



UNIVERSITATEA DE MEDICINĂ ȘI FARMACIE
“CAROL DAVILA” din BUCUREȘTI



**„CAROL DAVILA” UNIVERSITY OF
MEDICINE AND PHARMACY, BUCHAREST
DOCTORAL SCHOOL
MEDICINE**

***THE LAPAROSCOPIC APPROACH TO THE
MANAGEMENT OF RECURRENT INGUINAL HERNIAS***

ABSTRACT OF THE DOCTORAL THESIS

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Dedication

The present doctoral work is the result of a complex scientific endeavour, the completion of which was made possible through the guidance and support of distinguished academic personalities, to whom I express my profound gratitude.

I extend my sincere thanks to my PhD supervisor, Florian Popa, for his scientific rigor, attentive guidance, constant support, and essential contribution to the development and completion of this study. At the same time, I express my deep appreciation for his formative role, as a model of professional excellence and academic conduct, whose values have had a significant impact on my professional development.

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The professional and academic model provided by these distinguished professionals will continue to serve as a source of inspiration in my future activity.

"Mens, manus, et cor !"

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Introduction

Surgical repair of inguinal hernia represents one of the most common elective procedures in general surgery, with over 20 million operations performed annually worldwide, underscoring the major significance of this pathology [1,2,3]. Hernia recurrence remains a significant clinical problem, with a substantial impact on quality of life, necessitating the optimization of surgical techniques and the materials used in order to reduce the risk of recurrence. Recurrence is not determined exclusively by technical factors, but also involves complex biological mechanisms, particularly alterations in wound healing and collagen metabolism, which lead to inferior-quality scar tissue [4,5]. In this context, the treatment of recurrent inguinal hernia has increasingly shifted toward minimally invasive approaches, especially laparoscopic techniques, which are associated with benefits such as reduced postoperative pain, shorter hospital stays, and faster reintegration [6,7]. However, the complexity of reoperations requires the development of efficient and standardized therapeutic strategies [8].

The present doctoral thesis aims to elucidate the complex relationship between collagen metabolism and the recurrence of inguinal hernia, analysing the implications of risk factors—particularly patient comorbidities—on the occurrence of recurrence. By correlating a systematic review of the specialized literature with the results of original research, the study seeks to highlight the mechanisms involved in this complication. At the same time, the processes of tissue integration of the prosthetic material are examined through the correlation of clinical data with morphological analyses (optical microscopy and polarized light microscopy), with the aim of characterizing collagen.

In Romania, there is no prospective national registry dedicated to hernias, which limits the systematic evaluation of surgical practices within a healthcare system characterized by the coexistence of public and private sectors. The present thesis analyses the management of recurrent inguinal hernia at the national level by comparing surgical activity across the two sectors, assessing the degree of adoption of minimally invasive techniques, and identifying current trends in the use of the laparoscopic approach.

In conclusion, the doctoral thesis entitled “*The Laparoscopic Approach to Recurrent Inguinal Hernias*” aims to contribute to the advancement of knowledge in this field through an integrative analysis of the biological, clinical, and systemic factors involved, thereby providing support for the optimization of surgical strategies and the improvement of the quality of patient care.

GENERAL CONSIDERATIONS

1. Current state of knowledge

1.1. Significance of the problem

The treatment of inguinal hernia represents one of the most frequently performed elective surgical procedures in general surgery worldwide, with global estimates exceeding 20 million operations annually [2,9]. Approximately 700,000 hernia repair procedures are performed each year in the United States, 200,000 in Germany, 100,000 in France, 80,000 in the United Kingdom, and around 15,000 in the Czech Republic [2,10]. The prevalence of inguinal hernia is significantly higher in men, with a lifetime risk estimated between 27% and 43%, compared to a risk of 3% to 6% in women [11,12]. Men have an eightfold higher risk than women of developing an inguinal hernia and are approximately twenty times more likely to undergo surgical repair [13].

Surgical intervention represents the standard therapeutic approach; however, recurrence remains a significant issue, particularly in the context of the complexity of reoperations and the associated morbidity [14,15,16]. Reported recurrence rates in inguinal hernia vary depending on the surgical approach employed and the methodology of postoperative follow-up. Registry-based studies and large clinical series indicate that the frequency of recurrence or the need for reoperation after inguinal hernia repair generally ranges between approximately 1% and 10% [17,18,19]. In particular, over the past two decades, the laparoscopic approach has been associated with reported recurrence rates ranging from approximately 1% to 7.9% [17,20,21].

