„TITU MAIORESCU" UNIVERSITY, BUCHAREST

DOCTORAL SCHOOL

FIELD OF MEDICINE

MINIMALLY INVASIVE APPROACH THROUGH TAR (TRANSVERSUS ABDOMINIS RELEASE) TECHNIQUE IN ABDOMINAL PARIETAL DEFECTS – INDICATIONS, RESULTS

Doctoral Supervisor:

PROF. DR. COCHIOR DANIEL M.D.

Doctoral Candidate:

VASILE MIHAI ALEXANDRU M.D

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Introduction

The pathology of the abdominal wall, particularly hernias, has been extensively studied over time, but the evolution of surgical techniques has not always guaranteed long-term satisfactory outcomes. Hernias affect both males and females, having diverse etiologies and mechanisms influenced by individual factors, living conditions, and external elements. Initially, treatment focused on repairing parietal defects through anatomical suturing; however, high recurrence rates led to the development of modern techniques, including synthetic prosthetics to cover defects.

In the past two decades, minimally invasive surgery has redefined this field by offering procedures that reduce abdominal wall trauma, accelerate postoperative recovery, and provide economic benefits. Choosing appropriate therapeutic strategies remains critical, particularly in complex cases, given the high risk of complications and recurrences. In this context, the technique of posterior component separation, performed in the preperitoneal retromuscular space, has gained popularity due to favorable outcomes and reduced risks, becoming preferred in specialized centers.

The posterior component separation method, introduced and developed over time, allows the installation of large mesh coverings, preventing complications such as intervisceroparietal adhesion syndrome. Compared to the anterior separation technique, TAR offers the advantage of avoiding large cutaneous flaps and limitations in juxtaosseous hernias, being applicable in complex cases such as subxiphoid or post-transplant hernias. Studies have highlighted encouraging results regarding quality of life, reconstruction longevity, and the functional and aesthetic advantages of this minimally invasive approach.

Nevertheless, TAR technique is not without risks. Potential complications, including continuity solutions, deep infections, or neurovascular structure injuries, require extensive knowledge and surgical experience. Hence, clinical and paraclinical studies and experiences are essential for correct patient selection, surgical technique optimization, and risk reduction of complications.

The general objectives pursued in this thesis are:

- Optimization of the procedure for patients with parietal defects.
- Correlations between clinical-paraclinical findings and surgical technique in patients with parietal pathology.
- Evaluation of immediate and long-term postoperative outcomes.
- Identification of prognostic factors for complications and their optimal management.
- Correlation of the surgical technique with clinical-paraclinical data, comorbidities, and patient's biological status.
- Comparison of results obtained from the analysis of two study groups and identification of specific indications for each approach.

The doctoral thesis titled "MINIMALLY INVASIVE APPROACH THROUGH TAR (TRANSVERSUS ABDOMINIS RELEASE) TECHNIQUE IN PARIETAL DEFECTS – Indications, Results" is a prospective study conducted over six years (2019-2024), targeting postoperative outcomes and clinical-paraclinical correlations of the posterior component separation technique, both minimally invasive and open, applicable to a patient cohort. All patients benefited from the implementation of the Early Recovery After Surgery protocol adapted to parietal surgery by the same surgical team from Surgery Section 1 at the Central Military Emergency University Hospital Bucharest. A well-established perioperative algorithm was utilized to evaluate associated comorbidities, diagnose parietal pathology, adhere to operative timings, and assess postoperative results. Inclusion criteria were patients with anterolateral parietal defects suitable for the TAR technique, both minimally invasive and open. Exclusion criteria were patients who refused surgery or underwent a different procedure.

Chapter 1: General information

1.1. Embryology of abdominal wall development

During ontogenetic development, following the fusion of the embryonic folds, the reuniens membrane forms, serving as the foundation for the development of the abdominal wall muscles. These muscles originate from the last seven thoracic somites and the first lumbar somite, with the latter responsible for the psoas major muscle. The anterior portions of the mioamelas invade this membrane, with the neurovascular bundle following their trajectory; subsequently, the components fuse to form the abdominal muscles and their aponeuroses. The involved nerves include the intercostal nerves VII-XI, subcostal nerves, iliohypogastric, ilioinguinal, and genitofemoral nerves, while the arteries are intercostal, subcostal, and lumbar. These muscles exhibit a primitive metamerism characterized by tendinous intersections at the level of the rectus abdominis, reflecting their segmental organization. [1]

As development progresses, the abdominal wall consists of three primitive muscular layers: external, middle, and internal, each with fibers following different trajectories. The neurovascular bundles are distributed obliquely, from posterior to anterior, among these layers, maintaining their primitive origins. The external oblique muscles derive from the outer layer, the internal oblique and rectus abdominis from the middle layer, and the transversus abdominis and quadratus lumborum from the internal layer, with their neurovascular supply being intermuscularly distributed between these layers. [1,3]

1.2. Anatomy and physiology of the abdominal wall

During embryological development, the abdominal wall muscles form in the sixth week from metameric myotomes of the mesoderm. By the twelfth week, the rectus abdominis derives medially, while the antero-lateral muscles (external oblique, internal oblique, transversus abdominis) develop laterally and migrate toward the end of the seventh week. [2] The muscle fibers have oblique trajectories, providing essential functions such as static and dynamic trunk stabilization, facilitating flexion, rotation, and lateral tilting movements. The tonicity of these muscles supports visceral function and can be affected by visceral inflammation, increasing hernia risk. [3] In respiration, abdominal muscles assist in expiration, coughing, vomiting, and support urination, defecation, and childbirth. [3]

The superficial layer of the wall comprises skin, subcutaneous fat, and the fascia (fascia externa). The musculo-aponeurotic component includes three pairs of lateral muscles—external oblique, internal oblique, transversus abdominis—and one pair of rectus abdominis. [4,5,6] The external oblique lies beneath the fascia externa and is covered by fascia transversalis; the internal oblique and transversus have intermuscular trajectories separated by superficial and deep interparietal fasciae, facilitating dissection and potential hernia formation. The intermuscular space between internal oblique and transversus abdominis contains the intercostal, iliohypogastric, and ilioinguinal nerves and vessels, crucial in surgical procedures.[4,5,6]

Functionally, the abdominal wall is organized into resistance pillars:

- median linea alba anteriorly;
- lateral linea alba laterally at the junction between muscle and aponeurosis;
- posterolaterally, the posterior aponeuroses of internal oblique and transversus abdominis;
- posteriorly, the vertebral column.

The muscle belts are classified as:

- anterior (rectus and pyramidalis);
- lateral (external and internal obliques, transversus abdominis);
- posterior (quadratus lumborum, paravertebral muscles);
- superior (thoraco-abdominal diaphragm);
- inferior (pelvic diaphragm). [7]

The external oblique, the most superficial of the three lateral muscles, originates from the lower margins and outer surfaces of the last eight ribs, forming a trapezoidal shape with borders defined by the iliac crest, spino-umbilical line, ribs V-XII cartilage, and a vertical line intersecting rib IX. Its aponeurosis continues and attaches to the xiphoid process and the linea alba, extending over the outer lip of the ilium and the SIAS. Its superficial surface contacts the origin of the pectoralis major, while the deep part adheres to the last six ribs and the internal oblique. As a paired muscle, it produces unilateral trunk tilting and rotation, and bilateral flexion and expiration.

Innervation comes from thoracic nerves V-XI, subcostal nerves, and iliohypogastric nerves; vascularization is via intercostal, subcostal, and circumflex iliac arteries. Venous return occurs through their corresponding veins, and lymph drains via intercostal, lumbar, diaphragmatic, and iliac lymph nodes. [8]

The internal oblique, positioned between the external oblique and transversus abdominis, originates from the thoracolumbar fascia and iliac line, inserting onto the last four ribs, linea alba, and sometimes intercalating with the aponeurosis of transversus. Unilateral contraction causes ipsilateral tilting and rotation; bilateral contraction depresses the ribs and aids expiration and trunk flexion. Its blood supply comes from intercostal, epigastric, and musculophrenic arteries, innervated by thoracic nerves VIII-XI, subcostal, iliohypogastric, and ilioinguinal nerves. [9]

The transversus abdominis muscle, located in the deepest plane, forms a 'corset' around the abdomen. It originates from the last six ribs, thoracolumbar fascia, the inner lip of the ilium, and the inguinal ligament. It has a quadrilateral shape, with borders: superiorly from the costal arches to the lower thoracic aperture; posteriorly, continuous with the posterior aponeurosis, reinforced by the thoraco-abdominal fascia; anteriorly, defined by the semilunar line and linea alba; and inferiorly, forming a conjoint tendon with the internal oblique. The insertion is on the linea alba, pubic tubercle, and pectineal line, separated from the transversalis fascia. The intermuscular space between the transversus and internal oblique carries the intercostal, subcostal, iliohypogastric, and ilioinguinal vessels and nerves. Its main action is increasing intra-abdominal pressure, essential in defecation, childbirth, coughing, and forced expiration. The blood supply is from the epigastric, intercostal, subcostal, and lumbar arteries, innervated by the thoracic nerves T6-T12, L1, iliohypogastric, and ilioinguinal nerves. [8,10]

The rectus abdominis, a paired muscle, extends from the base of the thorax to the pubic symphysis, with fibers segmented into 3 to 6 muscle bellies separated by intermediate tendons. Its origin includes costal cartilages V–VII, the xiphoid process, and the surrounding aponeurosis; insertion is on the pubic symphysis and pubic crest, sometimes along with the ligament of Henle. In the upper part, its aponeurosis forms leaflets that join to constitute the linea alba, while in the lower part, the aponeurosis disappears contact with the transversalis fascia. Laterally, this zone forms the semilunar line or the lateral abdominal line. Anteriorly, the muscle contacts the anterior sheath and the inferior pyramidalis muscle; posteriorly, it faces the anterior surface of the costal cartilages VI–IX, separated from the preperitoneal tissue by the transversalis fascia. At the level of the umbilicus, musculature fuses in the linea alba, which on the lateral side forms the lateral sulcus. The muscle maintains visceral position, participates in trunk or pelvic flexion, and is involved in forced expiration. Its blood supply is from the superior and inferior epigastric arteries, and its innervation stems from the thoracic nerves T5–T12, subcostal, iliohypogastric, and ilioinguinal nerves. [11,12]

The pyramidalis, an inconstant triangular-shaped muscle, arises from the pubic symphysis and, with fibers running obliquely medially, inserts onto the linea alba in the anterior sheath of the rectus abdominis, contributing to tensioning the linea alba and maintaining the integrity of the anterior abdominal wall. [13,14]

Regions of the abdominal wall

In the study of the abdominal wall regions, emphasis is placed on the antero-lateral area, which is conventionally divided into three levels (superior, middle, and inferior) by two horizontal lines, and into six regions delineated by vertical and horizontal lines. The superior level contains the epigastric region, situated between the xiphoid process and the rib cage, while laterally are the hypochondriac regions. The middle level includes the umbilical region, centered on the anterior abdominal wall, and the lateral regions or flanks (right and left). The lower level, beneath the bi-spinal line, comprises the hypogastric region, continued laterally by the inguinal regions. These delimiters are important in parietal defect pathology due to their anatomical relationships and stratification. [15,16]

The epigastric region, at the center of the superior level, is bounded by the xiphoid process, the rib arches, and the inferior thoracic fascia, containing parts of the stomach, liver, pancreas, and the abdominal segment of the aorta. The umbilical region, centrally located on the anterior wall, is marked by the L4 vertebral level, which corresponds to the bifurcation of the aorta and the inferior vena cava. Here, the preperitoneal tissue adheres to the scars of the connective tissue, being devoid of the strict fascia of the exoabdominal wall. The pubic or hypogastric region, bounded by the bi-spinal line, contains structures such as the medial umbilical ligament and the preperitoneal space. [17]

The hypochondriac region, located laterally and superiorly near the costo-diaphragmatic recess, houses organs such as the liver, stomach, and spleen, with relationships to the costal recess. The lateral (flank) region, bounded superiorly by the rib line and the axillary line, contains the thigh muscles and intercostal arteries IX-XI, serving as an access point for lumbar approaches and for the ascending and descending colon. The inguinal region, located inferiorly, includes the inguinal canal, with the transversalis fascia forming its posterior wall, and the inguinal regions or iliac fossa, both crucial in hernia pathology. [18]

Weak zones of the antero-lateral abdominal wall

The linea alba is a tendinous ridge extending from the xiphoid process to the pubic symphysis, representing a key surgical landmark, especially for laparotomies and a common site for epigastric and juxtaumbilical hernias. [19]

The semilunar line, initially described at the junction of the transversus abdominis and its aponeurosis, forms a curve with medial concavity where vessels and nerves pass through perforations, serving as potential hernia sites during intra-abdominal pressure increases (e.g., coughing or tumors). [20]

The umbilical region is a vulnerable zone, prone to hernias, due to the absence of the exoabdominal and transversus fasciae, and the presence of a peritoneal recess that favors direct and indirect hernias, with the umbilical ring serving as the embryological remnant. [21]

The inguinal canal is a weak area of the anterior wall, with an oblique trajectory of approximately 4 cm, connecting the peritoneal cavity to the scrotum in men and the labia majora in women. It is bounded anteriorly by the external and internal oblique aponeuroses, posteriorly by the transversalis fascia, and includes the inguinal ligament, which supports the canal structures and plays a vital role in hernia formation. [22]

Inguinal hernias occur through the mio-pectineal gap, bounded superiorly by the transversus abdominis muscle and inferiorly by the pectineus muscle and Gimbernat's ligament, classified into direct, indirect, and femoral types depending on their point of passage and ligamentous boundaries.[23]

The femoral ring, situated between Gimbernat's ligament and the femoral vein, has a larger diameter in women, explaining the higher prevalence of femoral hernias among females, and continues into the femoral canal, which drains into the femoral vein—making this a common site for femoral hernias. [24]

Chapter 2: Clinical aspects of parietal pathology

2.1. Definition

A hernia is a surgical pathology characterized by the protrusion of an abdominal or pelvic viscus through a parietal defect or a weak zone of the abdominal wall.

2.2. Epidemiology

From an epidemiological perspective, ventral wall defects rank second after inguinal hernias, with an incidence of approximately 25-35%. The most common types are umbilical and epigastric hernias. Ventral defects are characterized by anterior-lateral abdominal wall weakness, without inguinal or hiatal localization. Annually, around 350,000 ventral hernia repairs are performed in general surgery departments. [25]

Despite advances in minimally invasive techniques, laparotomy remains the most frequently used approach in abdominal surgery. A French study by the Programme de Médico-organisation des Systèmes d'Information (PMSI) reported 361,004 laparotomies and 288,224 laparoscopies, with incisional hernia rates of 11.3% for laparotomy patients and 9.9% for laparoscopic cases. [25]

2.3. Classification of parietal defects

Over time, several classifications of ventral hernias have been proposed to compare their characteristics. The first classification, described in 2000 by Chevrel and Rath, focused on three main parameters: defect location, size, and the number of surgical interventions performed for curative purposes, categorizing hernias as R0 (no interventions), R1 (one intervention), and Rn (two or more interventions). [26]

In 2005, Bassi and Ammaturo expanded this classification by adding a new parameter: the ratio of the defect surface to the abdominal wall surface. Later, in 2009, the European Hernia Society (EHS) proposed a separate classification for primary hernias and incisional hernias, further refining the categorization. [26]

Primary hernia:

<table>
<tr><td rowspan="5">According to defect location</td><td rowspan="3">Median</td><td>Epigastric</td></tr>
<tr><td>Juxtaumbilical</td></tr>
<tr><td>Subumbilical</td></tr>
<tr><td rowspan="2">Lateral</td><td>Lumbar</td></tr>
<tr><td>Spiegelian</td></tr>
<tr><td colspan="2" rowspan="3">According to defect size</td><td>Between 0 and 2 cm</td></tr>
<tr><td>Between 2 and 4 cm</td></tr>
<tr><td>Larger than 4 cm</td></tr>
</table>

Tabel 2.3.1. – *Classification of primary hernias*[26]

I. Secondary hernia:

According to defect location	Median	M1 = subxiphoid
		M2 = epigastric
		M3 = umbilical
		M4 = infraumbilical
		M5 = suprapubic
	Lateral	L1 = subcostal
		L2 = flank
		L3 = iliac
		L4 = lumbar
According to defect size		W1 = between 0 and 4 cm
		W2 = between 4 and 10 cm
		W3 = grater than 10 cm

Tabel 2.3.2. – C*lassification of primary hernias* [26,27]

An additional criterion was integrated for hernia recurrence, namely recurrence itself. In the case of multiple parietal defects located along the same incision, these are classified separately; from a dimensional perspective, the distance between the most lateral edges of each defect is used for sizing [27].

The recently introduced HPW classification evaluates hernias based on three parameters: the parietal defect, categorized as H1 (<10 cm), H2 (10-20 cm), and H3 (>20 cm); [28] the degree of comorbidities, classified as P0 (none) or P1 (at least one of obesity, diabetes, smoking, or immunosuppression); and the contamination level of the wound, classified as W0 (clean) or W1 (contaminated). This classification facilitates the estimation of recurrence risk and morbidity. [8]

2.4. Diagnosis and clinical examination

The identification and characterization of a hernia rely on a thorough patient history and a comprehensive clinical examination to gather all necessary information. Anamnesis may reveal lifestyle and work conditions involving significant physical effort or prior surgical history in the case of incisional hernias. One of the main reasons for presentation at a medical facility is the appearance of a pseudotumoral formation at the level of the anterior-lateral abdominal wall or along a post-surgical scar. This mass may display an expansile character during provocation maneuvers or following intense physical effort, can be reducible both at rest and upon palpation, and may be accompanied by painful discomfort. [29]

2.5. Paraclinical examination

Ultrasound of soft tissues is a dynamic, straightforward imaging method that directly visualizes the hernial defect and sac without exposure to radiation. In contrast, computed tomography (CT) provides detailed images in multiple planes, assisting in surgical planning, but involves ionizing radiation and may cause hernias to appear smaller in the dorsal decubitus position. Imaging results reveal the number, size, location of defects, sac contents, and musculature status, making them crucial for preoperative planning and postoperative assessment [30]. CT measures the sac volume relative to the peritoneal cavity to evaluate the feasibility of tension-free treatment. Alternatively, MRI offers accurate images without radiation exposure. [31]

2.6. Risk factors

Risk factors for hernias are classified into three main categories: factors that increase intra-abdominal pressure, such as coughing, sneezing, and physical effort; factors related to the patient's biological status, including age, sex, body mass index, and associated conditions; and factors related to previous surgical interventions. Additionally, causative factors like the persistence of the peritoneal-vaginal canal in inguinal hernia are noted, along with predisposing factors divided into congenital, physiological (age, sex, occupational effort), and pathological (neoplasms, digestive or urinary disorders), which weaken the abdominal wall in vulnerable areas [32].

Chapter 3: Mesh

3.1. History

The term "protection" in Greek means "to place in front," inspiring the use of reinforcement materials for parietal defects in hernias. In antiquity, Egyptians and Greeks used bandages, containment devices, and threads of silver or gold for reducing and suturing hernias [33]. In 1940, Dr. Burke introduced the first tantalum metal prosthesis; however, postoperative complications led to research into other materials such as nylon, polypropylene, PTFE, Dacron, and polyethylene, developed to decrease the risk of infection and hernia recurrence. [3]

3.2. Generalities

Ventral parietal defects, commonly affecting males and accounting for up to 15% of work disability cases, have historically been repaired using anatomical techniques that generate parietal tension and carry a recurrence risk of 25-30%. Advances in technology have led to the adoption of synthetic meshes designed for tension-free procedures, significantly reducing recidivism and improving postoperative outcomes [3]. Initially, rigid materials increased postoperative pain; to withstand maximum intra-abdominal pressure, the Light-Weight mesh concept was developed, featuring a reduced surface area and increased elasticity, which decreased inflammatory response, though the risks of recurrence and infection remain. [34]

More recently, composite meshes combining materials such as titanium and ePTFE with polypropylene or polyester have been used in intraperitoneal spaces to minimize adhesions. Additionally, collagen matrix biomaterials have been developed to promote rapid tissue integration and remodeling, but they pose a risk of recurrence in contaminated environments [3].

3.3. Properties

Meshes must have a tensile strength of at least 180 mmHg to withstand intra-abdominal pressures around 170 mmHg. Light-weight meshes are preferred due to their higher elasticity and better tissue response, offering greater flexibility compared to heavy-mesh prostheses. High porosity facilitates tissue integration, while modern composite materials, such as titanium and polypropylene, enable rapid recovery but may have reduced resistance in contaminated environments. The elasticity of meshes varies between 20-35% for light-weight types and 4-16% for heavy-mesh, affecting the abdominal wall's distensibility.[35]

3.4. Complications of prosthetic materials

Each type of mesh offers specific advantages: ePTFE meshes reduce the risk of adhesions but increase the likelihood of postoperative infection, whereas polypropylene meshes are durable and limit infections but tend to promote adhesions and rigidity. The risk of postoperative infection varies between 0.1% and 3%, being higher in parastomal hernias or contaminated wounds. Low porosity (<10 μm) impairs immune cell migration, increasing infection risk, while high porosity (>75 μm) reduces this risk; antiseptic impregnation may further be beneficial. [36]

The recurrence rate of hernias is significantly decreased with mesh use, although late recurrences are often linked to improper fixation, reduced dimensions, or collagen imbalances occurring after 2-3 years. Postoperative pain diminishes with alloplastic techniques but can persist in cases of nerve injury or reactions to small porosity materials, and complications such as seroma formation and material degradation—especially in polyester—may lead to calcification. [37]

3.5. Biological meshes

A primary goal of parietal surgery is infection control, leading to the use of biological meshes with acellular collagen matrices, which have shown success rates of up to 75% in contaminated fields and up to 90% in sterile conditions. The cross-linking technique enhances the mesh's strength and inhibits angiogenesis, thereby increasing resistance to degradation, while the stripping method reduces the incorporation capacity by modulating cellular growth. [38]

3.6. Quality of postoperative scar formation

The body's response to prosthetic materials manifests as an inflammatory reaction that stimulates collagen synthesis. Light-weight meshes with high porosity promote the conversion of type III collagen into type I, thus rapidly enhancing tensile strength after surgery. Polypropylene meshes support superior collagen formation with no significant differences observed between types I and III. [39]

3.7. Body response

The immune response to prosthetic materials involves both acute and chronic inflammation, which facilitate healing; however, an excessive reaction can lead to complications, and it is influenced by the surface and type of the material. [40]

3.8. Bacterial Colonization

The immune response to prosthetic materials involves both acute and chronic inflammation, which facilitate healing; however, an excessive reaction can lead to complications, and it is influenced by the surface and type of the material. [41]

Chapter 4: Open approach of the TAR procedure

4.1. Tehnica operatorie

The patient is positioned in dorsal decubitus with arms abducted, head and legs inclined at 10-15°, and general anesthesia with intubation ensures abdominal muscle relaxation. The surgical field is prepared with antiseptic solutions, a urinary catheter and nasogastric tube are placed, and the abdomen is exposed from the xiphoid process to near the pubic symphysis, with the parietal defect marked.

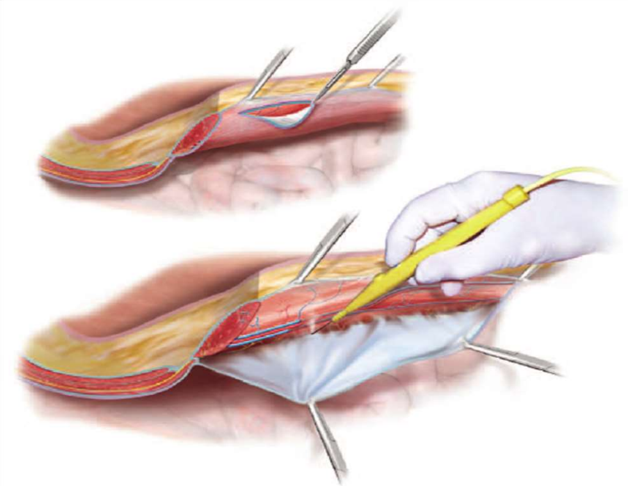


Figure 4.1.1 – Incision of the right rectus sheath and retromuscular dissection[42]

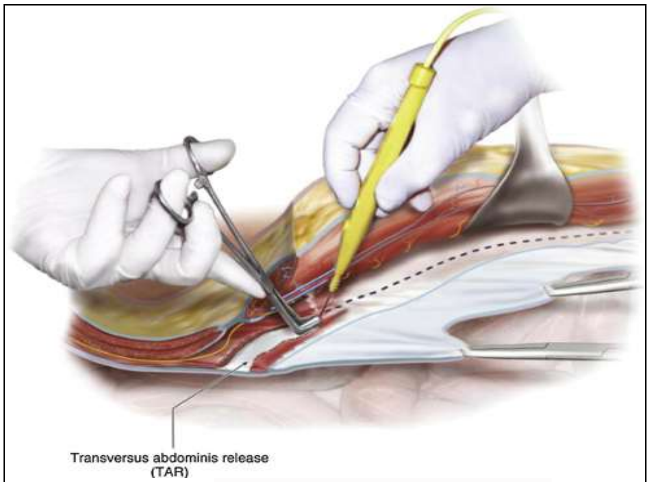


Figure 4.1.2. – Section of the transversus abdominis muscle insertion [43]

A median xifo-suprapubic incision is made, and all abdominal wall layers are opened carefully to avoid hernia content injury. Visceral adhesions are released using electrocautery, with visceral lysis performed in cases of intense adhesions to facilitate access. Sutures and previous materials are removed to prevent complications. A sterile field is established for protection. Dissection of the retromuscular space begins at 1 cm lateral to the right rectus muscle border, starting cranially and caudally, up to the semilunar line. The vascular branches of the epigastric arteries and nerves T7–T11 are preserved to avoid complications like linea alba hernias. Dissection continues cranially towards the retroxiphoid area and caudally towards the Retzius space.

For the transversus abdominis muscle, the posterior sheath is incised 1 cm from the pedicles, taking care to avoid perforating the peritoneum and transversalis fascia. Dissection between transversus and internal oblique is performed in an avascular plane, extending cranially under the costal margin and caudally towards the iliopectineal hiatus. The posterior layer is sutured with resorbable thread, and if necessary, drainage tubes are placed.

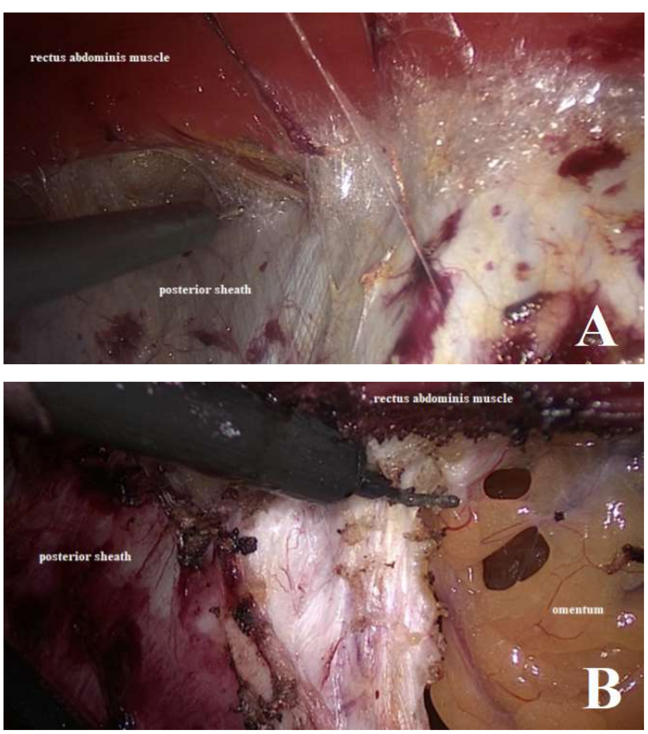
The mesh is installed in the preperitoneal space, covering the entire defect, fixed or unfixed depending on its size. After placement, the anterior layer is sutured, possibly with a subcutaneous drain. The subcutaneous tissue is closed, excess skin is excised, antiseptic solutions are applied, sterile dressings are placed, and a containment belt is fitted. The patient is then transported for postoperative monitoring.

4.2. Possible pitfalls and correction methods during the procedure

During TAR procedures, common pitfalls include incorrect cavity entry, injury to the transversalis fascia, epigastric vessels, neurovascular pedicles, or the semilunar line, as well as incomplete dissection of the transversus abdominis. It is crucial to avoid uneven dissection, including excessive cranial or caudal dissection, and to prevent iatrogenic openings in the posterior layer to avoid internal hernias. Proper positioning of the mesh and avoiding contact with viscera are also essential to prevent internal hernias and seromas. Careful nerve block management is necessary to prevent postoperative hemodynamic instability. Lateral extension and a lateral approach facilitate dissection and help preserve the integrity of the posterior layer, thereby reducing the risk of complications and recurrences.

Chapter 5. Minimally invasive approach of the TAR procedure

5.1. Operative technique



The positioning of the patient during minimally invasive TAR involves dorsal decubitus with arms fully abducted and the head and legs inclined at 10-15° for optimal abdominal field exposure. General anesthesia with endotracheal intubation ensures muscle relaxation. The skin is prepared with antiseptic solutions, a sterile field is set, and instruments are prepared.

A 10 mm trocar is inserted into the left hypochondrium in a retromuscular position under video guidance, followed by CO_2 insufflation at 12 mmHg to create space. Dissection is performed with specialized tools,

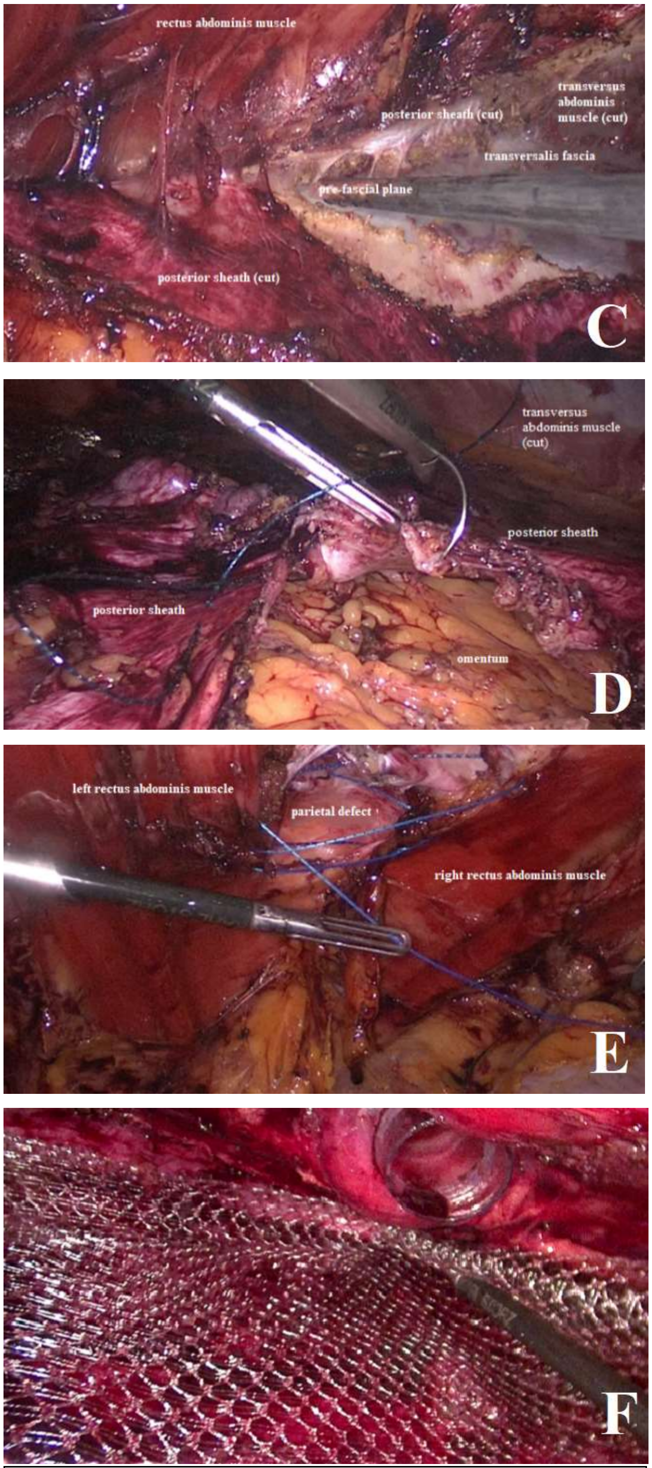


Figure 5.1.1. Retromuscular space dissection (A), posterior sheath section (B), transversus abdominis dissection (C), posterior layer closure (D), anterior layer closure (E), mesh placement (F) — intraoperative aspect of the same patient.

ensuring preservation of vascular and nerve supplies, including the epigastric vessels and intercostal branches, to avoid intraoperative complications. The dissection proceeds cranially and caudally, up to the semilunar line and prevesical space, to fully release the hernia sac and reduce its contents.

If the transversus abdominis muscle margins cannot be closed tension-free, its insertion is sectioned at the cranial level with careful incision and dissection in a vascular plane between the transversalis fascia and the muscle. The posterior sheath is liberated and medialized up to 10 cm to allow tension-free defect closure. After hernia contents are reduced, the anterior defect is closed with continuous sutures, avoiding seroma formation. If present, the hernia sac is used to seal the posterior layer, with verification and suturing of any continuity defects to ensure compatibility and prevent internal hernias.

The mesh is measured and placed in a diamond shape, without fixation, covering the defect and extending at least 5 cm beyond the edges. Light-Mesh, with high porosity and low weight, is preferred and mounted in the retromuscular space, fixed or not depending on the case. In case of extensive dissection, an aspirative drain may be installed to prevent fluid accumulation. The CO_2 used for space creation is gradually evacuated to maintain mesh position, and instruments are withdrawn under visual guidance. The skin is closed with sutures, and sterile dressings are applied.

Finally, a sterile dressing is placed, an abdominal containment belt is fitted, and the patient is monitored postoperatively with attentive surveillance to prevent complications and recurrences. [44]

5.2. Advantages and disadvantages of the minimally invasive technique

In recent years, TAR technique has increasingly gained popularity as a procedure for complex parietal defects, offering a reduced risk of postoperative complications and recurrence. An increasing number of surgeons are analyzing the role of minimally invasive approaches in performing posterior component separation. [45]

The classical approach allows easier exposure of the hernia sac content through a wide incision, whereas the minimally invasive technique complicates sac content handling due to ergonomic and visualization limitations. The trauma to the abdominal wall is significantly decreased with the minimally invasive method, leading to faster postoperative recovery and a notable reduction in postoperative pain. [46] Studies on small incisions for trocar placement in minimally invasive TAR have shown a lower infection rate compared to the classic approach. Systemic complications following laparotomy are approximately 26.5%, which is significantly higher than with minimally invasive procedures.[47]

The average duration of surgery for minimally invasive TAR is about 270 minutes, roughly halving the operative time compared to the classic approach, depending on the surgical team's experience. Suturing the posterior and especially the anterior layers can negatively impact operative time in minimally invasive surgery. The length of hospital stay is shorter for patients undergoing minimally invasive procedures, with a slightly lower reoperation rate relative to those treated via open surgery.[48]

Chapter 6. Evolution and prognosis

6.1. Intraoperative complications

Intraoperative complications include bleeding, hematomas, and injuries to viscera or vessels, especially in large or longstanding defects. Conversion to the classic technique may be necessary in cases of intense adhesions to prevent difficult-to-manage injuries.[49]

6.2. Early postoperative complication

The most common early postoperative complications are infections, hematomas, seromas, abscesses, and evisceration, all requiring careful monitoring, appropriate treatment, and sometimes surgical intervention. Elderly patients with multiple comorbidities may also develop systemic issues such as respiratory, cardiovascular, or thromboembolic problems, which demand a multidisciplinary management approach.[50]

6.3. Late postoperative complications

Recurrence involves protrusion of visceral content through a parietal defect caused by trauma or iatrogenic factors, with the presence of the viscera subcutaneously. Factors contributing to eventration are categorized into two groups: those related to the surgical act - such as wound suppuration, suture materials, immediate postoperative complications like paralytic ileus, cough, or vomiting - and those linked to the patient’s biological status - advanced age, protein deficiency, anemia, high BMI, and others.

6.4. Prognosis

Surgical intervention remains the only curative method for hernias, with postoperative prognosis significantly influenced by factors such as young age, absence of comorbidities, and low sarcopenia index. Conversely, advanced age, chronic smoking, and strenuous work increase the risk of severe complications like incarceration or strangulation of viscera, potentially leading to ischemia, bowel obstruction, and surgical emergency.

Chapter 7: Working hypothesis and general objectives

7.1. Introduction

Ventral hernias, common in both general and plastic surgery, exhibit a rising incidence despite modern techniques. Over the past decade, the alloplastic approach has gained popularity for restoring abdominal wall integrity; however, difficulties in closing complex defects have led to the development of Ramirez's anterior component separation technique, which enables tension-free closure. [51,52] Although effective for complicated hernias, this method has drawbacks, including the risk of content reduction and proximity to bony structures like the costal margin or SIAS, as well as an increased risk of infection and recurrence. In 2012, Novitsky introduced the posterior component separation technique (transversus abdominis release), which provides superior outcomes in juxta-umbilical hernias by means of extended lateral dissection in the preperitoneal space and an expanded dissection plan, representing an advanced variant of the Rives-Stoppa procedure.[53]

7.2. Working hypothesis

- Smoking has a detrimental impact on intra-abdominal pressure by contributing to the rigidity of the abdominal wall and redistributing visceral fat, which can exacerbate postoperative outcomes.
- Body mass index (BMI), along with patients’ lifestyle and work conditions, can influence disease prognosis.

- Patients with complex parietal defects and associated pathologies are more likely to require open surgical interventions.
- High BMI patients typically present larger diameters and volumes of the abdominal cavities, leading to increased intra-abdominal pressure and a higher risk of complications during surgery.
- A thicker muscular wall can contribute to elevated preoperative intra-abdominal pressure and generate greater pressure differences.
- The TAR procedure can significantly reduce parietal tension, even in cases of rigidized abdominal walls with prosthetic materials, thereby improving structural stability and postoperative functional outcomes.
- The risk of postoperative complications varies substantially depending on the technique used, whether minimally invasive or open approach, each with different profiles of risks and benefits.

7.3. Objectives

- To determine the optimal timing for surgery and enhance therapeutic strategy.
- To establish the appropriate surgical approach based on the patient's surgical history and defect dimensions.
- To analyze clinico-paraclinical correlations and treatment outcomes in patients with parietal defects.
- To define criteria for the use of prosthetic materials in abdominal wall reconstruction.
- To assess the influence of defect characteristics on the risk of postoperative complications.
- To evaluate the effects of smoking on perioperative features of the anterior-lateral abdominal wall and the parietal defect.

Chapter 8: General research methodology

8.1. Establishing inclusion and exclusion criteria

For the development of the doctoral thesis, prospective studies were conducted on various cohorts of patients diagnosed with primary or secondary anterior-lateral abdominal wall defects following previous surgical interventions. All patients were admitted and treated in Section 1 of the Central Military Emergency University Hospital, Bucharest. It is important to note that all surgical procedures included in the study were performed by the same surgical team. The study spans from 2019 to 2024 and was conducted under the supervision of Professor Daniel Cochior, MD, with approval from the Commandant of the Central Military Emergency University Hospital and the head of Section 1.

Inclusion criteria encompassed patients over 18 years old, diagnosed clinically and paraclinically with anterior-lateral abdominal wall defects, whether primary or secondary, for which the posterior component separation technique with alloplastic reinforcement was performed. Both minimally invasive and open surgical approaches were included in the study.

Exclusion criteria consisted of patients admitted, evaluated, and later refusing the proposed surgical intervention. Additionally, patients who underwent alternative alloplastic or tissue-based procedures for reconstructing the anterior-lateral abdominal wall were excluded from the study.

8.2. Study group

All patients in the study were evaluated according to a standardized algorithm that included detailed clinical consultations, paraclinical investigations such as CT scans, spirometry, and laboratory assessments (hemogram, biochemistry, inflammatory markers, coagulogram, blood type). These evaluations aimed to determine the optimal surgical technique and associated risks. Throughout the perioperative period, biological parameters such as hemoglobin, hematocrit, leukocytes, CRP, and ESR were continuously monitored to identify anemia, infections, or other complications, which were promptly addressed. Follow-up included imaging examinations and reevaluation of biological data to ensure optimal recovery and prevent complications and recurrences.

Following application of inclusion and exclusion criteria, 62 eligible patients were prospectively followed over a period of 54 months (from the inclusion of the first patient until the last operated patient).

The cohort was divided into two groups based on the surgical approach used: Group 1 included patients treated with the minimally invasive posterior component separation technique (Transversus Abdominis Release, TAR), and Group 2 consisted of patients undergoing open surgery.

Out of the total 62 patients, 46 (71.9%) underwent minimally invasive procedures (Group 1), while 18 (28.1%) were operated via open approach (Group 2).

8.3 Statistical data

In Group 1, the majority of patients were women (90.9%), with an average age of 62.6 years (SD = 9.56), and over 60 years old in 68.2% of cases. In Group 2, women accounted for 88.9%, with a mean age of 62.3 years (SD = 10.05), and the highest proportion over 60 years (66.7%). The average age of men in Group 1 was 64.3 years (SD = 5.85, p = 0.975), while women had an average age of 62.3 years (SD = 10.05, p = 0.766). In Group 2, men had a mean age of 71 years (p < 0.001), and women 66.9 years (p = 0.367). The majority of patients undergoing minimally invasive procedures were over 60, whereas those treated with open surgery were older.

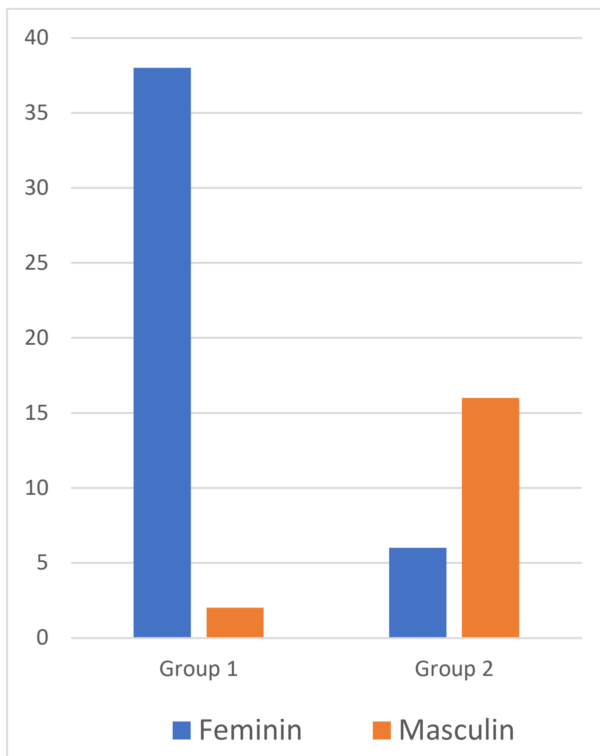


Figure 8.3.1 – Distribution of sex across the two study groups.

In the calculation of BMI, the reference interval for males was 25.76 – 30.04, with a normal distribution (Shapiro-Wilk W = 0.84, $p = 0.09$), while for females, the reference interval was 22.59 – 38.57 and did not follow a normal distribution (Kolmogorov-Smirnov D = 0.192, $p = 0.031$). No significant statistical differences were observed between the study groups for sex: males ($p = 0.197$) and females ($p = 0.802$).

Study group	Sex	Mean BMI ± SD	p value
Group 1	M	27,5 ± 12,47	0,289
	F	28,2 ± 12,39	< 0,001
Group 2	M	28,7 ± 12,12	0,061
	F	29,9 ± 16,68	0,093

Tabel 8.3.1 – The distribution of mean BMI values according to sex within both study groups.

Regarding comorbidities, patients were classified using the ASA score [54]:

In Group 1, the distribution was: 4.4% ASA I, 50% ASA II, 45.6% ASA III, with no patients in ASA IV or V - indicating a population with relatively good general health. In Group 2, 22.2% had ASA II and 77.8% ASA III, with no ASA I or IV/V cases; most patients had severe comorbidities (ASA III). Cardiovascular diseases were most prevalent, especially hypertension, present in 78.1% overall, more frequent in Group 1 (86.4%) than in Group 2 (66.7%). For type II diabetes, 12 cases (18.8%) were identified, with a sex ratio of 5:1 (F:M), and a higher prevalence among men (25%) compared to women (17.9%). The first lot included 22.7% diabetics, the second 11.1%, with a total of 34.4% cases of oncologic history, without significant differences between groups ($p = 0.185$).

A first classification by Chevrel and Rath[55] assessed the number of previous surgical interventions, with the following observations across the entire study cohort:

Study group	R0	R1	Rn
Group 1	2 (4,6%)	24 (54,6%)	18 (40,8%)
Group 2	0 (0%)	12 (66,7%)	6 (33,3%)

Tabel 8.3.2. – Clasificarea descrisă de Chevrel și Rath în cadrul celor 2 grupuri de studiu.

Applying the Chevrel and Rath classification, group 1 exhibits a varied distribution of surgical history, with 54.6% having a single intervention and 40.8% multiple interventions, whereas group 2 is homogeneous, with all patients having previous surgeries - most (66.7%) with only one intervention. There were no statistically significant differences between the groups (Chi-Square = 0.7708, p = 0.379).

8.4. History, clinical examination and paraclinical investigations

After establishing the preliminary diagnosis, patients were admitted on an outpatient basis for confirmation. The anamnesis focused on the parietal condition, frequently revealing pseudotumoral formations, pain, and digestive symptoms. Pain was present in nearly all patients, either colicky or continuous; in one-third of cases, it occurred spontaneously, while in the rest, it was triggered by increased intra-abdominal pressure from coughing, sneezing, or defecation. Most often, pain was localized at the hernia defect site; in 20% of cases, it was diffuse throughout the abdomen, often associated with expansion of the hernia contents, subsiding when the provoking maneuver ceased. The onset of pain was categorized into three periods: less than 6 months (9.7%), between 6 and 12 months (58.1%), and over 12 months (32.2%).

In group 1, 9.1% reported onset of pain in less than 6 months, 50% between 6 and 12 months, and 40.9% after 12 months. In group 2, 11.1% experienced pain in less than 6 months, 77.8% between 6 and 12 months, and 11.1% after 12 months, with most cases falling into the 6 - 12 months category. The difference between the groups was statistically significant (Chi-Square = 6.9528, p = 0.008).

Most patients performed minimal or moderate effort: 30 patients (48.4%) overall, with 22 (50%) in group 1 and 8 (44.4%) in group 2; only about 6 (9.7%) performed intense effort, equally distributed. In group 1, 50% had insignificant effort, 40.9% moderate, and 9.1% intense effort; in group 2, proportions were similar: 44.4% insignificant, 44.4% moderate, and 11.2% intense effort, indicating a relatively uniform distribution. No significant correlation was found between the defect area and effort level ($r_s = 0.14222$, $p = 0.445$), nor was there a significant difference between the groups (Chi-Square = 0.2737, $p = 0.991$).

In group 1, the interventions mainly occurred in 2022 (40.9%, 18 patients), followed by 2019 (31.8%, 14 patients), with fewer in 2020 (4.5%, 2 patients) and 2021 (9.1%, 4 patients). In group 2, the most active year was also 2022 (33.4%, 6 patients), with a more uniform distribution across earlier years. No significant difference was found between the groups regarding the years of intervention (Chi-Square = 0.309, $p = 0.578$).

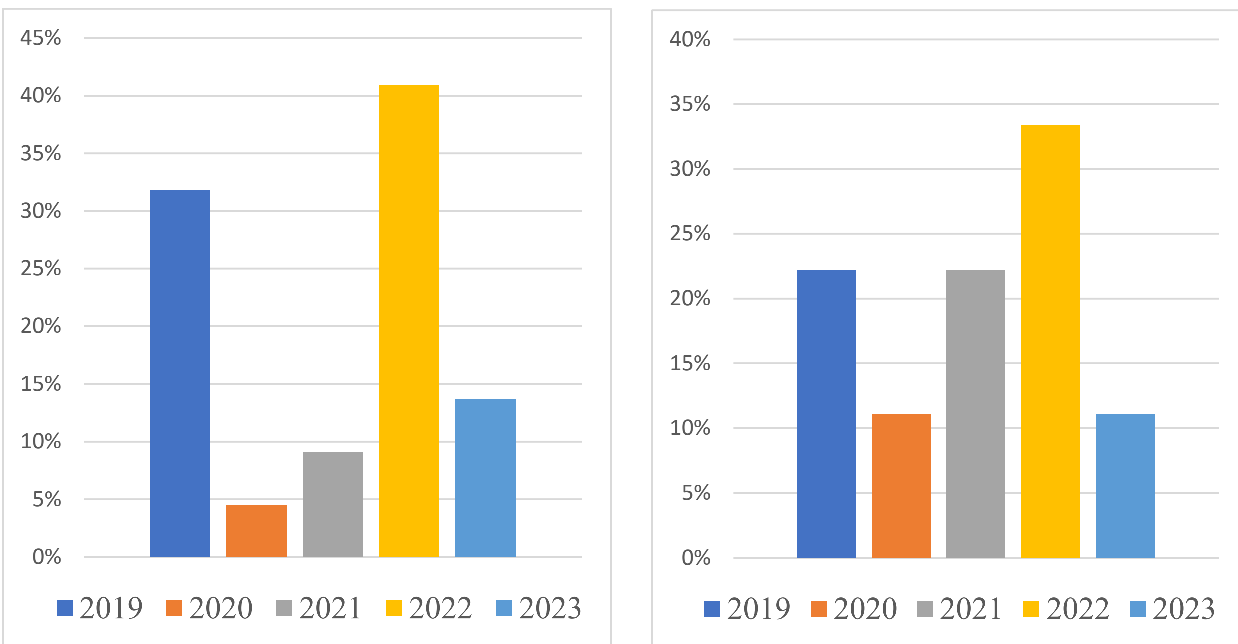


Figure 8.4.1 – The distribution of surgical intervention years for both patient groups is shown in the respective images (left – Group 1, right – Group 2).

Total operative time

The total operative time (skin to skin) ranged from 100 to 312 minutes, with a mean of 248.45 minutes (SD = 54.97), and did not follow a normal distribution ($p = 0.003$). The Kruskal-Wallis test on the entire cohort revealed a significant difference between years (H = 12.9875, $p = 0.011$), which was confirmed by the Dunn post hoc test, demonstrating an increasing trend in operative time over the years, especially during the COVID-19 pandemic and in 2023, with a continuous upward trend.

In Group 1, operative times varied between 100 and 310 minutes, with a mean of 259.54 minutes (SD = 38.97), and followed a normal distribution ($p = 0.105$). No significant differences were observed between years (H = 3.1978, $p = 0.525$).

In Group 2, times ranged from 100 to 310 minutes, with a mean of 221.11 minutes (SD = 78.33), and also followed a normal distribution ($p = 0.299$). The Kruskal-Wallis test showed significant differences between years (H = 26.2076, $p < 0.001$), confirmed by the Dunn post hoc test, indicating a consistent increase in operative time over the five-year period, both before and during the pandemic.

8.5. Localization of parietal defects

The localization of parietal defects was assessed using native computed tomography scans across the three levels (thoracic, abdominal, and pelvic) in three planes (coronal, axial, and sagittal). Imaging was performed both outpatiently at the Surgery Clinic 1 of the Central Military Emergency Hospital Bucharest and in other private clinics, with results interpreted by the radiology-surgery team. To standardize defect localization, the European Hernia Society Classification (EHS Classification) was used.

In the first study group, the highest proportion of patients had defects located in M2 and M4 (40.9% each), indicating increased frequency of these localizations. Over one-third (31.8%) of patients had two combined defect sites, and 4.55% had more than three localizations, demonstrating diversity in defect distribution. In the second group, high frequencies were also observed in M2 and M4, each present in 44.4% of cases. Chi-square analysis showed no significant statistical difference in the median localization of defects between the two groups (p=0.917). The L2 localization had the highest incidence (55.6%) in this group, suggesting a higher frequency of such defects among patients in group 2. Additionally, 55.6% of patients had two associated defect localizations, suggesting a slight simplification compared to group 1, which had a higher percentage of patients with multiple simultaneous defect localizations.

8.6. Number of parietal defects

In the studied cohort, in group 1, 45.4% of patients had a single parietal defect, 27.3% had two defects, and 27.3% had three or more. Conversely, in group 2, the majority (66.7%) exhibited two defects, with only 11.1% presenting a single defect; the difference was statistically significant ($p = 0.008$)

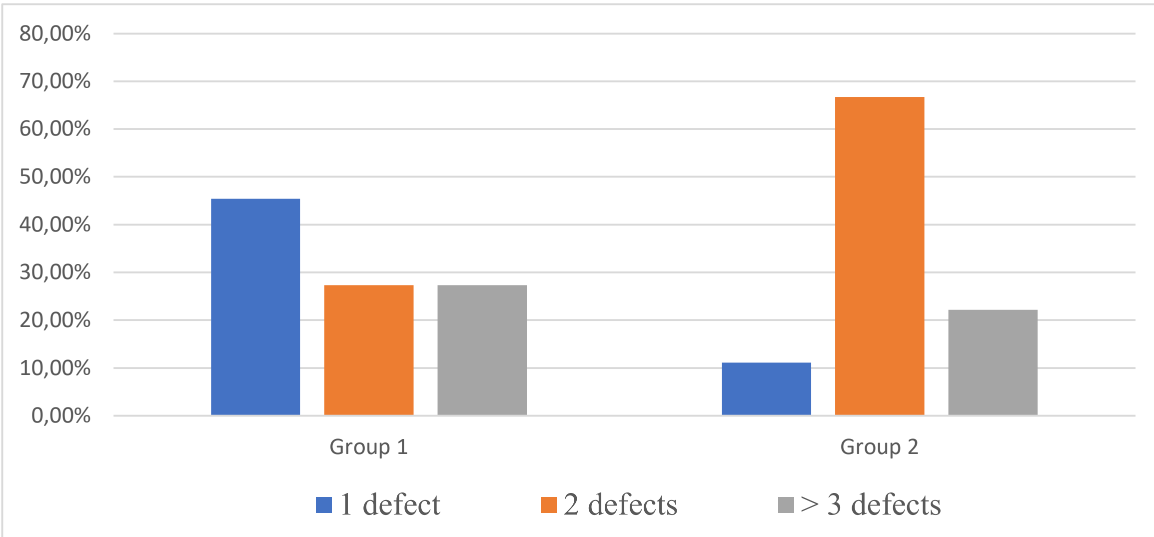


Figure 8.6.1 – Statistical analysis of the number of parietal defects within the two study groups

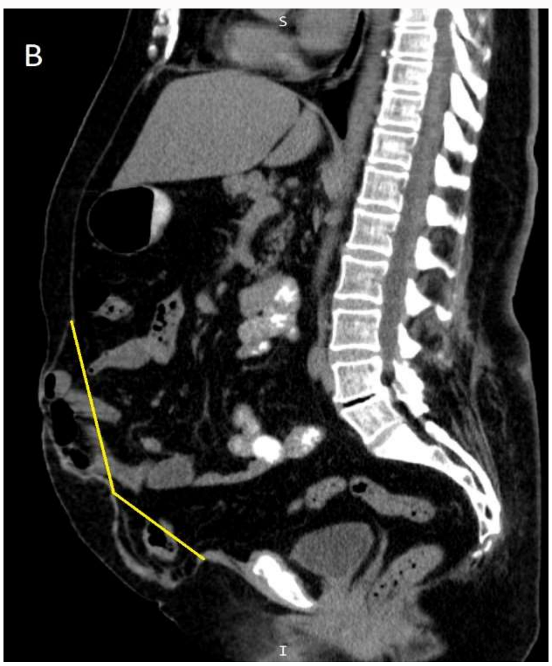
No significant correlation was found between BMI and the number of defects ($r_s = 0.07612$, $p = 0.684$), although most patients with BMI >30 presented with over three defects. An almost significant association was observed between age over 55 and the number of parietal defects ($r_s = 0.33566$, $p = 0.064$), with older patients more frequently having multiple defects.

8.7. Anatomo-functional changes post-TAR

Within the study, the defect dimensions were evaluated through computed tomography in the three levels (thorax, abdomen, and pelvis), using precise measurements of the defect length (L_d), defect width (W_d), and defect area (A_d), calculated according to the formula:

$$A_d = \pi\,(W_d/2)(L_d/2) = \pi/4 \times W_d \times L_d$$ [56]

Figure 8.7.1 – Measurement of L_d (image B) and W_d (image A) for calculating A_d – CT aspect of the same patient.



In group 1, L_d varied between 3.4 cm and 18 cm, with an average of 8.09 cm (SD = 3.8), and ld ranged between 4.9 cm and 12.5 cm, with an average of 8.46 cm (SD = 3.37); the values showed a non-normal distribution ($p < 0.001$ and $p = 0.008$ for L_d and W_d). Regarding the defect area, the values ranged between 21.89 cm² and 80.54 cm², with an average of 51.4 cm² (SD = 27.7), also non-normal ($p = 0.008$).

In group 2, L_d ranged from 3.6 cm to 12.3 cm, with a mean of 7.16 cm (SD = 3.17), and W_d ranged between 4.2 cm and 13.4 cm, with an average of 9.31 cm (SD = 4.46), both without a normal distribution ($p = 0.012$ and $p = 0.015$). The mean defect areas were 56.73 cm² (SD = 35.95), with minimum and maximum values of 12.15 cm² and 126.49 cm², respectively, also non-normally distributed ($p = 0.032$).

	$A_{d\ min}$	$A_{d\ max}$	$A_{d\ mean}$
Group 1	21,89 cm^2	80,54 cm^2	51,4 cm^2 ± 27,7
Group 2	12,15 cm^2	126,49 cm^2	56,73 cm^2 ± 35,95

Tabel 8.7.1 – Representation of the value range (minimum, maximum, mean) for A_d.

	$L_{d\ min}$	$L_{d\ max}$	$L_{d\ mean}$	$W_{d\ min}$	$W_{d\ max}$	$W_{d\ mean}$
Group 1	3,4 cm	18 cm	8,09 cm ± 3,8	4,9 cm	12,5 cm	8,46 cm ± 3,37
Group 2	3,6 cm	12,3 cm	7,16 cm ± 3,17	4,2 cm	13,4 cm	9,31 cm ± 4,46

Tabel 8.7.2 – Representation of the value range (minimum, maximum, mean) for the lengths and widths of parietal defects.

According to the Mann-Whitney statistical analysis, no significant differences were found between the two groups regarding the dimensions of L_d ($p = 0.541$), W_d ($p = 0.389$), and A_d ($p = 0.631$). However, a statistically significant correlation was observed between BMI and defect area ($r_s = 0.67191$, $p < 0.05$), indicating that as BMI increases, the defect area tends to be larger. Regarding surgical history, in group 1, 2 patients (4.6%) had primary hernia, while the remaining 42 (95.4%) had previously undergone hernia repair. In group 2, all 18 patients had recurrent hernias. Thus, the prevalence of recurrent hernias was extremely high, suggesting that most patients had a surgical history, which could influence treatment strategies and outcomes.

Another classification of parietal defects was based on W_d, with the following findings:

Classification W_d	Group 1	Group 2
W1	0 (0%)	4 (22,2%)
W2	30 (68,2%)	4 (22,2%)
W3	14 (31,8%)	10 (55,6%)

Tabel 8.7.3 – Classification of parietal defects according to ld within the two study groups.

In group 1, the majority of patients (68.2%, 30 cases) had W2-type defects, with no cases of W1, indicating specificity in this group. In group 2, the distribution was more balanced, with 55.6% (10 patients) in W3 and presence also in W1 and W2, showing greater diversity in defect types. The Chi-square test revealed a significant statistical difference between the two groups ($\chi^2 = 13.2025$, $p = 0.001$), with a clear difference: 30 cases of W2 in group 1 versus only 4 in group 2, while differences in the W3 category were less pronounced.

Both patients with single and multiple parietal defects were included in the study. It is noteworthy that measurements evaluated in patients with multiple defects were taken over the maximum surface area containing the defects (applicable for single defects), while for multisite defects, the dimensions of the largest defect were used, measuring the following diameters:

Figure 8.7.2 – Measurement of the anteroposterior diameter (DAP) (yellow line) between the anterior abdominal wall and the anterior surface of the T12 vertebral body – CT aspect of the same patient.

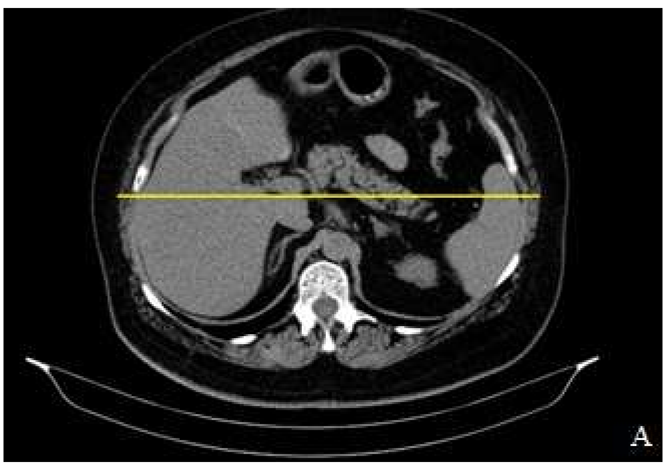


Figura 8.7.3 – Measurement of the transverse diameter (DT) at the level of the T12 vertebra (A) and the diaphragm-infrasymphysial diameter (DDI) between the diaphragmatic dome and the inferior pole of the pubic symphysis (B) – CT aspect of the same patient.

In the comparative study, the average anteroposterior diameter (APD) was 16.4 cm in group 1 (median 16.7 cm; min 13.6 cm; max 18 cm), and 17 cm in group 2 (median 16.4 cm; min 15.9 cm; max 18.7 cm), with no significant difference ($p = 0.406$). The transverse diameter (TD) measured was 26.9 cm in group 1 (median 27.1 cm; min 23.4 cm; max 29.7) and 26.7 cm in group 2 (median 26.6 cm; min 24.8 cm; max 29.1), without significant difference ($p = 0.659$). The diaphragmo-infrasimphizar diamter (DID) had mean values of 39.6 cm in group 1 and 40.7 cm in group 2, with no significant difference ($p = 0.089$). The graph illustrates the mean values of the diameters measured in both study groups.

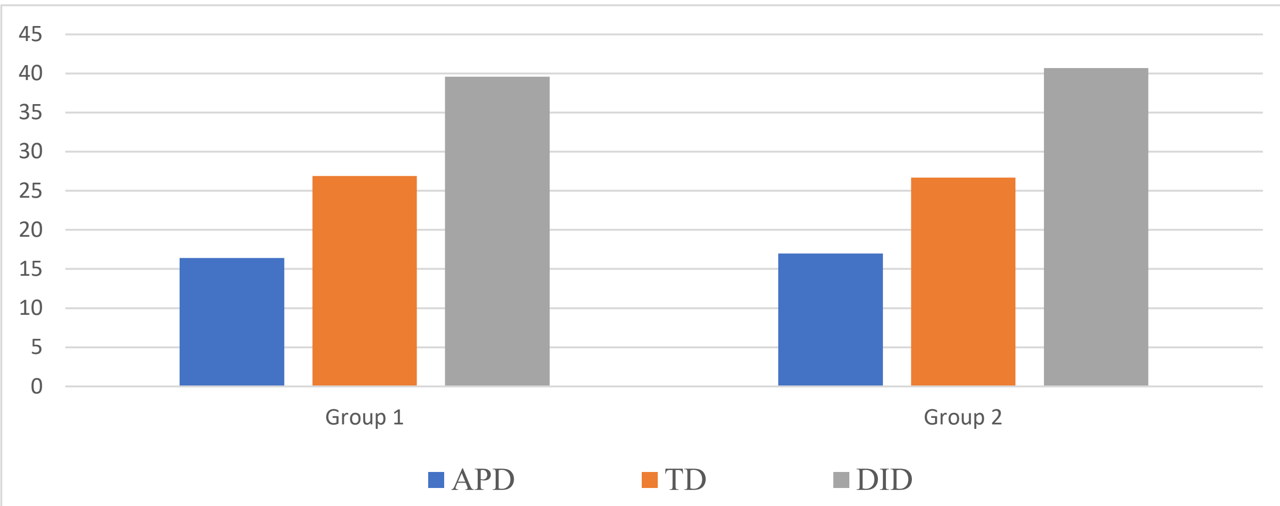
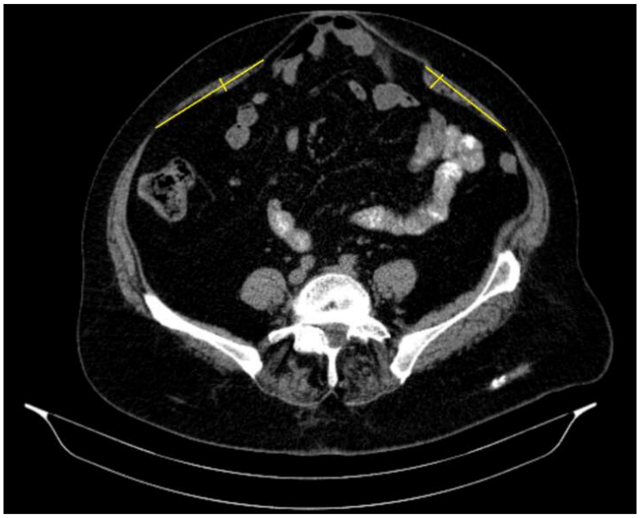


Figura 8.7.8 – The graphical representation of the mean values of the diameters measured within groups 1 and 2 of the study

8.8. Aspects related to the antero-lateral abdominal wall muscles

Using preoperative tomography, aspects related to the anterolateral musculature of the abdomen could be measured:



Width (W), calculated as the transverse diameter of the muscular portion, and thickness (T), as the anterior-posterior diameter of the muscular portion at half the transverse diameter.

Figure 8.8.1 – Measurement of the width and thickness of the rectus abdominis muscles at the level of the parietal defect – CT aspect of the same patient

In the first group, the mean width of the rectus abdominis was 7.4 cm (min 4.6 cm, max 11.1 cm), with $p = 0.003$, while the mean thickness was 1 cm (min 0.6 cm, max 1.3 cm), with $p = 0.333$. In the second group, the mean width was 4.7 cm (min 3.8 cm, max 8.1 cm), with $p < 0.001$, and the mean thickness was 1 cm (min 0.8 cm, max 1.2 cm), with $p = 0.077$. A significant difference between groups was observed in the width of the rectus abdominis ($p < 0.001$), with the median being higher in the first group (6.3 cm) compared to the second (4.6 cm). The muscle thickness showed no significant difference ($p = 0.908$), being similar in both groups.

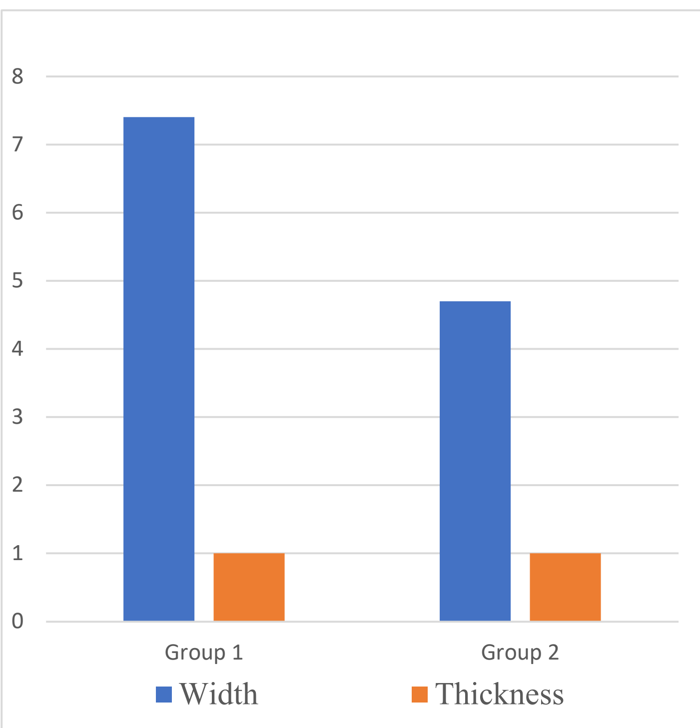


Figure 8.8.2 – Statistical analysis of the mean values of the width and thickness of the rectus abdominis muscles measured in both study groups.

Significant statistical differences were observed between the groups regarding the width of the rectus abdominis ($p < 0.001$), with a higher median in the first group (6.3 cm) compared to the second group (4.6 cm). In contrast, muscle thickness showed no significant difference ($p = 0.908$), being similar in both groups with a value of 1 cm and slight variations within the minimum and maximum limits.

Similarly, the widths and thicknesses of the lateral abdominal muscles were measured using the same principle.

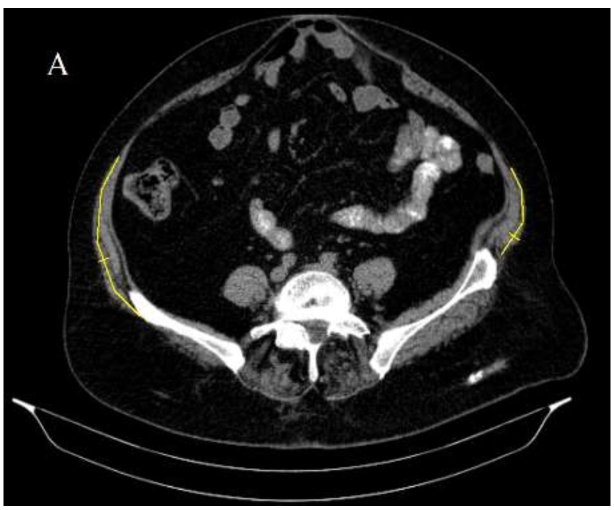


Figure 8.8.3 – Measurement of the width and thickness of the lateral abdominal muscles (figure A – external oblique muscle, figure B – internal oblique muscle, figure C – transverse abdominal muscle) – CT aspect of the same patient.

Group 1	T.A.	O.I.	O.E.
Min	2,2 cm	3,8 cm	5,8 cm
Max	15,3 cm	18,2 cm	15,4 cm
Mean	10,1 cm	12,9 cm	13,2 cm
p value	0,012	0,004	< 0,001

Tabel 8.8.1 – The table presents the minimum, maximum, average values, and p-values for the width of the lateral abdominal muscles within study group 1.

Group 1	T.A.	O.I.	O.E.
Min	0,4 cm	0,6 cm	0,6 cm
Max	4,6 cm	1,3 cm	1,8 cm
Mean	1 cm	0,9 cm	1,1 cm
p value	0,026	0,023	0,114

Tabel 8.8.2 – The table also shows the minimum, maximum, average values, and p-values for the thickness of the lateral abdominal muscles within study group 1.

Group 2	T.A.	O.I.	O.E.
Min	4,4 cm	9,1 cm	10,4 cm
Max	12,4 cm	13,2 cm	15,3 cm
Mean	8,1 cm	11,1 cm	12,9 cm
p value	0,3	0,208	0,415

Tabel 8.8.3 – The table presents the minimum, maximum, average values, and p-values for the width of the lateral abdominal muscles within study group 2.

Group 2	T.A.	O.I.	O.E.
Min	0,5 cm	0,5 cm	0,5 cm
Max	1 cm	1,2 cm	2 cm
Mean	0,8 cm	0,8 cm	0,9 cm
p value	0,456	0,097	0,002

Tabel 8.8.4 – The table also shows the minimum, maximum, average values, and p-values for the thickness of the lateral abdominal muscles within study group 2.

A significant difference was found in the thickness of the transversus abdominis ($p = 0.043$), with medians of 0.6 cm in group 1 and 0.8 cm in group 2. The mean width of the internal oblique was larger in group 1, suggesting better muscle development, but this was not statistically significant ($p = 0.085$). The mean width of the external oblique was similar across groups, with a tendency towards a larger median in group 1 (0.6 cm) versus group 2 (0.5 cm), but without significant difference ($p = 0.089$). The average thickness of the three lateral abdominal muscles was greater in group 1, with a median of 0.6 cm, compared to 0.8 cm in group 2, and this difference was statistically significant ($p = 0.043$). A value close to the significance threshold was observed in the comparison of the external oblique thickness between groups, with medians of 1.1 cm in group 1 and 0.6 cm in group 2 ($p = 0.056$).

The cross-sectional area of the transversus abdominis muscle was considered useful to calculate based on tomographic section measurements of its diameter, to assess its impact on intra-abdominal pressure changes. Thus, the sectional area was determined as the product of its width and thickness, resulting in the following values:

	A_{min}	A_{max}	A_{medie}	*p* value
Grupul 1	1,61 cm^2	11,43 cm^2	6,42 cm^2	0,548
Grupul 2	3,15 cm^2	10,53 cm^2	6,33 cm^2	0,505

Tabel 8.8.8 – Table representation of the minimum, maximum, average values, and p-value for the cross-sectional area of the transverse abdominal muscle within both study groups.

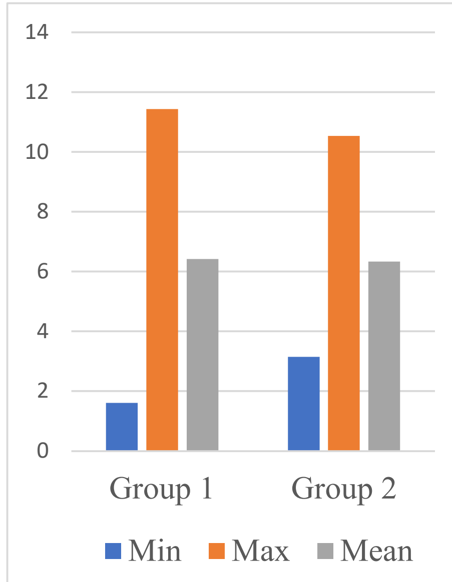


Figure 8.8.8 – Statistical analysis of the minimum, maximum, and mean values of the cross-sectional area of the transverse abdominal muscle within both study groups..

Group 1 had an average area of 6.42 cm², slightly larger than Group 2, with an average of 6.33 cm², without significant differences (*p* = 0.933). The minimum area was 1.61 cm² in Group 1 and 3.15 cm² in Group 2, with the maximum being 11.43 cm² for Group 1 and 10.53 cm² for Group 2. After measuring the dimensions of the three lateral abdominal muscles, the wall thickness was calculated as the sum of the three muscle thicknesses, resulting in the following values: the average posterior wall thickness was 2.56 cm in Group 1 and 2.3 cm in Group 2, with a significant difference (*p* = 0.038). The minimum thickness was 1.6 cm in Group 1 and 1.8 cm in Group 2, while the maximum thickness was 4.1 cm for Group 1 and 3.9 cm for Group 2.

8.9. Volumes and specific indices

Using the respective diameters, the corresponding volumes were calculated:
The abdominal cavity volume (ACV), expressed in cm^3, was calculated using the formula:

ACV = 4/3π (TD/2)(DID/2)(APD/2) ≈ TD × DID × APD/2 [Eroare! Marcaj în document nedefinit.]

The average ACV in group 1 was 8734.74 cm^3, with minimum values of 5709.34 cm^3 and maximum values of 10966.74 cm^3 ($p = 0.062$). In group 2, the mean was 9290.74 cm^3, with minimum values of 8175.82 cm^3 and maximum values of 10828.99 cm^3 ($p = 0.645$). The medians for these groups were 8,600 cm^3 for group 1 and 9200 cm^3 for group 2, indicating a tendency for patients in group 2 to have a larger visceral volume, but the difference was not statistically significant ($p = 0.645$).

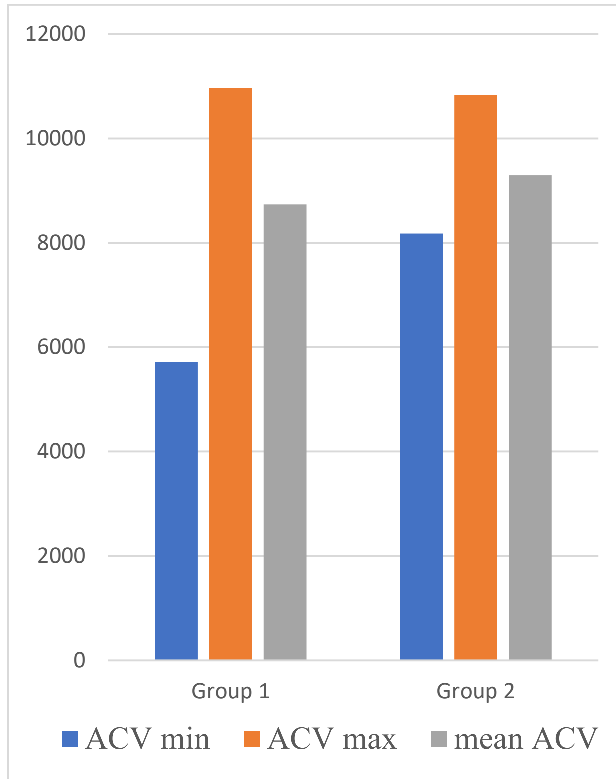


Figure 8.9.1 – Statistical analysis of the minimum, maximum, and mean values of ACV within both study groups.

The hernia sac volume (HSV) was also calculated using the following formulas:

$$HSV = 4/3\pi \text{ (herniated sac width/2)(herniated sac length/2)(herniated sac height/2)}$$

$$\approx \text{herniated sac width} \times \text{herniated sac length} \times \text{herniated sac height/2}$$

Figure 8.9.2 – Measurement of the hernia sac dimensions (hernia sac width – A, hernia sac length – B) – CT aspect of the same patient.

The average HSV in group 2 was 212.41 cm³, with minimum values of 42.67 cm³ and maximum values of 355.67 cm³, while in group 1, the mean was 139.77 cm³, with minimum values of 33.09 cm³ and maximum values of 355.67 cm³. The difference between medians is 139.0 cm³ for group 1 and 212.4 cm³ for group 2. The Mann-Whitney test indicated no statistically significant difference between the two groups ($p = 0.144$).

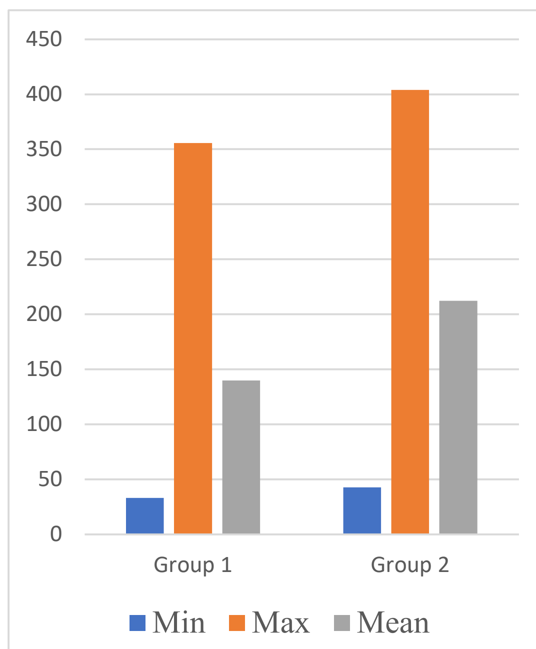
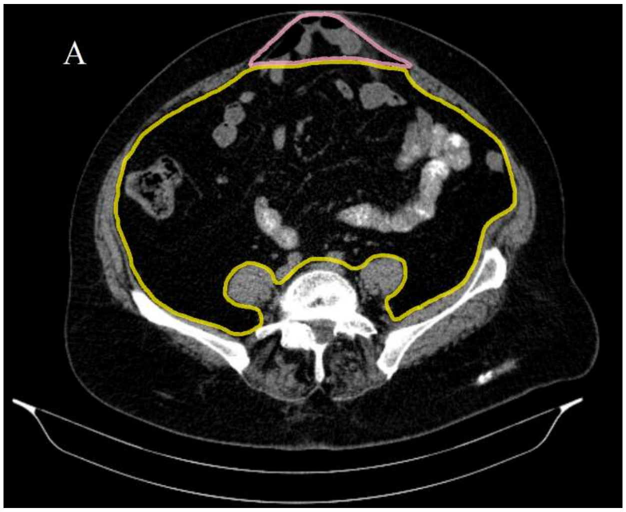


Figure 8.9.3 – Statistical analysis of the minimum, maximum, and mean values of hernia sac volume (HSV) within the two study groups.

The volume of the peritoneal cavity (PCV) is the sum of the abdominal cavity volume (ACV) and the hernia sac volume (HSV), expressed in cm³ (PCV = ACV + HSV).



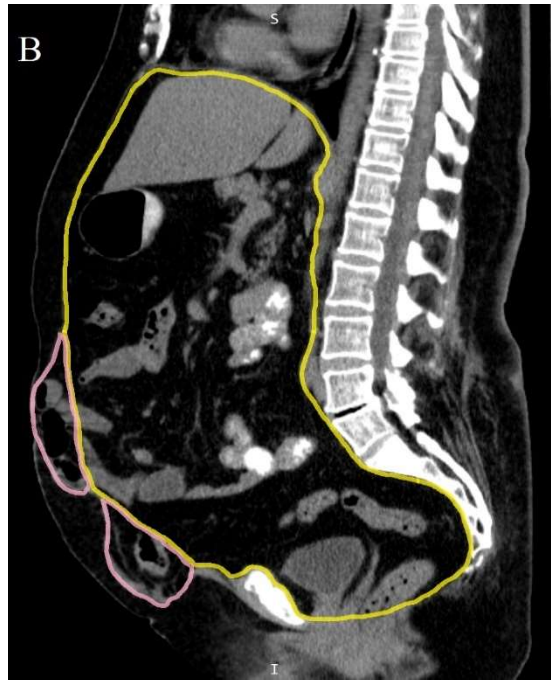


Figure 8.9.4 – The contours of VCA (yellow outline) and VSH (pink outline) are shown in the transverse plane (A) and sagittal plane (B) – CT aspect of the same patient.

Group 1 has an average PCV of 8874.51 cm³, with minimum values of 5896.64 cm³ and maximum values of 11011.25 cm³ ($p = 0.222$). Group 2 exhibits a mean PCV of 9503.15 cm³, with ranges between 8257.9 cm³ and 11135.73 cm³, and the difference between the means is not statistically significant ($p = 0.222$). The variability in volume size is similar across both groups, and the maximum ranges are comparable, indicating a wide diversity in volume among all patients.

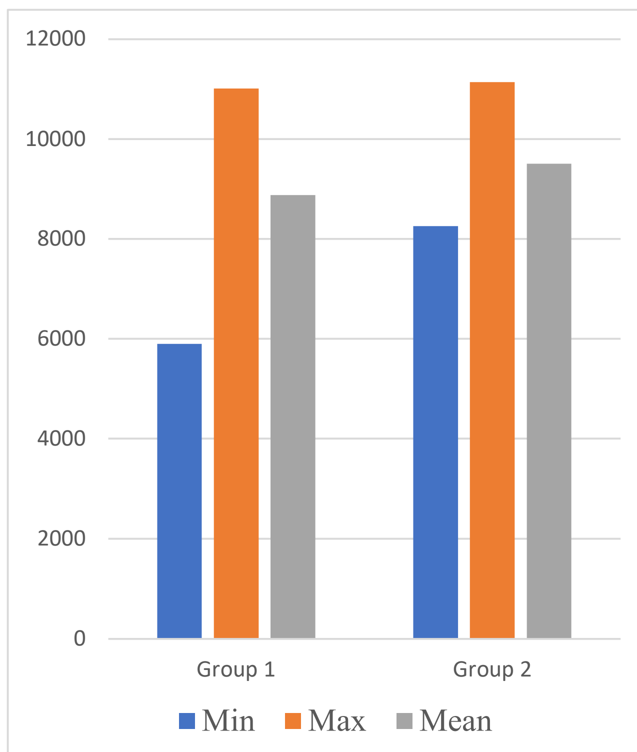


Figure 8.9.5 – Statistical analysis of the minimum, maximum, and mean values of PCV within the two study groups.

To better observe and characterize post-TAR changes, both the measurements of the abdominal rectus and lateral muscles, as well as the diameters and volumes after surgery, were performed.

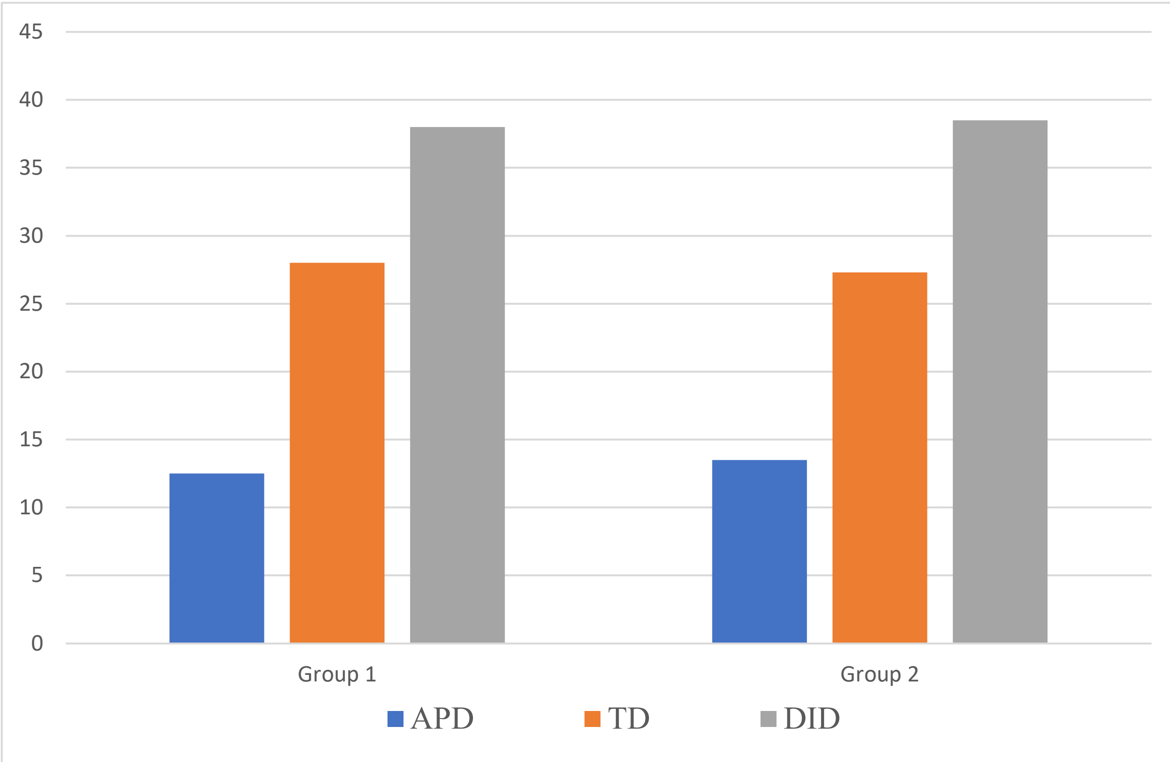


Figure 8.9.6 – The graphic depiction of the mean values of postoperative diameters measured within study groups 1 and 2.

Within study groups 1 and 2 shows that the average postoperative APD was 12.5 cm (range 10.7 – 15.3 cm) in group 1 and 13.5 cm (range 11.3 – 15.9 cm) in group 2, with no significant difference between medians (p = 0.414). The postoperative TD averaged 28 cm (range 24 – 32.5 cm) in the first group and 27.3 cm (range 23.2 – 34.5 cm) in the second, with no significant statistical difference (p = 0.979). For the postoperative DID, the mean values were 38 cm in group 1 and 38.5 cm (range 20.4 – 40.7 cm and 37.7 – 40.1 cm, respectively), with the difference also statistically non-significant (p = 0.123).

In the comparative study, group 1 had an average ACV of 6932.12 cm³, with minimum and maximum values of 3547.15 cm³ and 9053.01 cm³ (*p* = 0.747). Group 2 exhibited a higher mean value of 7223.58 cm³, with ranges between 4967.93 cm³ and 9864.07 cm³ (*p* = 0.390). The difference between the means of the two groups was not statistically significant (*p* = 0.296), although the values in group 2 suggest a different body composition, possibly with higher visceral fat levels. Additionally, group 1 included patients with smaller abdominal cavities (min 3547.15 cm³) compared to group 2 (min 4967.93 cm³), yet the maximum ranges were similar, indicating the presence of some patients with large ACVs in both groups. Overall, the differences between the groups were not statistically significant (*p* = 0.157).

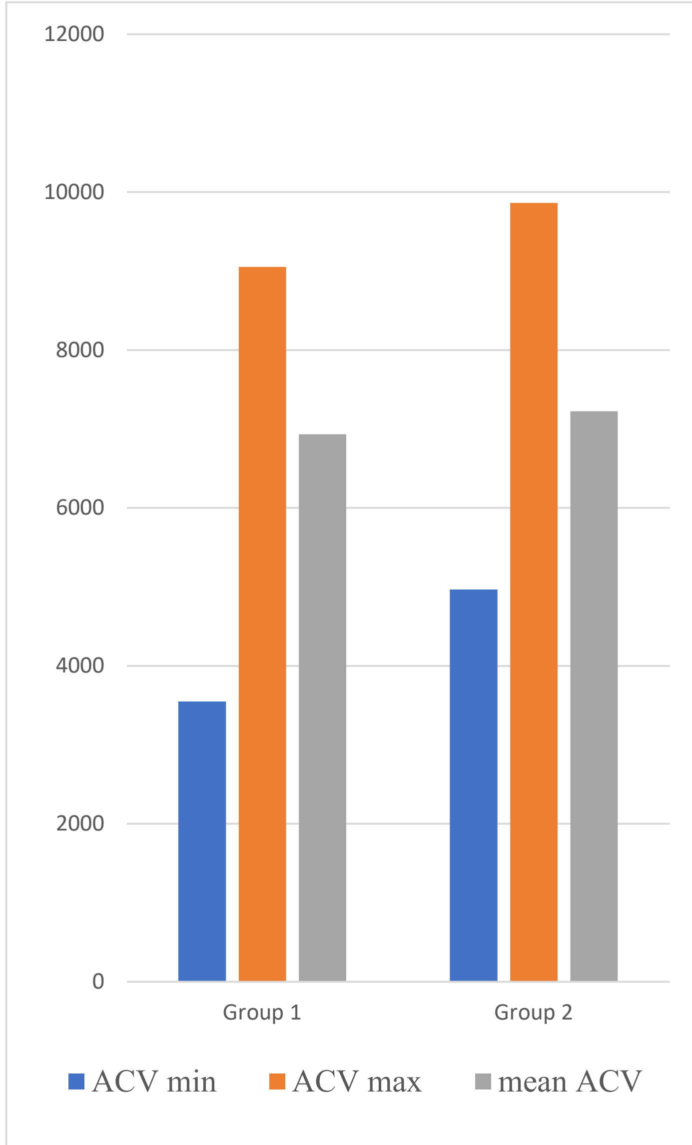


Figure 8.9.7 – Analysis of the minimum, maximum, and mean values of VCA within both study groups.

I also calculated the dimensions represented by the width and thickness of the rectus and lateral muscles of the abdomen, obtaining the following: in group 1, the mean postoperative width of the rectus abdominis was 6.65 cm (min 4.6 cm, max 11.1 cm), with a significant difference compared to group 2 ($p < 0.001$), median values being 6.65 cm and 4.6 cm respectively. The mean muscle thickness was 1.1 cm (min 0.7 cm, max 1.6 cm) in both groups, with no significant difference ($p = 0.637$).

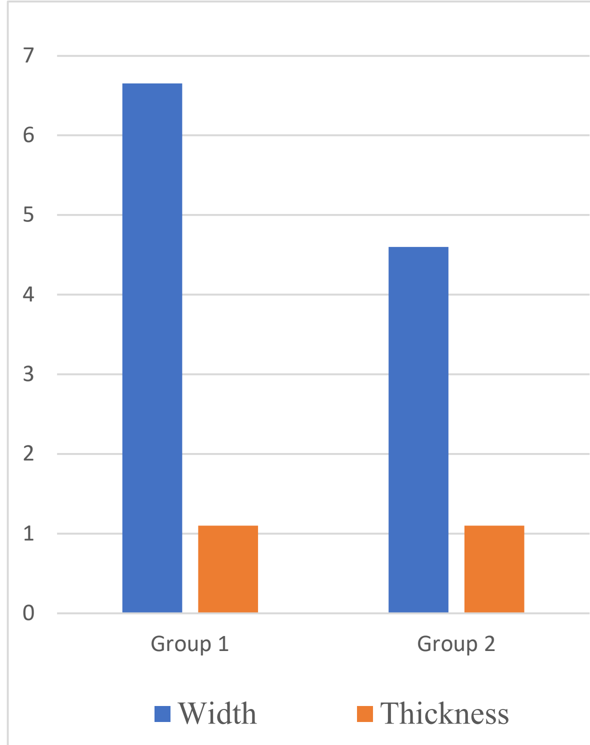


Figure 8.9.8 – Statistical analysis of the mean values of the width and thickness of the rectus abdominis muscles measured postoperatively in both study groups.

Similar to the preoperative regime, the same measurements of the three lateral abdominal muscles were used, and the following were observed:

Group 1	T.A.	O.I.	O.E.
Min	1,4 cm	2,4 cm	4,5 cm
Max	13 cm	15,6 cm	13,4 cm
Mean	6,66 cm	8,9 cm	10,6 cm
p value	0,392	0,642	0,152

Tabel 8.8.1 – Presentation in a table of the minimum, maximum, mean values, and p-value of the width of the lateral abdominal muscles in study group 1 postoperatively.

Group 1	T.A.	O.I.	O.E.
Min	0,3 cm	0,7 cm	0,6 cm
Max	1,2 cm	1,9 cm	2,3 cm
Mean	0,68 cm	1 cm	1,2 cm
p value	0,291	0,007	0,228

Tabel 8.8.2 – Presentation in a table of the minimum, maximum, mean values, and p-value of the thickness of the lateral abdominal muscles in study group 1 postoperatively.

In group 1, the average postoperative width of the transversus abdominis muscle was 6.66 cm (range 1.4 – 13 cm), with $p = 0.392$. The mean width of the internal oblique muscle was 8.9 cm (range 2.4 – 15.6 cm), with $p = 0.642$, and that of the external oblique muscle was 10.6 cm (range 4.5 – 13.4 cm), with $p = 0.152$. The mean thickness of the transversus abdominis was 0.68 cm (range 0.3 – 1.2), $p = 0.291$; for the internal oblique, 1 cm (range 0.7 – 1.9), $p = 0.007$; and for the external oblique, 1.2 cm (range 0.6 – 2.3), $p = 0.228$. In group 2, the postoperative widths of the lateral muscles were: transversus abdominis 2.8 – 8.9 cm (mean 4.98 cm, $p = 0.303$), internal oblique 5.8 – 12.1 cm (mean 8.3 cm, $p = 0.796$), and external oblique 7.5 – 14.5 cm (mean 10 cm, $p = 0.466$). The muscle thicknesses ranged: transversus abdominis 0.5 – 1.3 cm (mean 0.83 cm, $p = 0.193$), internal oblique 0.7 – 1.4 cm (mean 0.9 cm, $p = 0.469$), and external oblique 0.4 – 2.4 cm (mean 1 cm, $p = 0.060$). No significant differences were found between groups regarding the measurements of muscle widths and thicknesses.

Group 2	T.A.	O.I.	O.E.
Min	2,8 cm	5,8 cm	7,5 cm
Max	8,9 cm	12,1 cm	14,5 cm
Mean	4,98 cm	8,3 cm	10 cm
p value	0,303	0,796	0,466

Tabel 8.8.3 – Presentation in a table of the minimum, maximum, mean values, and p-value of the width of the lateral abdominal muscles in study group 2 postoperatively.

Group 2	T.A.	O.I.	O.E.
Min	0,5 cm	0,7 cm	0,4 cm
Max	1,3 cm	1,4 cm	2,4 cm
Mean	0,83 cm	0,9 cm	1 cm
p value	0,193	0,469	0,060

Tabel 8.8.4 – Presentation in a table of the minimum, maximum, mean values, and p-value of the thickness of the lateral abdominal muscles in study group 2 postoperatively.

The cross-sectional area of the transversus abdominis was also calculated during the postoperative CT, using the same method as preoperatively. The mean postoperative area in group 1 was 4.47 cm² (range 0.7 – 13.92), $p < 0.001$, and in group 2, 4.42 cm² (range 1.4 – 10.68), $p = 0.158$. The mean values were similar ($p = 0.681$), with no significant differences in the cross-sectional area between groups. The mean thickness of the abdominal wall muscles was 2.77 cm in group 1 and 2.65 cm in group 2, with no significant difference ($p = 0.655$). The maximum thickness was 4.5 cm in group 1 and 4.4 cm in group 2, while the minimum was 1.9 cm and 2.0 cm, respectively.

The TAR index was calculated by reporting the parietal defect width relative to the width of the rectus sheath (Index TAR = DW/RW). Situations such as a parietal defect width at least twice the width of the posterior sheath of the rectus abdominis guide the surgical approach towards posterior component separation, as described by the algorithm implemented by Carbonell.[57]

The average TAR index value was 1.20 (range 0.6 – 2.23, $p = 0.255$) in group 1, and 1.82 (range 0.91 – 3.23, $p = 0.1$) in group 2. The difference between medians was close to statistical significance ($p = 0.052$), indicating a trend for parietal defects in group 2 to have a relatively larger width compared to the rectus sheath, which could suggest greater severity of herniation pathology in this group. Additionally, the value ranges were narrower in group 1 compared to group 2.

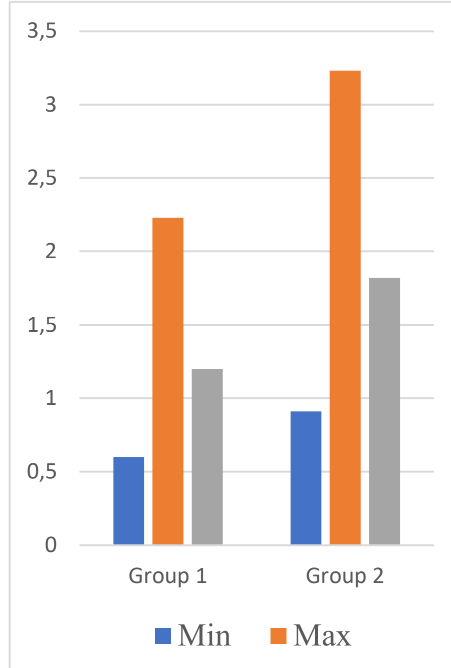


Figure 8.9.9 – Comparative statistical analysis of the minimum, maximum, and mean values of the TAR Index applied to both study groups.

8.10. Impact of the TAR technique on intra-abdominal pressure

Intra-abdominal pressure is defined as a static pressure within the abdominopelvic cavity, playing an important role in physiological processes such as supporting visceral positioning, vomiting, defecation, micturition, childbirth, coughing, sneezing, etc. It is generated by the tone and elasticity of the muscles involved in the abdominal wall (rectus abdominis and lateral abdominal muscles). The most critical muscle in generating and maintaining intra-abdominal pressure during various physiological processes is the transversus abdominis, due to the transverse arrangement of its muscle fibers.[58]

This pressure normally ranges between 0 and 5 mmHg, and an increase beyond a certain threshold becomes pathological, indicating abdominal hypertension. The latter is classified into four grades based on the pressure interval:

- Grade I = intra-abdominal pressure of 12–15 mmHg
- Grade II = 16–20 mmHg;
- Grade III = 21–25 mmHg;
- Grade IV = >25 mmHg.[59,60]

In this pathology, it is also important to mention the abdominal compartment syndrome, characterized by an increase in intra-abdominal pressure above 20 mmHg and associated with at least one visceral failure. Another predictor of this syndrome is abdominal perfusion pressure, defined as the difference between systolic blood pressure and intra-abdominal pressure. It is considered pathological when this difference is < 60 mmHg.[61]

To assess the impact of TAR technique on intra-abdominal pressure, multiple parameters were monitored:

This pressure was measured on the day before surgery using urinary catheterization. Each patient was informed about the procedures, and consent was obtained for these maneuvers and access to the data they provided for study inclusion. The units of measurement used were mmHg, converted from cmH_2O using the formula: 1 mmHg = 1.36 cmH_2O. [62]

	Min	Max	Mean	*p* value
Group 1	0	8	4,6	0,015
Group 2	3	7	5,2	0,639

Tabel 8.10.1 – Table representation of the minimum, maximum, and mean values (mmHg), as well as the p-value, of intra-abdominal pressures measured preoperatively in both study groups.

	Min	Max	Mean	*p* value
Group 1	0	12	3	< 0,001
Group 2	0	4	1,7	0,3

Tabel 8.10.1 – Table representation of the minimum, maximum, and mean values (mmHg), as well as the p-value, of intra-abdominal pressures measured postoperatively in both study groups.

The intra-abdominal pressure had more limited values in group 2 preoperatively. In group 1, the pressure significantly decreased after the intervention ($p < 0.001$), while in group 2, the postoperative pressure remained stable at 1.7 mmHg. Differences between groups were not statistically significant ($p = 0.317$ preoperatively, $p = 0.471$ postoperatively). The postoperative pressure differences are negative in both groups, with a mean of -2.1 mmHg in group 1 and -3.1 mmHg in group 2, indicating a decrease in intra-abdominal pressure after surgery; group 1 had a greater variation (-7 to 6 mmHg), compared to group 2 (-5 to -1 mmHg). According to the Mann-Whitney test, the differences between groups were not statistically significant ($p = 0.284$).

The impact of the TAR technique on the patient’s respiratory function was also analyzed by calculating plateau pressures (Pplat) via the inhalo-sedation device. Pplat was monitored at three stages of the surgical procedure, in the order of the surgical act. During measurements, the patient was placed in dorsal decubitus, both upper limbs in complete adduction, and the operating table in position 0. CmH2O was used as the unit of measurement in all three assessments.

In the first measurement, Pplat in group 1 ranged between 17 and 25 cmH2O, with an average of 23.6 cmH2O ($p < 0.001$), while in group 2, it ranged between 11 and 25 cmH2O, with an average of 22.2 cmH2O ($p < 0.001$); the difference was not significant ($p = 0.406$).
In the second measurement, after closing the posterior layer, Pplat in group 1 ranged between 16 and 31 cmH2O, with an average of 22.3 cmH2O ($p < 0.001$), and in group 2, between 13 and 23 cmH2O, with an average of 20.8 cmH2O ($p < 0.001$); the difference between groups was not significant ($p = 0.406$).

In the final assessment, after closing the anterior layer, the values in group 1 ranged between 16 and 31 cmH2O, with a mean of 22.2 cmH2O ($p < 0.001$), and in group 2, between 13 and 23 cmH2O, with a mean of 20.7 cmH2O ($p < 0.001$); the difference was not significant ($p = 0.144$).
The negative average of plateau pressure differences in both groups suggests that, overall, the closure technique was effective in reducing intra-abdominal tension, a desirable outcome of the tension-free procedure. The anesthesiology-surgical team's intervention considered that the two cases in group 1 with positive pressure differences did not require prolonged intubation, indicating a need for a more detailed analysis of other clinical factors influencing the decision. In group 2, the smaller differences in cases with positive values indicate a lower pressure impact, reducing the necessity for intensive postoperative management.

8.11. Intraoperative blood loss

One of the intraoperative aspects monitored in this study was bleeding. Data collection was performed using the same estimation method of blood loss by calculating the difference between the total amount of aspirated fluids and the total amount of administered normal saline solutions during lavage. In group 1, blood loss ranged from 100 ml to 300 ml, with an average of 231.8 ml ($p < 0.001$), while in group 2, it ranged from 100 ml to 400 ml, with an average of 222.2 ml ($p = 0.287$); the difference between the means was not statistically significant ($p = 0.681$).

8.12. Adhesions at the level of the parietal defect

Another intraoperative aspect followed was the intervisceroparietal and intervisceral adhesion process at the level of the parietal defect. Most patients had parietal defects secondary to previous surgeries, so the local adhesion syndrome was divided into 3 groups as follows: Group 1 includes defects without adhesions; Group 2 includes defects with intervisceroparietal adhesions or omental content, without organ adhesion to the cavity or parenchyma; Group 3 includes defects with both intervisceral and intervisceroparietal adhesions, with at least one visceral or parenchymal content.

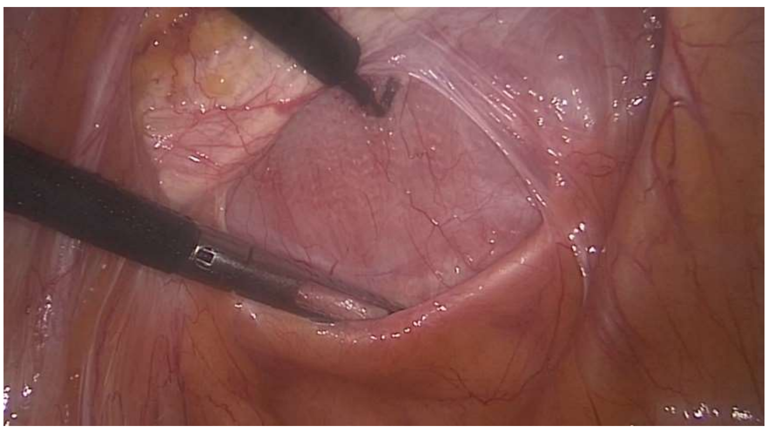


Figure 8.12.1 – Ventral parietal defect with hernia sac without content (classified in group 1) – intraoperative aspect.

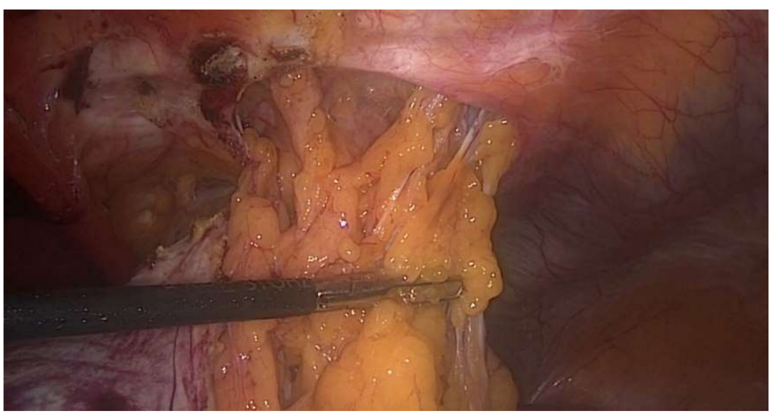


Figure 8.12.2 – Ventral parietal defect with omental content of the hernia sac (classified in group 2) – intraoperative aspect.

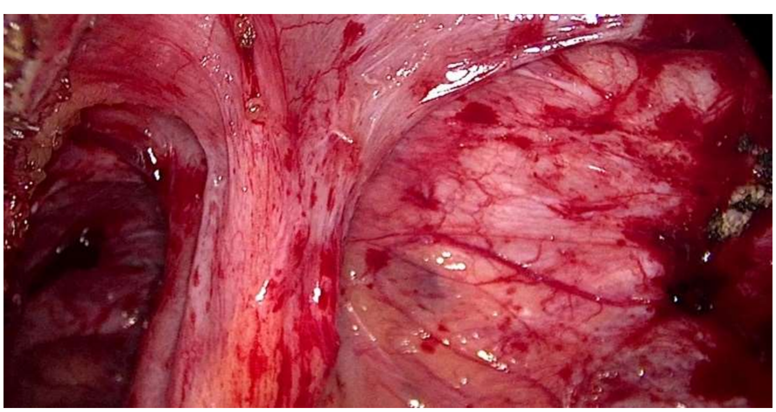


Figure 8.12.3 – Ventral parietal defect with intervisceroparietal and intervisceral adhesion syndrome involving the omentum and intestinal loops (classified in group 3) – intraoperative aspect.

In group 1, patients were distributed as follows: 9.1% in group 1, 40.9% in group 2, and 50% in group 3, with no significant differences compared to group 2 ($p = 0.162$). In group 2, 11.1% were in group 1, 66.7% in group 2, and 22.2% in group 3, indicating a similar distribution.

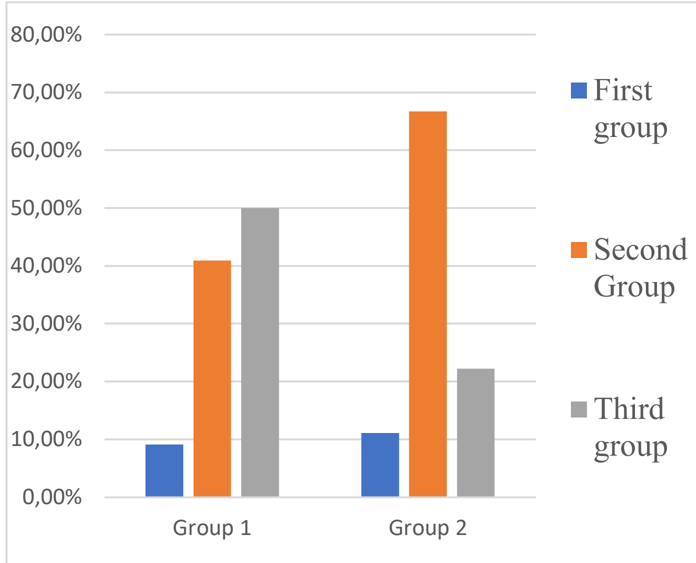


Figure 8.12.4 – Statistical analysis of the three adhesion syndrome groups at the level of the hernia sac within the two study groups

8.13. Practical aspects during the desinsertion of the transversus abdominis muscle

In this subchapter, the number, topographical location, and dimensions of defects resulting from the dissection of the transversus abdominis insertion and the preparation of the supra-fascial/preperitoneal plane were analyzed. The topographical positioning of these defects was divided into 3 groups as follows:

- Group 1 includes peritoneo-fascial defects located at the hypochondrium;
- Group 2 includes defects at the flank level;
- Group 3 includes defects at the iliac fossa level.

Analysis revealed significant statistical differences in the distribution of defects between the right and left sides ($p = 0.689$), with predominance in the flank and iliac fossa regions, both in Group 1 and Group 2.

Another characteristic studied was the maximum transverse diameter of these defects. To accurately assess the dimensions, a sterile flexible ruler was used. Defects with a maximum transverse diameter smaller than 5 mm were approximated at 5 mm. For statistical analysis, the transverse diameters were grouped into three categories:

- Group 1: diameters between 5 – 10 mm;
- Group 2: diameters between 11 – 20 mm;
- Group 3: diameters over 21 mm.

The grouped analysis showed a relatively uniform distribution of defect diameters between 5 and 10 mm, with 50% in each group ($p > 0.05$). Larger defects, up to 40 mm, were more frequently observed in group 1, accounting for 45.5% of cases, with a significant difference between the two study groups ($p = 0.040$).

Chapter 9. Mesh placement

The alloplastic material used in the study was a polypropylene, monofilament, macroporous, low-weight type, measuring 30.5 cm x 30.5 cm (Soft Mesh – Bard).

Figure 9.1 – Illustration of the type of mesh used in the study.[63]

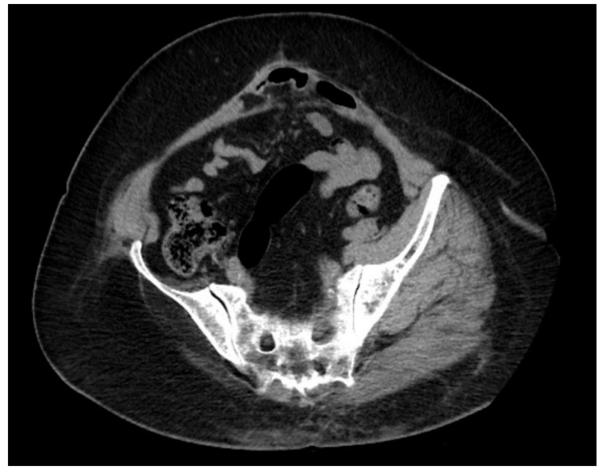
In the comparative study, group 1 showed an average length of 27.3 cm (range 23 – 33 cm, $p = 0{,}285$), an average width of 24.2 cm (range 16 – 41 cm, $p = 0{,}007$), and an average area of 663.3 cm² (range 368 – 1200 cm²). For patients in group 2, the length was 26.7 cm (range 23 – 30 cm), width 22.5 cm (range 16 – 30 cm), and area 600.6 cm² (range 368 – 780 cm) ($p = 0{,}006$). In group 2, the length had a mean of 27.7 cm (range 24 – 30 cm, $p = 0{,}473$), width 27.3 cm (range 25 – 29 cm, $p = 0{,}343$), and area 756.3 cm² (range 650 – 812 cm², $p = 0{,}041$). Significant differences were observed for width ($p = 0{,}016$) and area ($p = 0{,}013$), with the median width larger in group 2 (28 cm vs. 24.5 cm) and the area larger in group 2 (783 cm^2 vs. 625 cm^2). This suggests a different surgical approach and possibly a more voluminous mesh in group 2. In all cases, fixation of the prosthetic material was not necessary. Additionally, no drains were placed in any of the cases.

Chapter 10. Postoperative evolution

All patients were discharged on the first postoperative day, with the first follow-up scheduled at 14 days to remove skin sutures, then at 1 month, 6 months, and annually thereafter. Regarding complications, a classification into two main categories was used:

- Immediate postoperative complications (SSO) that typically occur within the first month after surgery, including wound infections, hematoma, seroma, bleeding, and wound dehiscence.
- Late postoperative complications (DSO) that manifest after 30 days post-surgery, including recurrence, postoperative pain syndrome, bowel obstructions, and complications related to sutures or mesh materials.

In the overall patient cohort, two cases of SSO (3.1%) were identified, both being seromas subsequently evacuated. It is important to note that this percentage was observed within the minimally invasive surgery group. Additionally, there were four cases of DSO (6.3%), specifically recurrences detected during the 6-month postoperative control both clinically and via follow-up CT scan. No complications were reported in the second study group during routine follow-up examinations.

Figures 10.1. and 10.2. – Native CT cross-sectional section highlighting the presence of the parietal defect (preoperative – figure on the left) and the recurrence area identified during follow-up (postoperative – figure on the right) – CT aspect of the same patient.

Figures 10.3. and 10.4. – Native CT sagittal section highlighting the presence of the parietal defect (preoperative – figure on the left) and the recurrence area identified during follow-up (postoperative – figure on the right) – CT aspect of the same patient.

Chapter 11. Statistical analysis and correlations with smoking status

11.1. Impact of smoking on intra-abdominal pressures and Pplat

We correlated tobacco use with the number of postoperative complications following TAR, hypothesizing that smokers or former smokers have an increased risk of developing both early and late postoperative complications. The analysis of the results indicated that, in the entire cohort, smokers had higher preoperative intra-abdominal pressure compared to non-smokers, but the difference was not statistically significant ($p = 0.184$). Within the groups, group 1 showed no significant difference between smokers and non-smokers ($p = 0.5$), whereas in group 2, the difference was significant ($p = 0.029$), suggesting that smokers had a higher pressure compared to non-smokers, which indicates a different influence of smoking depending on the group. Regarding the difference in pressure between preoperative and postoperative values, in group 1, the differences between smokers and non-smokers were not significant ($p = 0.720$), and in group 2, the differences were also not significant ($p = 0.847$). Overall, smoking did not have a consistent, significant impact on intra-abdominal pressure or its variations during and after the intervention, with differences remaining statistically insignificant.

11.2. Effects of smoking on parietal defect

Results showed that, in group 1, smokers had an average of 3 defects ($p = 0.016$), while non-smokers had 1.25, indicating a significant association with smoking. In group 2, the difference was not statistically significant ($p = 0.477$), but the total cohort had a higher average in smokers (2.7) than in non-smokers (1.54), with a significant association ($p = 0.047$). Regarding the defect area, no significant differences were observed in group 1 ($p = 0.644$), but in group 2, smokers had an average area of 72.96 cm^2, larger than the 24.24 cm^2 in non-smokers ($p = 0.063$). Across the entire cohort, the difference was nearly significant ($p = 0.151$), and the post hoc Tukey test revealed a significant difference between the mean defect sizes of smokers and non-smokers in group 2 ($p = 0.004$).

11.3. Intraoperative blood loss among smokers

Smoking significantly affects bleeding time due to chemicals that can impair platelet function. This leads to prolonged clot formation and increases the risk of intra- and postoperative hemorrhages, potentially complicating recovery and surgical outcomes. In the first group, average blood loss was 228.57 mL for smokers and 237.5 mL for non-smokers, with no significant difference ($p = 0.883$). In the second group, smokers lost an average of 266.66 mL, compared to 133.33 mL in non-smokers, with a statistically significant difference ($p = 0.028$). Overall, no significant differences between groups were observed ($p = 0.124$).

11.4. Effects of smoking on ACV and HSV

In the analysis of the association between smoking and ACV, data from both groups were compared by evaluating the mean volumes for smokers and non-smokers. Overall, the average ACV values were 8926.42 cm^3 in smokers and 8841.13 cm^3 in non-smokers, with no statistically significant difference ($p = 0.287$). At the group level, in group 1, the median ACV for smokers was 8600 cm^3, while for non-smokers it was 8931 cm^3 ($p = 0.741$). In group 2, the median for smokers was 9635.55 cm^3 and for non-smokers 8661.1 cm^3 ($p = 0.126$), with differences not statistically significant. Regarding HSV, the mean for smokers was 162.48 cm^3 overall, compared to 157.9 cm^3 in non-smokers, with no significant difference ($p = 0.466$). In group 1, smokers had an average hernia sac volume of 156.14 cm^3, while non-smokers had 111.12 cm^3 ($p = 0.351$), suggesting no significant correlation. In group 2, the mean for smokers was 177.29 cm^3 versus 282.65 cm^3 for non-smokers ($p = 0.475$), also indicating no significant association.

11.5. Changes in abdominal wall musculature

Based on the hypothesis that smoking affects the dimensions of the abdominal muscles, impairing musculature through reduced blood flow and oxygen supply, which may lead to muscle atrophy and decreased muscle mass, a comparative analysis of muscle sizes and smoking status revealed the following: Regarding the thickness of the rectus abdominis muscles, smokers had an average of 0.96 cm (min 0.6 cm, max 1.6 cm) in group 1 and 0.98 cm (min 0.8 cm, max 1.3 cm) in group 2, with no significant differences ($p = 0.224$). The average width of the rectus muscles was 7.14 cm (min 4.6 cm, max 11.1 cm) in group 1 and 4.76 cm (min 3.9 cm, max 8.2 cm) in group 2;

the median difference was significant ($p = 0.042$), with smaller values in group 2. For the lateral musculature, smokers had an average thickness of 2.58 cm in group 1 and 2.1 cm in group 2, differences being not significant ($p = 0.285$). Regarding the areas of the mesh, smokers had an average of 672.92 cm² in group 1, 738.16 cm² in group 2, and 692.5 cm² in group 3, with no statistically significant differences ($p = 0.628$), indicating that smoking status does not have a significant influence on muscle dimensions or mesh areas.

Chapter 12. Statistical analysis and pre- and postoperative correlations

12.1. Effects on abdominal musculature

An alternative hypothesis examined was the association between the dimensions of the rectus and lateral abdominal muscles and intra-abdominal pressure. Post-TAR changes in these dimensions may impact the ability to modulate intra-abdominal pressure. The differences between preoperative and postoperative measurements of the antero-lateral muscles were analyzed to highlight anatomical modifications after TAR, as well as the differences between the two study groups. In group 1, the thickness of the rectus muscles was 1.0 cm (min 0.6 cm, max 1.6 cm), and in group 2, 0.98 cm (min 0.8 cm, max 1.3 cm), with no significant difference ($p = 0.224$). The average width of the rectus muscles was 7.14 cm (min 4.6 cm, max 11.1 cm) in group 1 and 4.76 cm (min 3.9 cm, max 8.2 cm) in group 2, with a statistically significant difference ($p = 0.011$), median values being 7.6 cm and 4.7 cm respectively. The thickness of the lateral muscles was 2.58 cm (min 2.1 cm, max 2.7 cm) in group 1 and 2.1 cm (min 1.7 cm, max 2.6 cm) in group 2, differences not significant ($p = 0.285$). Regarding the mesh areas, smokers had 672.92 cm² (group 1), 738.16 cm² (group 2), and 692.5 cm² (group 3), with no significant differences ($p = 0.414$).

12.2. Impact of demographic factors and living conditions on intra-abdominal pressures

To compare the intra-abdominal pressure results recorded preoperatively and postoperatively, a series of correlations were used, yielding the following findings:
Within the study groups, no significant differences were observed regarding age group, BMI, or sex in pre- or post-operative intra-abdominal pressure, with p-values > 0.05. In group 2, a strong correlation was detected between smoking and preoperative intra-abdominal pressure ($p < 0.05$), indicating that smokers had, on average, higher pressure values; however, this association was not maintained in the postoperative period.

In the total sample, correlations between smoking and intra-abdominal pressure at both moments were insignificant, suggesting that demographic factors and lifestyle aspects do not statistically influence intra-abdominal pressure in this study context. Preoperative pressure values were 4.21 mmHg (range 3 – 6 mmHg) in non-smokers and 5.12 mmHg (range 3.5 – 8 mmHg) in smokers, with no significant difference ($p = 0.281$). In the technical groups, in group 2, the difference between mean values was significant ($p = 0.018$), with smokers presenting higher pressure (mean 6.33 mmHg) than non-smokers (mean 4.66 mmHg). Conversely, in group 1, the difference was not significant ($p = 0.281$), and in the total lot, the association was weakly negative and not significant ($p = 0.081$). Postoperatively, all values decreased, and differences between smokers and non-smokers remained non-significant in both groups ($p > 0.05$), with mean values between 1 - 3 mmHg, indicating that smoking does not significantly influence intra-abdominal pressure during the postoperative period.

12.3. Relationship of preoperative tomographic measurements with intra-abdominal pressures

The correlation between certain preoperative tomographic measurements and intra-abdominal pressure, both before and after the TAR procedure, revealed several significant associations:
In group 1, the ACV exhibited a moderate and significant correlation with preoperative pressure ($p = 0.013$), suggesting that larger ACV is associated with higher pressure prior to surgery.

Regarding muscle measurements, the thickness of the rectus abdominis muscles had a weak and non-significant correlation preoperatively ($p = 0.224$) and nearly significant postoperatively ($p =$

0.087). For the transversus abdominis, the correlation was moderately positive and nearly significant preoperatively ($p = 0.055$), and strongly negative and significant postoperatively ($p < 0.001$). In group 2, the values for the thickness of the rectus and transversus muscles were weakly correlated and not significant both pre- and postoperatively.

Regarding the length of the rectus muscle, in group 1, a weak negative and non-significant correlation was observed preoperatively, but a significant and strongly negative correlation was found postoperatively ($p < 0.001$), indicating that a longer length is associated with lower pressure after surgery. In the total cohort, the correlation between the length of the rectus muscle and postoperative pressure was also significant and negative ($p < 0.05$). Thus, both ACV and muscle dimensions, especially the length and thickness of the transversus abdominis, have a substantial impact on intra-abdominal pressure, with these associations becoming more evident during the postoperative period.

12.4. Impact of operative time on intra-abdomnal pressures

Any long operative time hypothesized to be associated with increased intra-abdominal pressure, which may negatively impact postoperative outcomes in parietal defect correction, was correlated with both preoperative and postoperative intra-abdominal pressures, revealing the following: In group 1, no significant association was found between preoperative operative time and intra-abdominal pressure ($p > 0.05$), while postoperatively, a longer operative time was significantly correlated with higher pressure ($p < 0.05$). In group 2, a significant negative correlation was observed preoperatively ($p < 0.05$), indicating that a longer operative time leads to lower pressure, whereas in the entire cohort, after surgery, the correlation was close to significance and positive ($p > 0.05$), suggesting that prolonged operative time may be associated with higher intra-abdominal pressure, highlighting the importance of careful monitoring of surgical duration.

12.5. Relationship of defect and mesh dimensions with intra-abdominal pressures

The relationship between parietal defect size and the reinforcement mesh is crucial for controlling intra-abdominal pressure, both preoperatively and postoperatively. Studies suggest that the size of the parietal defect influences the distribution and effectiveness of the meshes used in abdominal reconstruction, directly affecting intra-abdominal pressure and potentially leading to more favorable clinical outcomes and reduced risk of postoperative complications. Therefore, these variables were correlated with measured intra-abdominal pressure before and after surgery, revealing the following:

In the study, the correlation between defect area and intra-abdominal pressure was weakly positive in group 1 before and after surgery, with no statistical significance ($p > 0.05$), indicating that defect size does not have a clear impact on intra-abdominal pressure. In group 2, this correlation was moderate preoperatively and very weak postoperatively, also lacking significance ($p > 0.05$), suggesting minimal influence of defect size on intra-abdominal pressure. Overall, the relationship was weakly positive and not significant across the total cohort. The greater variability in defect sizes in group 2 (± 35.95) compared to group 1 (± 27.7) indicates a larger diversity in defect nature, which could influence postoperative pressure behavior. Regarding the mesh surface area, no significant associations were observed with intra-abdominal pressure in either group, although a non-significant negative trend was noted in the preoperative period for group 2, suggesting that other additional factors should be considered in risk assessment and postoperative evolution.

Chapter 12. Discussions

In the development of this study, a series of objectives considered important for the perioperative management of anterior-lateral parietal defects through the TAR technique were followed.

Data analysis suggests that, although the age distribution is normal across the entire cohort, significant differences based on sex can affect health assessment and surgical decision-making; men, with a higher and more homogeneous age distribution, require careful consideration of comorbidities, while the high variability of BMI among women in group 1 indicates the need for personalized approaches. Additionally, the distribution of the ASA score shows a lower surgical risk in group 1 compared to group 2, which has a predominance of patients with ASA III scores, and the high prevalence of oncological history (34.4%) highlights the necessity for careful perioperative risk management.

Analysis of parietal defect localizations in both groups reveals that neither group includes patients with M1, L1, L3, or L4, suggesting possible clinical specificity or patient typology tendencies; however, group 2 shows a more concentrated distribution around M2 and M4, while group 1 demonstrates greater diversity. Differences in the number of defects between the two groups suggest potential influences from demographic characteristics, medical history, or the nature of previous interventions, with a higher prevalence of multiple defects in group 2, indicating a more advanced disease stage. This diversity, along with the non-normal distribution of defect sizes, underscores the importance of detailed assessment of these characteristics to optimize therapeutic plans and surgical interventions, as larger defect sizes can influence the surgical approach.

A significant correlation between BMI and defect area suggests that patients with higher body mass index tend to have larger defects, and the high recurrence rate (95.4% in group 1 and 100% in group 2) indicates the necessity of performing the posterior component separation technique. The classification of defects based on width revealed a high prevalence of W2 type defects in group 1, while group 2 showed a significantly more diverse distribution.

The sizes of diameters measured preoperatively are critical for planning surgical procedures, impacting the choice of techniques and helping anticipate complications, especially given the abnormal variability of APD and DID in group 1, which highlights the need for detailed patient evaluations. The wider width of the rectus abdominis muscles in this group indicates better muscle development, which may facilitate postoperative recovery, while the increased variability of lateral muscles suggests significant differences among patients. The thickness of the psoas major, an indicator of trunk stability, and the muscular wall thickness are also essential for abdominal function and intra-abdominal pressure management, playing an important role in preoperative assessments for prognosis.

The comparison of the related volumes provides a clear picture of the structural state of the abdominal cavity, with group 2 having higher values of ACV and HSV, suggesting increased hernia severity and possible surgical difficulties. Assessing the length and associated indices (LOD and IP) is essential for estimating intervention risks and evaluating the impact on respiratory function and postoperative outcomes. Additionally, knowing the TAR index is crucial in surgical strategy, with higher mean values in group 2 possibly indicating more severe hernias and greater susceptibility to recurrences, emphasizing the importance of careful planning in managing parietal defects.

Monitoring preoperative and postoperative intra-abdominal pressure is vital for preventing complications such as abdominal compartment syndrome, as the reduction of this pressure in both groups indicates a significant impact of surgical procedures on internal pressure dynamics. Furthermore, assessing the plateau pressure values is crucial for estimating postoperative risks, facilitating careful care and avoiding severe complications.

Proper mesh dimensions play a crucial role in the success of surgical procedures, influencing both the effectiveness of defect repair and the risk of recurrence. A larger mesh, as observed in group 2, could provide better support in cases of extensive defects. The higher overlap value in group 2, especially laterally, suggests a more effective surgical technique or repair strategy that benefited these patients and could indicate a lower risk of defect recurrence.

Although the results are not sufficient to draw definitive conclusions about the impact of smoking on postoperative intra-abdominal pressure, observed trends in group 2 suggest that smokers may face a higher risk of complications, particularly in group 2, where significant differences were recorded. This analysis indicates that smoking could negatively influence recovery and postoperative condition, especially regarding plateau pressure.

Studies suggest that smokers generally have a higher incidence of parietal defects compared to non-smokers, with a more pronounced trend in group 2, although differences are not always statistically significant. Additionally, smokers in group 2 experienced significantly greater blood loss during surgery, indicating a possible association between smoking and intraoperative risks.

The analysis of the two study groups showed that, although there are variations in the volume of the abdominal cavity and hernia sac between smokers and non-smokers, the high *p*-values indicate the absence of a significant correlation, suggesting that smoking does not have a pronounced impact on these measurements.

The results suggest that the TAR procedure significantly affected the dimensions of the abdominal muscles, with notable reductions in width and thickness in group 1, confirmed by *p*-values < 0.05. Conversely, group 2 exhibited significant increases in the thickness of the internal and external oblique muscles, also observed across the entire patient cohort.

The correlations between the defect area and intra-abdominal pressure were weak and not statistically significant, indicating that intra-abdominal pressure is not a reliable postoperative predictor. However, a larger preoperative intra-abdominal volume was associated with higher preoperative pressures, highlighting the need for careful monitoring of patients with increased ACV.

The analysis of the dimensions of the rectus abdominis muscles in group 1 suggests a significant inverse postoperative correlation between the muscle length and intra-abdominal pressure, indicating that a longer muscle could help reduce this pressure. Additionally, the significant negative correlation between the thickness of the transversus abdominis and postoperative pressure, especially in group 1, suggests that increased muscle thickness may contribute to lowering intra-abdominal pressure, a relationship not observed in group 2.

In group 2, a significant negative correlation was found between operative time and intra-abdominal pressure, suggesting that longer surgeries may result in lower pressures, contrary to expectations. In contrast, group 1 showed positive postoperative correlations, indicating that longer operative durations might be associated with higher intra-abdominal pressures, potentially due to fluid accumulation or tension changes in muscles, as demonstrated across the entire cohort.

Chapter 13. Conclusions and personal contribution

The conclusions below are the result of a comprehensive analysis of the cases in the studied cohort and represent both a confirmation of findings reported in the scientific literature and new observations or percentage benchmarks related to perioperative events.

Following the analysis of demographic data and the results obtained from the two study groups, the following conclusions were drawn:

- The majority of patients in group 2 were older, with more severe comorbidities, and exhibited more complex parietal defect characteristics.
- The most frequently recorded comorbidity was cardiovascular disease, followed by type II diabetes.
- Patients within group 2 presented smaller dimensions of the antero-lateral abdominal muscles and larger preoperative cavity volumes compared to the minimally invasive surgery group (personal observation).
- Post-surgery, an increase in the width and thickness of the rectus abdominis muscles was observed, suggesting effective integration and stiffening of the anterior abdominal wall as a result of the TAR procedure (personal observation).
- A decrease in the width of the abdominal muscles was noted postoperatively, while their thickness increased, along with a general increase in the muscular wall thickness. These changes suggest an adaptation of the abdominal muscle structure to the surgical intervention and recovery process.
- The postoperative volume of the abdominal cavity showed an approximate increase of 2000 cm^3 compared to the preoperative measurement, with no impact on intra-abdominal pressures.
- Patients with a larger preoperative intra-abdominal volume were associated with higher preoperative intra-abdominal pressures, a finding confirmed in both patient groups.
- Monitoring intra-abdominal pressure pre- and postoperatively is essential for preventing complications. The reduction of pressure in both groups after interventions suggests a positive impact on internal dynamics.

- Among patients operated with the classic approach, a frequent association was observed between an older age group and higher preoperative intra-abdominal pressure. Higher pressure values were also associated with smoking status (personal observation).
- The difference between preoperative and postoperative intra-abdominal pressure was greater in patients operated openly compared to those operated minimally invasively (personal observation).
- Patients undergoing minimally invasive surgery demonstrated an association between greater abdominal wall thickness and lower postoperative intra-abdominal pressure. A similar effect was observed with a larger width of the rectus abdominis muscle (personal observation).
- In the minimally invasive group, the dimensions of the transversus abdominis muscle were associated as follows: larger thickness and width were correlated with lower postoperative intra-abdominal pressure, while a larger width was associated with higher preoperative pressure (personal observation).
- The plateau pressures recorded during the three measurements were higher in minimally invasive surgery compared to open surgery, and the difference was more significant in the second study group (personal observation).
- A longer operative time in minimally invasive surgery is associated with an increased risk of bleeding, as well as higher postoperative pressure and lower preoperative pressure. It was also observed that the majority of patients in group 1 had a more intense adhesional syndrome compared to open surgery patients (personal observation).
- In the group of patients operated with an open approach, it was found that a larger mesh area was required, with more extensive overlaps, especially along the cranio-caudal diameter (personal observation).
- A general trend of higher postoperative intra-abdominal pressures was observed in correlation with the use of a larger mesh area.
- Postoperative complications were recorded only in the minimally invasive group, manifesting as seromas and recurrences, both associated with smoking status and low BMI (personal observation).
- Seromas were associated with more than three previous surgeries, suggesting that patients with extensive surgical histories may have an increased risk of developing this complication (personal observation).

- An association was noted between hernia recurrences and the presence of more than two parietal defects, encompassing a larger defect area and a larger hernia sac volume, necessitating the use of a bigger mesh.

Personal contributions related to the comparison of the two patient groups, both minimally invasive and open, using the posterior component separation technique, were as follows:

- Patients operated with an open approach presented more complex pathology and a poorer performance status compared to those operated minimally invasively.
- In group 2, patients had smaller muscle mass, but their diameters and related volumes were larger compared to group 1.
- A better reduction in intra-abdominal pressure post-TAR was observed in patients operated open, which was also reflected in plateau pressures.
- The rate of peritoneo-fascial defects during dissection of the transversus abdominis muscle was higher in the minimally invasive technique, most frequently on the right side.
- The size of the prosthetic material used in open surgeries was larger, with greater overlaps along the cranio-caudal axis.
- Complications occurred only in the minimally invasive group, consisting of seromas and recurrences.
- Significant associations between smoking status and a more aggressive and complex form of pathology were identified in both study groups.
- Intraoperative bleeding was greater among smokers, with statistical significance in the minimally invasive group.

We consider that the research objectives listed above were achieved by analyzing the differences between the two study groups, as well as the technique's results across the entire patient cohort. Additionally, we believe that research in this field should continue through studies with greater impact and statistical significance.

In summary, the Transversus Abdominis Release procedure is a feasible minimally invasive technique, especially suitable for large parietal defects or juxtasomal, easy to perform, and with a significant favorable impact on abdominal wall function, with a low risk of complications. Patients with poorer functional status and more complex pathology approached via open surgery show certain advantages compared to the minimally invasive technique.

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