 years with one outlier of 88 years. The pre-operative target BMI of < 30 kg/m^2 was achieved in 85 patients. Smoking cessation and glycaemic control was achieved in all the patients of this cohort. Many patients had co-morbidities including diabetes mellitus (DM), chronic obstructive pulmonary disease (COPD), hypertension and ischemic heart disease (IHD). All the patients were cases of incisional hernia and 28 cases had a failed hernia repair in the past.

In the initial 14 surgeries the mean operative time was 302 minutes. Once the team was down the learning curve of the procedure, the overall mean operative time was brought down to 232 minutes. The time frame to completion of each step is noted in Tab. II.

The mean width of hernia defects was 13.2 cm in our study. Despite such a large hernia, complete PRS closure was achieved in all but 4 cases (closure rate of 95.6%). In 3 cases the residual defect was bridged with the hernial sac whereas an absorbable mesh was used to bridge the defect in one case. Anterior fascial closure was achieved in 83 cases (closure rate 90.2%). An HWPP mesh was used to bridge the defect in the remaining 9 cases. One patient underwent a concomitant stoma reversal procedure while one patient underwent cholecystectomy for symptomatic gall stone disease (Tab. III.).

The rise in plateau pressures while closure exceeded 5 mmHg in 5 cases necessitating elective mechanical ventilation for 24 hours. No patients had a rise of plateau pressure greater than 10 mmHg. The post-operative PFTs were comparable to the pre-operative results in all the cases. None of the patients required a peri-operative blood transfusion.

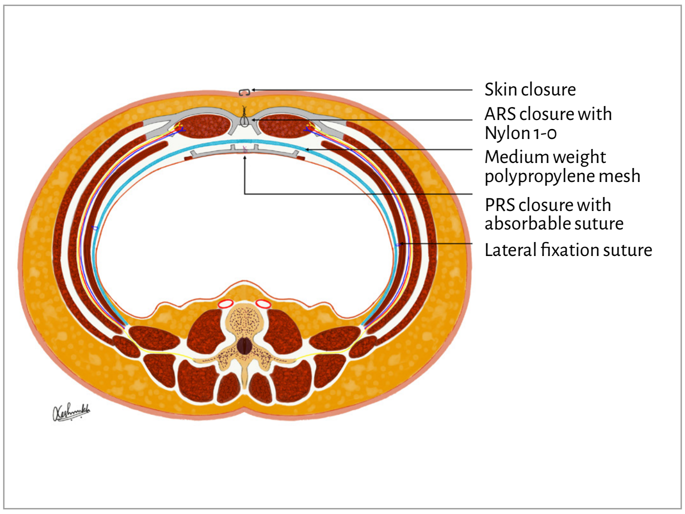

Fig. 5. A medium weight polypropylene mesh placed in the retromuscular plane (TAR plane) and fixed laterally under physiological tension. Linea alba reconstructed ventrally to the mesh using non-absorbable sutures.

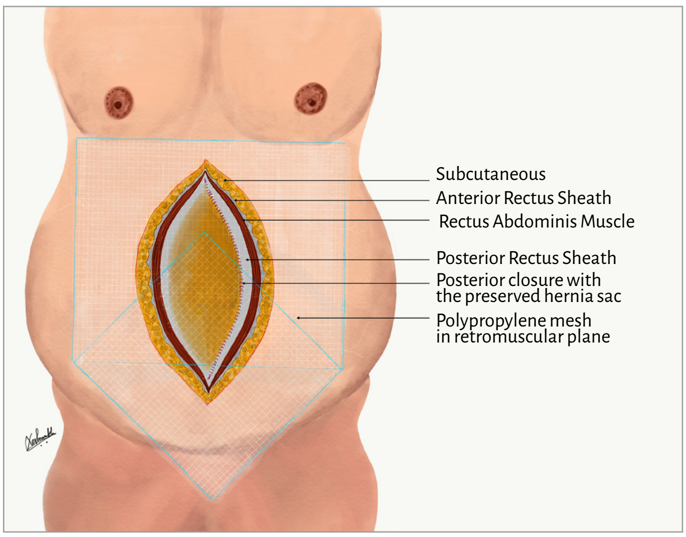

Fig. 6. Two 30 x 30 cm medium weight polypropylene mesh placed in the retromuscular or TAR plane in home plate configuration.

Tab. I. Patient demographics.