1.2. Historical Milestones in Surgical Treatment

Interest in hernia pathology has been documented since the earliest stages of surgical history [22]. During the Middle Ages, progress in the understanding and treatment of hernias was limited, followed by a resurgence in the Renaissance period, when Ambroise Paré contributed to the development of surgical techniques through detailed descriptions and innovative approaches [23,24]. In the same context, Kaspar Stromayr distinguished between direct and indirect hernias and documented early surgical interventions [23,25].

The advancement of anatomical knowledge during the 18th and 19th centuries enabled a better understanding of the inguinal canal, through the contributions of authors such as Astley Cooper, Abraham Colles, and Franz Kaspar Hesselbach [23,26–28]. However, surgical progress remained limited by the lack of effective infection control [29]. The

introduction of Edoardo Bassini's technique represented a pivotal moment, revolutionizing the treatment of inguinal hernia through the anatomical reconstruction of the posterior wall [9,28], and was subsequently refined by numerous surgeons [30–34].

The 20th century marked the transition toward the concept of “tension-free” repair, with the introduction of prosthetic materials and the abandonment of tension-based techniques, which had been associated with higher recurrence rates [35–37]. 8The introduction of synthetic meshes represented a decisive milestone in the evolution of hernia surgery [38], and fundamental criteria for the ideal prosthetic materials were subsequently established [39,40]. The modern concept of hernioplasty was consolidated through the technique developed by Irving Lichtenstein, which established the standard of tension-free repair [36,41]. Furthermore, the development of laparoscopic surgery enabled the expansion of minimally invasive approaches in the treatment of inguinal hernia [42].

1.3. Current Trends in Surgical Treatment

Technological progress enabled the development of minimally invasive approaches in the early 1990s—particularly the transabdominal preperitoneal (TAPP) and total extraperitoneal (TEP) techniques—which have proven superior through the reduction of postoperative pain, shorter hospital stays, earlier resumption of daily activities, and lower recurrence rates [6]. 5In recent years, robot-assisted inguinal hernia repair has emerged as a promising advancement in minimally invasive surgery [31], offering advantages related to the precision of surgical maneuvers and three-dimensional visualization, particularly in complex cases [43,44].

In parallel, the field has undergone rapid development with regard to the prosthetic materials used for reinforcing the abdominal wall [32], with modern meshes being designed to promote tissue integration and reduce postoperative complications [45,46]. Fixation techniques have evolved through the introduction of self-adhesive meshes and resorbable adhesives, aimed at minimizing tissue trauma and postoperative pain [47–49]; however, the selection of the optimal method remains variable in clinical practice [3,50]. Despite these advances, there is no universal consensus regarding the optimal technique, which must be individually tailored in order to ensure safe and effective outcomes [12].

1.4. Laparoscopic techniques

Mesh-based repair techniques represent the current standard, being effective in reducing recurrence, and clinical guidelines recommend their use in symptomatic inguinal hernias in adults [12]. The most commonly employed minimally invasive approaches are

transabdominal preperitoneal (TAPP) and total extraperitoneal (TEP) techniques [51], with comparable outcomes; the choice depends on the surgeon's experience and the individual characteristics of the patient [52–55]. Laparoscopic procedures are standardized and safe; however, they involve specific risks, with complication rates varying according to the operator's experience and the complexity of the case [56,57]. Prevention depends on adherence to surgical principles and a thorough knowledge of anatomy.

1.5. Prosthetic Materials

The use of prosthetic mesh in inguinal hernia repair has led to a significant reduction in recurrence rates, thereby inducing a paradigm shift in which hernia recurrence is no longer the primary indicator of postoperative outcome [58]. At present, increasing attention is being directed toward other adverse clinical outcomes, such as acute and chronic postoperative pain, as well as the overall duration of recovery following surgery [59]. The characteristics of the prosthetic mesh directly influence tissue integration and postoperative evolution, making it essential for the material to replicate the biomechanical properties of the abdominal wall [60–62].

Pore size, weight, and mesh composition determine the inflammatory response, the risk of infection, and the phenomenon of contraction [60,63,64]. Lightweight and macroporous meshes are preferred due to improved tissue integration and a reduction in complications, while modern materials currently in use, such as polypropylene, polyester, and expanded polytetrafluoroethylene (e-PTFE), aim to optimize the balance between mechanical strength and biocompatibility [60,65].

1.6. Fixation methods

The application of a mesh for reinforcement of the posterior wall of the inguinal canal requires the use of a fixation method to anchor the implant at the site of the defect and to prevent its migration during the early postoperative period [60]. Fixation involves a balance between achieving adequate stability and avoiding tissue trauma or nerve injury [13], and at present there is no consensus regarding the optimal method, the choice largely depending on the surgeon's experience. The main fixation methods include biological and synthetic adhesives, staples, sutures, and self-adhesive meshes, each with specific advantages and limitations. Adhesives (fibrin, cyanoacrylate) reduce tissue trauma and postoperative pain [66–69], whereas staples provide effective fixation but are associated with an increased risk of local complications [70,71]. Sutures remain a viable alternative, with their properties varying depending on composition and structure [72–74].

2. Risk Factors Involved in Hernia Recurrence

2.1. Preoperative Risk Factors

Preoperative risk factors represent a fundamental component in the assessment of the risk of hernia recurrence, being closely correlated with the patient's biological and metabolic characteristics [75,76]. Hernia recurrence reflects a complex interaction between the biological response and the integrity of the abdominal wall, and cannot be explained exclusively by technical factors [77].

Conditions such as obesity, diabetes mellitus, and cardiovascular diseases affect tissue healing, while imbalances in collagen metabolism contribute to the formation of inferior-quality scar tissue [78–81]. Factors such as age and smoking further influence these processes [75], underscoring the importance of accurate identification and stratification of preoperative risk.

2.2. Intraoperative Risk Factors

Hernia recurrence represents a failure of treatment and highlights the importance of proper surgical technique, appropriate selection of prosthetic material, and complete anatomical coverage [82]. It is frequently determined by intraoperative factors, particularly technical errors occurring during the procedure.

Inadequate dissection, improper mesh positioning, and insufficient fixation may favor recurrence through incomplete defect coverage or implant migration. In addition, early postoperative complications, such as hematoma or seroma, may impair mesh integration. Therefore, adherence to technical principles and careful attention to anatomical details are essential for reducing the risk of recurrence [59].

2.3. Postoperative Risk Factors

Postoperative complications constitute a major determinant of hernia recurrence, by impairing the healing process and the stability of the surgical repair. Events such as seromas, hematomas, and wound infections are frequently associated with an increased risk of recurrence, through the induction of a persistent inflammatory response and the alteration of mesh integrity [58,83].

Hematomas and wound healing disorders reduce tissue perfusion and impair collagen synthesis, thereby decreasing the strength of the abdominal wall [84,85]. In addition, chronic pain and the early resumption of physical exertion increase intra-abdominal pressure, favouring repair failure [58,83]. Thus, these complications act synergistically, increasing the risk of recurrence.

ORIGINAL RESEARCH

3. Working Hypothesis and General Objectives

The present doctoral thesis is based on the premise that hernia recurrence is not an exclusively technical phenomenon, but rather the result of the interaction between patient-related biological factors, tissue characteristics and comorbidities, as well as the influence of systemic factors such as access to modern techniques and the organization of healthcare services.

The central hypothesis posits that hernia recurrence is determined by interdependent factors, including biological status, healing capacity, and the specific features of the healthcare system, all of which contribute to the variability of postoperative outcomes.

In this context, the thesis approaches hernia recurrence from an integrated perspective, correlating epidemiological analysis with the underlying biological mechanisms, in order to achieve a more comprehensive understanding of the determinants of recurrence.

3.1. General Objectives of the Thesis

- Evaluation of hernia recurrence from a multidimensional perspective, through the integration of national-level epidemiological analysis with individual-level clinical and morphological assessment
- Characterization of surgical practice in the management of inguinal hernia in Romania, highlighting the differences between the public and private sectors
- Analysis of the geographical distribution of cases and identification of potential regional disparities in access to surgical services and minimally invasive techniques
- Assessment of clinical and demographic risk factors associated with hernia recurrence, with an emphasis on the role of comorbidities and age
- Investigation of the biological mechanisms involved in recurrence, through the analysis of tissue healing processes and the integration of prosthetic material
- Correlation of clinical data with histological changes, in order to highlight the relationship between the patient's biological status and postoperative outcomes
- Analysis of the impact of surgical technique and type of healthcare facility on postoperative evolution and the use of medical resources
- Identification of directions for optimizing hernia management, aimed at reducing the risk of recurrence and improving the quality of medical care

3.2. Anticipated Impact of the Study

- Contribution to a better understanding of the determinants of hernia recurrence through the integration of clinical, biological, and systemic factors
- Provision of relevant national-level data regarding surgical practice and the organization of services for inguinal hernia
- Highlighting existing disparities in access to modern techniques, with the potential to inform more equitable health policies
- Supporting the need for the implementation of a national hernia registry for outcome monitoring and improvement of the quality of care
- Establishing a basis for optimizing surgical management strategies, grounded in risk factor assessment and treatment personalization
- Contribution to the development of an integrated approach to hernia treatment, encompassing both technical and biological aspects
- Increasing awareness of the role of comorbidities and tissue healing processes in the occurrence of recurrence
- Enabling the use of results to improve surgical training and expand the adoption of minimally invasive techniques

4. General Research Methodology

The present research was designed as an integrated approach aimed at investigating hernia recurrence from a multidimensional perspective, combining population-level analysis with individual clinical and morphological evaluation. Given the multifactorial nature of recurrence, the methodology was structured to enable both the identification of epidemiological patterns and systemic variations, as well as the analysis of the biological mechanisms involved in the failure of surgical treatment.

The methodological approach included two complementary directions. Study I focused on the characterization of surgical practice at the national level and the estimation of inguinal hernia recurrence within the context of the Romanian healthcare system, while Study II aimed to analyse preoperative risk factors and the tissue processes involved in recurrence, through a detailed clinical and morphological evaluation. The integration of these data allowed the correlation of epidemiological observations with the underlying biological mechanisms.

Study I

Study I was conducted as a retrospective national-level analysis, using administrative data from the DRG system, which covers healthcare institutions in Romania. Adult patients who underwent surgical intervention for inguinal hernia were included and followed over a five-year period in order to evaluate recurrence and surgical practices.

Recurrence was estimated indirectly, through the analysis of reinterventions and the coding of recurrent hernia diagnoses. Demographic, clinical, and institutional variables were analyzed, along with the type of surgical approach, with comparisons made between the public and private sectors, as well as geographical and temporal evaluations. Statistical analysis included descriptive methods and multivariable regression models to identify associated factors.

Study II

Study II was an observational clinical study conducted in a single centre, including patients with recurrent hernia treated surgically. Demographic characteristics, comorbidities, and surgical history were analysed and correlated with morphological and histopathological evaluations of the tissues.

Microscopic analysis enabled the assessment of collagen organization and the inflammatory response, including examination under polarized light to differentiate between mature and immature collagen. Statistical analysis aimed to identify associations between clinical factors and recurrence, providing an integrated perspective on the underlying mechanisms involved.

5. STUDY I

Recurrence of Inguinal Hernia in the Adult Population of Romania: A Five-Year National Analysis of Surgical Practice and Healthcare System Disparities

5.1. Introduction

At the international level, the analysis of surgical practices is facilitated by the existence of national registries; however, their coverage remains limited [86], and the adoption of minimally invasive techniques varies significantly between countries, being influenced by health policies and available resources [87–90]. In Romania, the absence of a national registry and the differences between the public and private sectors limit the systematic evaluation of surgical practices, highlighting the need for a national-level analysis.

5.2 Working Hypothesis and Specific Objectives

The research hypothesis is based on the premise that significant variations arise from the dual structure of the healthcare system, in which the private sector, benefiting from more flexible resources, demonstrates a higher adoption of modern technologies compared to the public sector. These differences may influence surgical practices, patients' access to minimally invasive treatments, and, consequently, the quality of care.

In this context, the study aims to characterize the national distribution of surgical interventions, perform a comparative analysis of surgical practices, evaluate the use of laparoscopic techniques, and identify potential directions for optimizing the management of recurrent inguinal hernia.

5.3 Materials and Methods

The study was designed as a retrospective national-level analysis, including all adult patients (18,185 cases) who underwent surgical intervention for inguinal hernia in Romania in 2019, based on anonymized DRG data provided by INMSS, covering the entire network of 272 hospitals (231 public and 41 private). Patients were followed over a five-year period (2019–2023) in order to estimate recurrence and evaluate surgical practices. Recurrence was identified indirectly through the use of ICD-10 codes for recurrent inguinal hernia and surgical reinterventions, with two estimates calculated: a minimum estimate based on coded diagnoses and a maximum estimate including all reinterventions.

Demographic, clinical, and institutional variables were analysed, and the surgical

technique (open vs. laparoscopic) was considered the dependent variable. Statistical analysis included nonparametric methods and multivariable logistic regression models to identify factors associated with the use of the laparoscopic approach and recurrence.

5.4 Results

The analysis included 18,185 adult patients who underwent surgery for inguinal hernia in Romania in 2019, followed over a five-year period. During this interval, 888 patients required at least one reintervention, and 29 underwent three or more subsequent procedures.

Given the limitations of the administrative database, recurrence was estimated using two complementary methods: a minimum estimate, based on the explicit diagnosis of recurrent hernia, which indicated a rate of 0.58%, and a maximum estimate, based on all reinterventions, of 4.88%.

Open surgery was predominant (15,619 cases vs. 2,566 laparoscopic cases). The study population was predominantly male (87.86%), with a mean age of 60 ± 16 years. Most interventions were performed in public hospitals and university centres, confirming their central role in the management of this pathology.

The geographical distribution highlighted a concentration of cases in major university centers (Bucharest, Cluj, Mureş, Timiş), suggesting a centralization of treatment. