Original Article

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The Impact of Laparoscopic Transversus Abdominis Release on the Intra-Abdominal Pressure in Patients with Large Anterior Wall Defects

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Abbreviations:
TAR: Transversus Abdominis Release;
oTAR: Open Transversus Abdominis Release;
BMI: Body Mass Index;
PID: Phreno-infrapubic diametre;
APD: Antero-posterior diametre;
TD: Transvers diametre;
ACV: Abdominal Cavity Volue;
HSV: Hernia Sac Volume;
PCV: Peritoneal Cavity Volume;
PI: Peritoneal Index;
LOD: Loss of Domain;
IAP: Intra-abdominal pressure;
Pplat: Plateau pressure;
TST: Total surgical time;
RH: right hypochondrium;
LH: left hypochondrium;
RF: right flanc;
LF: left flanc;
RIF: right iliac fosa;
LIF: left iliac fosa.

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Rezumat

Impactul tehnicii laparoscopice Transversus Abdominis Release asupra presiunii intraabdominale în cadrul pacienților cu defecte parietale abdominale anterioare mari

Introducere: Acest studiu are ca obiectiv evaluarea impactului datelor demografice, stilul de viață, caracteristicile cavității abdominale asupra presiunii intraabdominale înainte şi după tratamentul minim invaziv prin tehnica Transversus Abdominis Release al marilor defectele parietale abdominale. De asemenea, studiul integrează rolul tomografiei computerizate (CT) ca investigație necesară interpretării caracteristicilor defectului şi al muşchilor, ce poate stabili indicația efectuării tehnicii TARşi la evaluarea rezultatelor obținute, alături de modificările presionale intraabdominale (IAP) şi ale presiunilor de platou (Pplat).
Metode: Acest studiu prospectiv a inclus un lot de 20 de pacienți cu defecte parietale cu lățimea mai mare de 10 cm, ce au fost investigați şi tratați într-un singur centru de chirurgie, în perioada 2019-2023. Toate intervențiile au fost realizate de către aceeaşi echipă prin tehnica TAR pe cale laparoscopică. În cadrul evaluării preoperatorii a fost inclusă şi efectuarea unei tomografii în vederea măsurării dimensiunilor defectului, volumele, dar şi presiunile intra-abominală şi de platou. Datele obținute au fost integrate sistematic într-o bază de date dedicată, cu urmărire postoperatorie la 6 luni.
Rezultate: Lotul de studiu a constat în 20 de pacienți, toate de sex feminin, cu un IMC mediu de 26,81 ± 3,05, iar volumul sacului herniar (HSV) a fost în medie de 159,01 ± 189,79 cm^3. Aria defectului a fost de 69,53 cm^2 (± 30,11). Presiunea intraabdominală a scăzut în medie de la 5 cmH2O (± 1,28) pre-operator la 1,91 cmH2O (± 1,93) postoperator. De asemenea s-au înregistrat scăderi ale Pplat după operație. Variațiile de presiune au fost influențate de localizarea topografică a defectului, cu presiuni mai mari observate în defectele epigastrice, şi de caracteristicile defectelor peritoneo-fasciale,

incluzând numărul, dimensiunea şi localizarea, care influențează rezultatele postoperatorii. În plus, s-au identificat corelații între dimensiunile muşchilor abdominali antero-laterali şi modificările de presiune. Aceste constatări subliniază importanța unei evaluări preoperatorii cuprinzătoare a caracteristicilor defectului, anatomiei musculare şi localizării defectului pentru a previzualiza modifiările de presiune şi pentru a ghida planificarea chirurgicală.
Concluzii: Un IMC mai mare şi defectele parietale mari, multiple, prezic creşteri ale IAP şi Pplat postoperator. Parametrii volumetrici şi morfometrici preoperatori, localizarea defectului şi caracteristicile topografice influențează semnificativ rezultatele presiunii. Tehnica TAR gestionează eficient defectele mari, minimizând creşterile de presiune, dar luarea în considerare a factorilor morfologici este crucială pentru rezultate optime.

Cuvinte cheie: presiune intraabdominală (IAP), presiuni de platou (Pplat), Transversus Abdominis Release (TAR), defecte parietale mari, tratament minim invaziv

Abstract

Introduction: The objective of this study was to collect and analyze data on patient demographics, lifestyle, abdominal cavity characteristics, and their impact on intra-abdominal pressure before and after minimally invasive treatment of large parietal defects in hernia pathology. Additionally, the study examines the role of the CT scan as a reliable and valid measure of defect and muscle characteristics, which can help establish the indication for performing Transversus Abdominis Release (TAR) and evaluate the outcomes of this procedure along with differences in intra-abdominal pressure (IAP) and plateau pressure (Pplat).
Methods: This prospective study involved 20 patients with parietal defects wider than 10 cm, treated over four years at the Central Military Hospital in Bucharest. All procedures were performed using the laparoscopic TAR technique by the same surgical team. Preoperative assessments included CT imaging to measure defect size, volumes, and IAP. Data including defect dimensions, muscle measurements, IAP, and Pplat were systematically recorded in a dedicated database with a follow-up at 6 months with clinical and imaging evaluations.
Results: In our cohort of 20 patients, all female, the mean BMI was 26.81±3.05, and the hernia sac volume (HSV) averaged 159.01±189.79 cm^3. The defect area was 69.53 cm^2 (±30.11). IAP decreased from 5 cmH2O (±1.28) preoperatively to 1.91 cmH2O (±1.93) postoperatively. The reduction in Pplat was similarly significant. Pressure variations were influenced by the topographic location of the defect, with higher pressures seen in epigastric defects, and by the characteristics of the peritoneo-fascial defects, including number, size, and localization, which affect pressure outcomes. Additionally, dimensions of the anterior-lateral abdominal muscles correlated with pressure changes. These findings highlight the importance of comprehensive preoperative assessment of defect characteristics, muscular anatomy, and defect location for predicting pressure reductions and guiding surgical planning.
Conclusions: Higher BMI and large, multiple parietal defects predict increased IAP and Pplat postoperatively. Preoperative volumetric and morphometric parameters, defect localization, and topographic characteristics significantly influence pressure outcomes. The TAR technique effectively manages large defects while minimizing pressure increases, but consideration of morphological factors is crucial for optimal results. Further research is needed to refine patient selection and surgical strategies.

Keywords: intra-abdominal pressure (IAP), Plateau pressures (Pplat), transversus abdominis release (TAR), large parietal defects, minimally invasive treatment

Introduction

Ventral hernias, particularly those classified as complex, present a challenging surgical scenario often necessitating innovative approaches for optimal patient outcomes. In recent years, the surgical landscape has witnessed a paradigm shift towards minimally invasive techniques, offering advantages such as reduced postoperative pain, shorter hospital stays, and faster recovery. Among these techniques, the TAR procedure has gained prominence due to its ability to address complex ventral hernias effectively. This surgical procedure involves the release of the transversus abdominis muscle, a key component of the abdominal wall, with the aim of facilitating the closure of large defects and restoring abdominal integrity. There are also many factors that increase the risk of developing this type of condition, that vary depending on the patient, his way of life, working conditions, as well as certain external factors (1,2,3).

The gold standard of parietal surgery is the alloplastic procedure, through the sub-lay positioning of a mesh in order to reduce parietal tension, as seen in TAR. This distension is achieved by the lateral extension to the Spigel line of TAR procedure in relation to Rives-Stoppa by creating a retromuscular preperitoneal space (1,2,4).

Repairing a ventral hernia (VHR) presents several challenges, notably the reconstruction of the abdominal wall while ensuring that herniated tissues are repositioned into the abdominal cavity without significantly increasing IAP. The physiopathology of midline VHs often leads to a shortening of the lateral abdominal musculature and a descent of the diaphragmatic dome, which reduces the volume of the abdominal cavity. Consequently, reintroducing herniated tissues into this smaller cavity can result in intra-abdominal hypertension (IAH), potentially leading to abdominal compartment syndrome (ACS) and serious complications for the patient. It is understood that as IAP increases, the defect area of a ventral hernia is likely to expand. However, the current literature lacks definitive evidence regarding the extent of this increase in vivo. Thus, the primary aim of this study was to objectively assess how the ventral hernia repair impacts IAP using TAR procedure (5,6).

Recent studies have shown that employing minimally invasive surgical techniques, such as TAR procedure, can significantly reduce tissue trauma and help maintain adequate abdominal cavity volume. Also these approaches lower the risk of increasing intra-abdominal pressure during the repair of ventral hernias (7). Additionally, optimizing surgical strategies through minimally invasive methods can lead to better postoperative outcomes by mitigating the risk of IAH. Finally, using such techniques not only improves recovery times but also enhances overall patient safety during ventral hernia repairs (8).

The hypothesis of this study is that the TAR procedure reduces IAP following the closure of large ventral wall defects. Additionally, lifestyle factors and preoperative characteristics of the defect and abdominal cavity may influence pressure variations. Recent studies suggest that TAR, by providing a more controlled and less traumatic approach to hernia repair, facilitates optimal reconstruction of the abdominal wall while adequately accommodating the herniated contents. For instance, research indicates that the anatomical realignment achieved through TAR can enhance lateral abdominal muscle engagement, thereby promoting a better reduction in IAP compared to traditional repair methods (9,10). Moreover, the ability of TAR to expand the abdominal cavity volume during repair may prevent the onset of abdominal compartment syndrome, ultimately leading to improved postoperative outcomes and reduced risk of complications associated with elevated IAH. Thus, it is posited that the application of TAR during ventral hernia repair can lead to a notable decrease in pressure within the abdominal cavity, which is crucial for patient safety and recovery (7).

Materials and Methods

This study presents a prospective review conducted in the Surgery Department 1 at the Central Military Emergency University Hospital in Bucharest, where all surgical procedures were performed by the same surgical team and consist of laparoscopic TAR. We focused on a cohort of patients diagnosed with abdominal wall defects from 2019 to 2024, analyzing relevant variables such as patient demographics, hernia characteristics, surgical details, and IAP. The primary aim of the study is to highlight the relationship between patient lifestyle and the development of larger parietal defects. Additionally, it examines changes in IAP and anatomical modifications before and after the TAR procedure. The hypothesis is that the TAR procedure reduces intra-abdominal pressure following the closure of large ventral wall defects, while lifestyle factors and preoperative characteristics may influence pressure variations.

All patients included in the study were admitted and evaluated using a standardized algorithm and therapeutic principle. This involved an initial outpatient consultation, which included conducting a thorough medical history, a comprehensive clinical examination of systems, and a local examination to identify parietal defect characteristics. Pain, as a symptom, was measured using the Numeric Rating Scale (NRS), ranging from 0 (no pain) to 10 (most severe pain), with a significance threshold set at 4. The duration from onset to surgical intervention was recorded in months. During this first consultation, the patient was informed about the general therapeutic sequence, potential perioperative complications, their management, and surgical intervention scheduling. The next step involved completing outpatient admission documentation for preoperative evaluation, including blood tests. To assess the locoregional characteristics of the parietal pathology, a three-level CT scan (chest, abdomen, and pelvis) was performed. The resulting images were analyzed by both the radiology and surgical teams to measure relevant diameters and volumes, aiding in determining the appropriate surgical technique. IAP was measured preoperatively and on the first postoperative day using bladder catheterization techniques. Intraoperatively, all vital signs, Pplat, defect characteristics, and TAR technique specifics were recorded. The follow-up period for those patients was at 6 months. All patients were thoroughly informed about the study, and no special consent was required.

Inclusion criteria comprised patients over 18 years old, clinically and paraclinically diagnosed with a parietal defect wider than 10 cm, according to Slater's criteria (11). Abdominal wall defects treated with posterior component separation technique (laparoscopic TAR) and alloplastic re-inforcement were included.

Exclusion criteria involved patients who, after admission, investigation, and refusal of the proposed surgical intervention or those for whom other alloplastic or tissue repair procedures or open TAR (oTAR) procedure were conducted.

Statistical Analysis

In this study, we used both parametric and non-parametric statistical methods to analyze the data. The Shapiro-Wilk test was used to assess the data distribution, while the Spearman's rank correlation was used to evaluate associations. For normally distributed data, analysis of variance (ANOVA) followed by post-hoc Tukey tests was performed. In cases of non-normal distribution, the Kruskal-Wallis test and Mann-Whitney U test were utilized.

Preoperative Evaluation

In preoperative evaluation, each patient underwent native abdominal-pelvic CT scan and the images were interpreted by both surgical and radiological team. the shape of the defect is considered to be oval and the dimensions were measured for maximum lenght and width. Subsequently the defect surface is calculated using the formula (12):

$$Ad = \pi\ (l_d/2)(L_d/2) = \pi/4 \times l_d \times L_d \quad (13)$$

In case of multiple defects, the total surface of the defects was considered for this study. The rectus sheath width was also measured to calculate the Carbonell`s algorithm (14) which indicates the posterior components separation technique when the maximum width of the defect is greater than twice the rectus muscle sheath.

The Abdominal Cavity Volume (ACV) and the Hernia Sac Volume (HSV) were calculated using the formula:

$$ACV = 4/3\pi\ (\text{transvers diameter}/2) \times (\text{phreno-infrasymphyseal diameter}/2) \times (\text{antero-posterior diameter}/2) \approx TD \times PID \times APD/2$$

$$VSH = 4/3\pi\ (\text{width of hernia sac}/2) \times (\text{lenght of hernia sac}/2) \times (\text{heigth of hernia sac}/2) \approx \text{width hernia sac} \times \text{lenght hernia sac} \times \text{heigth of hernia sac}/2$$

Afterwards, the Peritoneal Cavity Volume (PV) is calculated by the sum of those two volumes. The Peritoneal Index (PI) represents the loss of domain (LOD) and it is calculated by the ratio between HSV and ACV (15,16).

The Sabbagh method it is also used to define the percentage of the LOD of the contents and it is measured by the ratio between HSV and PV (17).

At the preoperative clinical examination are highlighted the biological status (blood tests), comorbidities such as hypertenssion, diabetes and their treatment because of their importance in healing the postoperative wound and the risk of occurrence of general complication during surgery. Patients are encouraged to avoid tabacco and alcohol comsumption for one month before the surgery. Also the sarcopenia index plays an important role in postoperative recovery and the recurence rate. In this case it is recommended to perform a minimum daily medium effort, in order to maintain the muscle tonicity. The deficits in blood tests are subsequently corrected and a hyperprotein diet is recommended before the intervention to maintain muscle tone (18,19).

Intraabdominal Pressure

The IAP is determined by the intravesical pressure. After the urethro-vesical catheterization, the patient remains in the supine position for the most accurate of the measurements. It is used approximately 50-100 ml of saline which are administered intravesical via a perfusor connected to the distal end. The bladder catheter is then directed to the anterior superior iliac spine and the perfusor upright and the fluid column is measured in cmH2O, subsequently converted to mmHg. The IAP is measured the day before surgery and 24 hours later.

Intraabdominal hypertension is a term used for increase intraabdominal pressure which is sustained over time. This hypertension has several grades: grade I (pressure = 12-15 mmHg/16-21 cmH2O), grade II (pressure = 16-20 mmHg/22-27 cmH2O), grade III (pressure = 21-25 mmHg/28-34 cmH2O) and grade IV (pressure > 25 mmHg/>35 cmH2O) (20,21).

Abdominal compartment syndrome is defined as intraabdominal pressure greater them 20mmHg associated with at least one organ failure (22).

When the patient is under general anesthesia the Pplat is measured. This represents the positive pressure applied to the airway during mechanical ventilation and is defined as the difference between the pressure recorded 20 minutes after oro-tracheal intubation and 20 minutes after the closure of the defects. If the difference exceed 6 mmHg, it is recommended to keep maintain the intubation 24 hours (23).

Intraoperative Management

After the first evaluation and all the acido-basic and hydro-electrolytic correction, patients with parietal defects corresponding to Carbonell`s algorithm (11) were selected in order to perform the bilateral TAR procedure. Also, during the surgery, our team measured the plateau pressure, the blood loss and the preservation of the neuro-vascular bundles that are distributed to the rectus muscle. Another important factors is the exposure time of the mesh with and the total intervention time. The peritoneal-fascial defects caused during the dissection of the transversus abdominis muscle were assessed and categorized into three groups. Group A includes 1-2 defects, Group B encompasses 3-5 defects, and Group C consists of more than 6 defects. The dimensions of the peritoneo-fascial defects were divided into four groups as follows: Group 0 (no fascial defect), Group 1 (0.5 – 1 cm), Group 2 (1 – 2 cm), and Group 3 (2 – 4 cm). The localization of these defects during the disinsertion of the TA muscle was represented topographically at the lateral spaces (hipocontracture – H, flank – F, iliac fossa – IF) for each side (right – R, left – L).

TAR Procedure – Laparoscopic

Patient positioning

In the minimally invasive technique, the patient's positioning is similar to that of the classical approach, with the arms in full abduction. Placement of the patient on the operating table should allow for the lowering of both the cephalic and cranial extremities, facilitating thoracic extension for better exposure of the abdominal field. General anesthesia with orotracheal intubation is employed. The skin is prepared with antiseptic solutions based on chlorhexidine, and the abdominal surgical field is established.

Trocar placement

An incision is made in the skin at the level of the left hypochondrium, and a 10 mm trocar is inserted retromuscularly under video guidance after incising the anterior sheath of the rectus abdominis muscle, followed by the introduction of CO2 at a pressure of 12 mmHg. Dissection is performed using the videoscope, facilitated by the CO2 insufflation of the left retromuscular space. A 10 mm trocar is inserted along the semilunar line, inferior to the optical trocar. Through this trocar, an electrosurgery instrument is introduced to continue the retromuscular dissection caudally and cranially. A 5 mm trocar is then placed inferiorly to facilitate the dissection. Using the triangulation method (with the central optical trocar and lateral working trocars), the dissection of the retromuscular space proceeds towards the medial margin.

Contralateral dissection

Using the monopolar electrosurgery device, the sheath of the rectus abdominis muscle is incised at the medial margin, approximately 5 mm from the insertion of the posterior sheath. The adipose tissue within the falciform ligament is visualized, dissected, and removed from the linea alba while maintaining its integrity. The posterior sheath of the contralateral rectus abdominis muscle is identified and incised about 5 mm from its insertion along the linea alba. The continuation of the dissection in the right retromuscular space is facilitated by the CO2 insufflation. Subsequently, a 10 mm trocar is placed subcostally on the right side, medial to the ipsilateral semilunar line.

Management of the fatty triangle

In cases where the defect is located in the lower abdomen (e.g., hypogastric), dissection of the fatty triangle near the xiphoid is typically avoided. When the defect is higher, dissection of this area is performed carefully, preserving the disinsertion plane of the transversus abdominis and avoiding diaphragm sectioning. The fatty triangle, characterized by adipose tissue in the preperitoneal and prevesical spaces, requires meticulous removal of excess fat while preserving blood supply. When extensive, resection or liposuction may be used to reduce dead space and facilitate mesh coverage, especially over the retroxiphoid area, minimizing the risk of recurrence and postoperative fluid collections. The mesh is extended cranially when needed to ensure complete coverage of the defect and the fatty triangle region.

Dissection of the hernia sac

With the main surgeon positioned cranially to the patient and utilizing the right subcostal optical trocar, the dissection of the right retromuscular space is performed caudally. The medial insertions along the linea alba of both posterior sheaths are incised down to the level of the parietal defect while preserving the linea alba intact. The hernia sac is dissected, and its contents are reduced. The dissection continues inferiorly to the level of the arcuate line described by Douglas, connecting the two retromuscular spaces. Depending on the location of the parietal defect, it may be necessary to extend the dissection to the prevesical space described by Retzius, ensuring that the mesh to be placed encompasses at least 5 cm from the edge of the defect.

Posterior component separation

At this point in the surgery, if the two medial edges of the posterior sheath cannot be closed in a "tension-free" manner, the insertion of the transversus abdominis muscle will be transected. This maneuver begins at the cranial end where it is easier to perform. By applying traction and countertraction on the posterior sheath, a minimal incision is made approximately 0.5 to 1 cm medial to the semilunar line, near the corresponding neurovascular pedicles. This allows for the exposure of the medial insertion of the transversus muscle fibers, which are then transected from cranial to caudal. The prefascial space (between the transversalis fascia and the transversus abdominis muscle) is then dissected, allowing for medial advancement of the posterior sheath by up to 10 cm. The release of the transversus muscle insertion facilitates the closure of the posterior layer without tension. Additionally, this maneuver can be extended to the contralateral side.

Closure of the posterior and anterior layers

After reduction of the hernia contents, the anterior defect is closed with a continuous suture to prevent postoperative seroma formation. The posterior layer is checked for any disruption that may occur due to the detachment of the transversus muscle fibers. Any disruptions can be closed with absorbable multifilament sutures to prevent contact between the underlying viscera and the mesh. The hernia sac is utilized to close the posterior layer formed by the peritoneum and the two medial edges of the posterior sheath without tension using a continuous suture.

Mesh placement

Using a measuring instrument, the dimensions of the newly created space are assessed, and the mesh is resized to maintain a "diamond" shape. After haemostasis is controlled, the prosthetic material, generally a lightweight polypropylene mesh with high porosity, is introduced into the space and stretched to cover the parietal defect, extending at least 5 cm beyond its edges. The mesh is placed without fixation (suturing or tacks), with its stability maintained mainly by the muscular tone and compression within the space, which has dimensions similar to the mesh. If the created space is too large to be covered by a single mesh, two meshes can be used with an overlap between them to ensure adequate coverage. Proper positioning is confirmed visually, and in cases of extensive dissection, a pre-prosthetic suction drain may be placed to reduce fluid accumulation. Subsequently, under video guidance, the introduced gas is gradually expelled to ensure the mesh remains in position during the closure of the retromuscular-preperitoneal space. The trocars are then removed under visual guidance, followed by suturing of the skin.

Attention is directed to compliance with the Early Recovery After Surgery protocol, from which we accomplish a faster recovery after surgery and social reintegration. The aim of the protocol is the early mobilization and if the patient has good tolerance, early per os nutrition is starting from 6 hours for solids and 2 hours for liquids (28,29).

The follow up is at 6 months and we performed a CT scan to visualize the integration of the mesh and any complications that may occur (20).

Results

Out of a total of 64 patients only 20 are suitable for this study and all of them were females. *Table 1* reveals that the patient population in this study generally consists of older individuals who are predominantly overweight, with significant underlying health issues such as hypertension and a notable percentage of smokers.

Table 2 presents the average values of both the measured IAP and Pplat, as well as the differences between postoperative and preoperative values.

A significant association was observed between elevated BMI and increased postoperative IAP (p = 0.012). Age did not appear to be significantly associated with measured pressures before and after surgery; however, a decrease in IAP and Pplat was noted in elderly patients. Similarly, smokers exhibited a decrease in pressures both pre- and postoperatively, suggestive of a potential association. Additionally, a significant correlation was identified between higher scores on the pain scale and elevated Pplat preoperative (p = 0.016).

In relation to the association between parietal defect dimensions, as detailed in *Table 3*, a tendency was observed for larger Ad to be associated with higher postoperative IAP (p= 0.090). Similarly, an increased number of parietal defects exhibited a comparable trend, though without statistical significance. The TAR index was associated with lower preoperative Pplat (p = 0.052) and higher postoperative Pplat (p = 0.021).

Furthermore, significant differences Pplat and postoperative IAP were identified based on the localization of the parietal defect, as illustrated in *Table 4*.

Following the Mann-Whitney test, significant differences were identified between the various localizations of parietal defects, as confirmed by the comparison of their medians. Thus, both plateau pressures and intraabdominal pressures showed higher values in cases of epigastric localization compared to juxtaumbilical and suprapubic sites, as detailed in *Tables 5, 6, 7*.

The mean values of diameters and volumes are represented in *Table 8*. Significant associations include a higher PID being correlated with a lower preoperative Pplat (p = 0.037). A higher APD is significantly associated with a lower postoperative

Table 1. Patient characteristics and medical history.

Characteristics	Value (mean ± SD)
Age (mean ± SD, years)	63.42 ± 6.96
BMI (mean ± SD)	26.81 ± 3.05
Pain (mean ± SD, months)	10 ± 3.55
Smokers (nr)	7
ASA (class, nr of patients)	II (15), III (5)
Hypertension (nr of patients)	15
Diabetes mellitus (nr of patients)	7

Table 2. Plateau pressure and intra-abdominal pressures measurements.

Pressures measurements	Value (mean ± SD)
Pplat preoperative (cmH2O)	22.67 ± 3.73
Pplat postoperative (cmH2O)	21.08 ± 2.71
Pplat difference (cmH2O)	1.92 ± 0.9
IAP (mmHg)	5 ± 1.28
IAP (mmHg)	1.91 ± 1.93
IAP difference (mmHg)	3.08 ± 2.31

Table 3. Defect characteristics.

Defect characteristics	Value (mean ± SD)
Location of defect (nr)	M2 = 16, M4 = 2, M5 = 4
Length (mean ± SD, cm)	7.31 ± 2.76
Width (mean ± SD, cm)	11.99 ± 0.99
Area (mean ± SD, cm2)	69.53 ± 30.11
Defects (mean ± SD, nr)	1.67 ± 0.65
TAR Index	1.82 ± 0.89

Table 4. Kruskall-Wallis test applied on locations of defects.

Pressure	p value
IAP postoperative	0.074
Pplat preoperative	0.012
Pplat postoperative	0.012
Difference in Pplat	0.013

Table 5. Mann-Whitney test applied on the epigastric and juxtaumbilical defects

Pressure	Epigastric	Juxtaumbilical	p value
IAP postoperative	3 mmHg	2 mmHg	0.064
Pplat preoperative	24 cmH2O	22 cmH2O	< 0.001
Pplat postoperative	23 cmH2O	21 cmH2O	< 0.001

Table 6. Mann-Whitney test applied on the juxtaumbilical and suprapubic defects

Pressure	Juxtaumbilical	Suprapubic	p value
IAP preoperative	6 mmHg	5 mmHg	< 0.001
IAP postoperative	2 mmHg	1 mmHg	< 0.001

Table 7. Mann-Whitney test applied on the epigastric and suprapubic defects.

Pressure	Epigastric	Suprapubic	p value
IAP postoperative	3 mmHg	1 mmHg	0.025
Pplat postoperative	23 cmH2O	21 cmH2O	< 0.001
Difference in Pplat	1 cmH2O	3 cmH2O	< 0.001

Pplat (p=0.022). Notably, the near-significant values observed include the association between increased PID and decreased postoperative intra-abdominal pressure (p=0.097), as well as increased TD with higher preoperative intraabdominal pressures (p=0.095), which may suggest a more significant visceral adipose tissue layer.

The association between increased HSV values and higher postoperative Pplat was found to be statistically significant (p=0.043). Moreover, elevated ACV is associated with lower post-operative Pplat (p=0.012) and with a larger plateau difference (p=0.034). A trend toward an association between higher ACV and lower post-operative intraabdominal pressure was noted (p=0.078). Additionally, an increased Sabbah value may contribute to higher postoperative Pplat (p=0.002) and a larger plateau difference (p=0.094).

The dimensions of the anterior-lateral abdominal muscles (width and thickness) are outlined in *Table 9*. The measurements of the RA were associated with Pplat postop: higher RA width values correlated with lower Pplat postop (p= 0.002), while increased RA thickness was associated with higher values (p=0.020).

Dimensions of the OE showed a tendency toward association: larger OE width values tended to correlate with higher preoperative IAP, approaching the significance threshold (p=0.063), and with lower values of the Pplat difference (p=0.034). Additionally, larger OE thickness showed a trend toward association with higher postop Pplat (p=0.096).

Greater OI width values were associated with lower IAP preop (p=0.002) and with a smaller Pplat difference (p=0.065), approaching statistical significance.

A wider TA was associated with lower values of postop Pplat (p<0.001), postop IAP (p=0.083), and Pplat difference (p=0.047). Moreover, higher TA thickness values tended to correlate with lower postop Pplat (p=0.073). Increased TA section area was significantly associated with a larger plateau difference (p=0.032).

The number of peritoneo-fascial defects was

Table 8. Preoperative diameters and volumes.

PID (mean ± SD, cm)	39.94 cm
APD (mean ± SD, cm)	16.91 cm
TD (mean ± SD, cm)	27.01 cm
ACV (mean ± SD, cm^3)	8607.26 ± 1058.79
HSV (mean ± SD, cm^3)	159.01 ± 189.79
PCV (mean ± SD, cm^3)	8766.28 ± 1067.19
Peritoneal Index	1.01 ± 0.01
Sabbah (mean ± SD, %)	1.35 ± 1.13

Table 9. Preoperative measurements of the muscles.

Measurement	Value (mean ± SD)
RA width (cm)	6.96 ± 3.07
RA thickness (cm)	0.93 ± 0.17
OE width (cm)	13.24 ± 1.5
OE thickness (cm)	0.95 ± 0.35
OI width (cm)	12.07 ± 1.41
OI thickness (cm)	0.77 ± 1.12
TA width (cm)	10.6 ± 3.71
TA thickness (cm)	0.76 ± 0.19
TA section area (cm^2)	5.47 ± 3.98
Muscle wall thickness (cm)	2.48 ± 0.55

divided into three groups, as described in the "Materials and Methods" section and highlighted in *Table 5*. The total surgical time (TST) was calculated for each group, and a statistically significant differences between these groups was identified using ANOVA testing (p=0.014), as shown in *Table 10*.

Later we performed post-hoc Tukey`s test which highlighted a significant statistical difference between groups as shown in *Table 11*.

The impact of the total number of peritoneo-fascial defects on IAP and Pplat was evaluated, revealing an association between a higher

Table 10. The patient`s surgical time in each defect`s group.

Group of defects (nr)	Patients (nr)	TST (average, min)
A (1 – 2)	3	225
B (3 – 5)	14	263.8
C (> 6)	3	265

Table 11. The post-hoc Tukey`s test of groups.

Groups of defects	p value
A – B	p = 0.995
A – C	p = 0.020
B – C	p = 0.024

number of defects and elevated postoperative Pplat, approaching statistical significance (p=0.066). Subsequently, a more detailed analysis was performed to assess the effect of defect localization on these pressures. Following the application of the Kruskal-Wallis test, significant differences were observed in postoperative IAP (p=0.049). Further, the Mann-Whitney test was employed to calculate median pressure values for each defect localization, resulting in significant differences, as presented in *Table 12*.

On the left side, defect occurrences were limited to two areas (LF and LIF), with no statistically significant differences observed in pressure values.

Differences and their impact on pressures between groups based on defect dimensions were also identified using the Kruskal-Wallis test, which revealed significant differences among the groups. Specifically, on the right side, statistically significant differences were observed in IAP differences (p=0.009), postoperative Pplat (p=0.007), and Pplat differences (p<0.001). On the left side, significant differences were detected in postoperative Pplat (p=0.012).

The Mann-Whitney test was subsequently applied, and median values for groups based on defect dimensions were calculated, as presented for the right side in *Table 13* and for the left side in *Table 14*.

It should be noted that in 4 cases, anterior layer closure could not be performed due to increased tensioning of the parietal tissue and suturing quality issues. In these instances, closure was avoided through anatomical or alloplastic methods. Statistical analysis comparing patients who underwent anterior layer closure with those whose defect remained open did not reveal significant differences in IAP and Pplat, according to the Mann-Whitney test. 2 of these cases had IAP on postoperative day 1 that was higher than the pressure recorded before the surgery, with a pressure difference of 1 cmH2O, yet this did not impact the Pplat postop or the quality of life and no action was needed.

No complications were recorded in this patient cohort during the follow-up period.

Table 12. Differences in peritoneo-fascial defect localizations based on postoperative IAP, assessed using the Mann-Whitney test.

Defect localization	p value	Median
RH – RF	0.019	0 – 2
RH – RIF	0.020	0 – 1
RF – RIF	0.810	-

Table 13. Differences among groups based on the dimensions of the peritoneo-fascial defects and the application of the Mann-Whitney test on the right side.

Dimension groups	p value	Median difference
	Difference in pressure	
Group 0 – Group 1	0.005	2 mmHg – 4 mmHg
Group 1 – Group 2	0.711	-
Group 0 – Group 2	0.103	-
	Pplat postop	
Group 0 – Group 1	0.173	-
Group 1 – Group 2	0.040	21 cmH2O – 22.5 cmH2O
Group 0 – Group 2	0.007	21 cmH2O – 22.5 cmH2O
	Pplat difference	
Group 0 – Group 1	0.005	2 mmHg – 3 mmHg
Group 1 – Group 2	0.30	-
Group 0 – Group 2	0.429	-

Table 14. Differences among the defect dimension groups and application of the Mann-Whitney test on the left side.

Dimension groups	p value	Median difference
	Pplat postop	
Group 1 – Group 2	0.173	-
Group 2 – Group 3	0.103	-
Group 1 – Group 3	0.005	21 cmH2O – 23 cmH2O

Discussion

Our results demonstrated a significant association between elevated BMI and increased IAP postoperative (p = 0.012), a finding consistent with studies by Liang et al. (24), which highlight that large defects and obesity exacerbate the risk of increased IAP and complicate surgical techniques. Although these differences did not reach statistical significance, trends suggest that age and smoking may influence these parameters, but their impact remains subtle, as supported by research from Sonnenberg (25).

Large parietal defects, particularly those exceeding 10 cm in width or involving multiple defects, can lead to elevations in IAP and Pplat, similar findings confirmed by Schlosser et al. (26), who reported a clear association between large defects and significant increases in pressures (p < 0.05). Our observations, in conjunction with these studies, underscore the importance of carefully evaluating defect size and number to accurately estimate the risk of postoperative pressure elevation.

Large hernia sac volumes are associated with higher Pplat, while increased ACV and APD are correlated with lower pressures, and a larger TD with higher preoperative IAP. Additionally, higher Sabbah indices are significantly correlated with increased postoperative Pplat (p=0.002) and larger differences between Pplat preoperative and postoperative (p=0.094). These findings suggest visceral fat redistribution, and are corroborated by studies from Muresan et al. (27), which emphasize the importance of preoperative tomographic measurements for risk assessment and personalized surgical planning.

The RA width was significantly correlated with lower postoperative Pplat values (p = 0.002), suggesting that a broader musculature may aid in reducing IAP by providing better anterior abdominal support. Conversely, increased RA thickness was associated with higher Pplat (p = 0.020), indicating a complex relationship between muscle structure and biomechanical function. These observations align with findings by García Moriana et al. (28), suggesting that muscle size and composition influence elasticity and pressure tolerance, emphasizing the importance of preoperative muscle assessment in surgical planning.

Defects localized in the epigastric region are particularly associated with higher Pplat and IAP values (p = 0.012 and p = 0.025, respectively). Larger and multiple defects are also correlated with significant increases in these pressures. Furthermore, the specific location of peritoneo-fascial defects, particularly those in the RF and RIF regions, are associated with higher or more variable pressures after closure, reflecting how defect position and size influence pressure dynamics through posterior layer tensioning. These findings underscore the necessity for thorough defect evaluation during TAR procedures and the tailoring of technical approaches to minimize risks associated with intra-abdominal pressure elevation, in line with the studies by McCulloch (29) and Misseldine (30).

Conclusion

Elevated BMI and defect characteristics, particularly large and multiple parietal defects, are key predictors of increased IAP and Pplat postoperatively, emphasizing the importance of detailed preoperative assessment to identify patients at higher risk.

Preoperative volumetric and morphometric parameters, such as hernia sac volume, Sabbah index, and muscle dimensions, significantly influence intra-abdominal pressure, highlighting the importance of imaging-based risk stratification for personalized surgical planning.

Specific defect localization, especially in the epigastric region, and peritoneo-fascial defects occurring in certain topographic areas such as the hypochondrium and iliac fossa and subsequently closed, along with defect size, markedly impact intra-abdominal pressure dynamics post-surgery.

The TAR technique offers a valuable approach for managing large abdominal wall defects, primarily by enabling defect closure while minimizing postoperative pressure increases. However, despite these advantages, it is essential to consider certain morphological and biomechanical factors, such as defect localization, muscular dimensions and more, to achieve optimal and favorable outcomes. Additionally, further research is necessary to expand the current evidence base, refine patient selection criteria, and enhance technical strategies. Continued investigation will be crucial to fully understand and maximize the benefits of TAR in complex abdominal wall reconstructions.

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Author's Contributions

Conceptualization: M.A.V., D.C., V.S.; Data curation: M.A.V.; Formal analysis: M.A.V.; Funding acquisition: M.A.V.; Investigation: M.A.V.; Methodology: M.V.A.; Resources: M.A.V., V.S., C.B., A.N., A.B..; Software: M.A.V., C.B., A.N., A.B.; Validation: M.A.V., D.C., V.S., F.L.T., D.E.G., O.E.; Visualization: M.A.V.; Writing - original draft: M.A.V., F.L.T., D.E.G., O.E.; Project administration: D.C. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

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Institutional Review Board Statement

The study was conducted in accordance with the Declaration of Helsinki, and approved by Ethics Committee of Dr. Carol Davila Clinical Emergency Hospital (Nr. 565/20.12.2022).

Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

Data Availability Statement

Datasets analyzed or generated during the study are available on demand, contact the corresponding author.

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