TOTAL PATIENTS	92
Sex	
MALE	43 (46.7%)
FEMALE	49 (53.3%)
Age, years	52 (38–66)
BMI [kg/m²]	27,9 (±1.69)
Comorbidities*	
Diabetes Mellitus	38 (41.3%)
Hypertension	22 (23.9%)
COPD	14 (15.2%)
Ischemic Heart Disease	4 (4.3%)
Number of Previous Hernia Repair	
Onlay Repair	22 (23.9%)
Intraperitoneal Repair (IPOM)	6 (6.5%)
Type Of Hernia (EHS Hernia Classification)	
M1	10 (10.8%)
M2	9 (9.7%)
M3	28 (30.4%)
M4	32 (34.7%)
M5	13 (14.1%)

Values are listed as either number (percentage), mean (±Standard Deviation) or median (interquartile range)
* Multiple comorbidities coexisted in a few patients

Tab. II. Breakdown of operative time in minutes.

MEAN OPERATIVE TIME	232
Adhesiolysis	46 (28–88)
Placement of TAR Towel	4 (2–9)
Creating the Rives-Stoppa Plane	17 (14–25)
Ipsilateral Transversus Abdominis Release	21 (16–30)
Creating the Retromuscular Plane	29 (24–42)
Release on Contralateral Side with creation of Retromuscular plane	48 (41–60)
Posterior Rectus Sheath Closure	19 (12–34)
Placement of Mesh	13 (7–22)
Anterior Rectus Sheath Closure	21 (15–45)
Subcutaneous Tissue and Skin Closure	14 (11–27)

Values are listed as mean (range).

All the patients were followed up for one year after surgery.

Eighteen (19.5%) patients developed an SSO of which three (3.2%) were SSIs which were managed with vacuum-assisted closure (VAC). Seven patients developed a seroma of which two symptomatic cases required aspiration after one month. As many as 8.6% of the patients developed wound dehiscence with skin loss, out of which 3 patients were given VAC dressings. The remaining cases were managed with bedside debridement and cleaning. No patients in this review developed post-operative respiratory complications. Fifteen patients (10.8%) were given total parenteral nutrition for 10 days due to a delay in the recovery of bowel function likely due to extensive adhesiolysis.

Two cases (2.1%) developed a recurrence requiring an intervention for repair.

Univariate analysis was first performed on all the collected variables to ascertain their influence on SSOs and hernia recurrence. A multivariate regression model was then developed to evaluate the independent effect of the variables found statistically significant on univariate analysis on the outcome. On univariate analysis, the width of the hernia, centimetres (P value 0.001), operative time, minutes (P value 0.001), failure of anterior sheath closure (P value 0.011) and M2 hernias (P value 0.048) had a significant bearing on the outcome variables. On multivariate analysis, the operative time, minutes (P value 0.047) were a statistically significant predictor of SSO (Tab. V.).

DISCUSSION

The goal of any ventral hernia repair is the restoration of a dynamic and functional abdominal wall. As the complexity of ventral hernia increases, the armamentarium of techniques used for their repair must continue to evolve.

In 1990 Ramirez et al. [2] described the ACS technique which provided medial myofascial advancement of up to 10 cm bilaterally [24]. This was achieved by incising the EO aponeurosis lateral to the linea semilunaris. However, this entailed creation of large lipocutaneous flaps which increased wound morbidity. Development of perforator-sparing techniques and minimally invasive techniques reduced SSOs but could not improve recurrence rates (up to 30%) [25]. The RS repair emerged as an excellent alternative with well proven results and fewer complications. This repair was however limited by the frequent difficulty in closure of the anterior fascia in larger defects and creation of a smaller sublay space.

AWR using the TAR approach addresses these limitations. A major advantage lies in the ability to develop a large retromuscular plane. This plane provides an ideal space for deployment of prosthetics as it is well vascularised resulting in a rapid in-growth and integration of the mesh [26, 27]. However, once this vast dissection is carried out, principles of hernia repair dictate the use of a large mesh to achieve adequate overlap. In all our cases, since a single mesh was insufficient for a desired overlap, two 30 x 30 cm MWPP meshes in a home plate configuration were used. A single 50 x 50 cm MWPP mesh may be used if adequate overlap is ensured.

Another advantage of this approach lies in the ability to recreate the visceral sac. This excludes the mesh from intraperitoneal contents, thus negating the use of expensive composite prosthetics and reducing adhesions and related complications. Closure of the visceral sac was achieved in 95.6% of the cases in this study. For the remaining cases either a part of the hernial sac or an absorbable mesh was used in an inlay position to bridge the defect. This is for this reason that we advocate preserving the

Tab. III. Operative data.

TOTAL PATIENTS	92
Width of Fascial Defect, cm	13,2 (8–19)
Operative Time, min	232 (170–382)
Estimated Blood Loss, mL	200 (50–600)
Complete Posterior Rectus Sheath Closure	88 (95,6%)
Complete Anterior Rectus Sheath Closure	83 (90,2%)
Concomitant Procedures	
Stoma Reversal	1 (1,0%)
Cholecystectomy	1 (1,0%)
Rise in Plateau Pressure, mmHg	
>5	5 (5,4%)
>10	0

Values are listed as either number (percentage), mean (range).

Tab. IV. Post-Operative data.

TOTAL PATIENTS	92
Surgical Site Occurrences (SSOs)*	18 (19,5%)
Surgical Site Infection (SSIs)	3 (3,2%)
Superficial	2 (2,1%)
Deep	1 (1%)
Organ Space	0
Seroma	7 (7,6%)
Wound Dehiscence	8 (8,6%)
Recurrence	2 (2,1%)
Systemic Complications	
DVT/PE	0
MI	2 (2,1%)
UTI	6 (6,5%)
Length of Hospital Stay, Days	14,4 (8–32)

Values are listed as number (percentage) or mean (range).
* Some patients had more than one surgical site occurrence.
DVT indicates deep vein thrombosis; PE, pulmonary embolism; MI, myocardial infarction; UTI, urinary tract infection.

Tab. V. Statistical analysis.

UNIVARIATE ANALYSIS	P VALUE
Operative Time, min	0,001
Width of Hernia Defect, cm	0,001
Closure of Anterior Rectus Sheath	0,011
M2 Hernia	0,048
Multivariate Analysis	**p value**
Operative Time	0,047
Width of Hernia Defect, cm	0,770
Closure Of ARS	0,999
M2 Hernia	0,978

hernial sac onto the PRS in all cases. The authors strongly feel that native body tissue is superior to any foreign prosthetic to achieve closure of the posterior fascia. We found using a second abdominal mop over the fascia transversalis-peritoneal complex resulted in fewer peritoneal button holes while creating the retromuscular plane. Lifting up the TA muscle superiorly rather than pushing the fascia transversalis-peritoneum complex downwards, as traditionally described, was another factor which reduced peritoneal injuries in our practice.

The release of the TA muscles releases the 'hoop tension' created by the synergistic action between the TA muscle and the posterior fibres of the IO muscle [8]. This provides for an increase in the abdominal cavity and significant medial fascial advancement. This led to restoration of the linea alba ventral to the mesh in 90.2% of the cases despite the large size of hernia defects in the present study. A longer duration of the hernia results in increased fibrosis. This fibrotic scar plate may reduce the elasticity of the anterior fascia and may predict difficulty in the closure of the ARS. Allis forceps were routinely used in this study to assess virtual closure of ARS before the actual suturing of the anterior fascia. The plateau pressures were monitored at the time of virtual closure and a rise in the plateau pressure of greater than 5 mmHg prompted us not to close the ARS completely and to bridge ARS with a heavy weight polypropylene mesh. This may explain the minimal requirement of post-operative mechanical ventilation in our patients.

With a 3% SSI rate our results are comparable to the existing literature [8, 27–29] and are favourable to other studies describing PCS techniques [3, 30]. Wound dehiscence and seroma were the major wound complications in our study which were effectively managed with negative pressure wound therapy. In no cases was a mesh explanation required. Minimal use of energy devices, complete obliteration of subcutaneous space and absence of subcutaneous flaps were responsible for minimising wound morbidity. A myofascial cover ventral to the mesh also provided for protection against SSIs. Failure of anterior sheath closure resulted in a higher risk of wound complications and some sort of soft tissue coverage like a rotational rectus femoris flap or a dermis flap may be used to eliminate mesh exposure and reduce contamination.

Several authors have reported recurrence rates of 5% to 7% for Rives-Stoppa repair [7, 31, 32] and 3.1% to 7.3% for other PCS techniques [3, 26, 30]. When compared to other retromuscular repairs, the current study demonstrated similar recurrence rates despite larger and complex hernias. Overall, a TAR plane accommodating larger meshes with a wide overlap of even the largest of hernia defects may explain the low repair failure rates of this procedure. This is in agreement with the Stoppa's philosophy of providing "giant prosthetic reinforcement of the visceral sac" [33, 34]. Preservation of the neurovascular supply to the RA muscles provides for a more functional AWR. In one case lateral displacement of the mesh due to give away of the transabdominal fixation suture was responsible for a recurrence at 3 weeks. An open onlay mesh repair was performed for this patient. The second recurrence was found in case of COPD where excessive coughing in the post-operative period led to a disruption of the fascia transversalis-peritoneum complex. In this case, the polypropylene mesh overlying the defect in the fascia transversalis-peritoneum complex was excised and the underlying defect was bridged with an absorbable mesh.

TAR can be exceptionally challenging in patients with a history of a retro-peritoneal surgery (such as radical cystectomy, pancreatic necrosectomy, excision of a retroperitoneal mass) and in patients with previous attacks of acute necrotising pancreatitis as the resultant retroperitoneal scaring and the loss of tissue planes makes the creation of a retromuscular plane impossible. A previously failed retromuscular hernia repair is also a relative contraindication to TAR. In such situations an ACS or a peritoneal flap hernioplasty should be attempted.

The potential deleterious effects of TAR on the muscles of expiration are a matter of concern [20]. However, no post-operative respiratory complications were noted in our study. We believe that *anatomical rehabilitation* with the use of an abdominal corset, *physiological rehabilitation* by using incentive spirometry with progressive tightening of the corset, *nutritional rehabilitation* with the help of a high-protein diet and *psychological rehabilitation* with pre- and post-operative counselling have been responsible for minimising complications in our study.

The authors postulate that a well-fitting abdominal corset replicates the 'hoop tension' exerted on the abdominal wall by the transversus abdominis muscle. By progressively tightening the corset in the pre-operative period we replicate the increased abdominal pressure (IAP) seen in the post-operative period. Increase in the IAP causes the diaphragm to move towards the cephalic end of the body thereby increasing the intra-thoracic pressures. Gradually, there is physiological adaptation to this increased pressure which explains why only five patients had a rise in plateau pressures of more than 5 mmHg in this study. We feel that this adaptation by the respiratory muscles resulted in pulmonary function tests comparable to the preoperative results in this cohort. The corset also dampens the lateral pull exerted by the oblique muscles which contributes to an increase in the size of the hernia defect. To our knowledge, this is the first study to advocate the use of an abdominal binder pre-operatively to strengthen the respiratory muscles and prevent a post-operative ventilatory failure. However, a larger study is needed to prove the equivalence of this concept.

Nutritional rehabilitation is advocated in all cases to achieve a target BMI of < 30 kg/m^2. A high-protein low-carbohydrate liquid diet with adequate micronutrient and vitamin supplementation is advised to patients for a period of 4–6 weeks to achieve the desired weight loss. This is similar to a diet given to bariatric patients pre-operatively under the guidance of a trained dietician.

Preoperative counselling is of paramount importance as the patients are usually unaware of the complexity of the repair. It is proven to allay anxiety and increase compliance of the patients to the post-operative care plan. This results in an early post-operative recovery and reduced duration of hospital stay [35].

Complete cessation of smoking for 4 weeks, strict glycemic control to achieve HbA1c < 7 gm% and weight loss to achieve a target BMI of < 30 kg/m^2 also aid in improving surgical outcomes [12–16]. Compensatory hypertrophy of the IO, EO and RA muscles, possible only because of preservation of the neurovascular bundles, was noted on the post-operative CT scan [8]. This resulted in a dynamic and robust hernia repair and we are confident about the safety of TAR during AWR.

We also advocate the formation of an AWR team in all specialized hernia centres to minimise the operative time and further reduce complications. A longer operative time increases chances of contamination of the operative field resulting in increased SSOs. In the initial part of our study the lack of coordination between the team members involved led to a longer operative time and increased morbidity. We then standardised our protocol by breaking the steps of surgery. Every team member was trained on cadaveric models to refine their surgical technique. This helped us to develop an AWR team in our department which brought down our average operative time from 302 minutes in the initial 14 surgeries to 232 minutes overall. Once the AWR team was well versed with their respective responsibilities and was adequately trained on the cadaveric models, there was reduced tissue handling which translated to a better patient tolerance post-operatively. We also noticed better surgical outcomes once the role of each member of the team was well defined.

A limitation of this study is that this is a single-institution study conducted in a highly specialized referral centre. Further multicentric studies are required to make the decalogue of TAR a standard of care.

CONCLUSION

In a large cohort with complex ventral hernias, we demonstrate that PCS using the TAR approach provides an effective repair with low failure rates and acceptable SSOs. The ability for extensive lateral development of the retromuscular plane and significant medial myofascial advancement are significant advantages of this approach. This results in a robust repair with restoration of the linea alba even in larger hernia defects. Preservation of the neurovascular bundles leads to a more functional reconstruction of the abdominal wall. Intimate knowledge of the anatomy of the anterior abdominal wall and strict adherence to principles of repair are necessary for good clinical outcomes. We recommend a holistic preoperative optimisation policy and the creation of a specialized AWR team to further increase the safety and efficacy of the procedure.

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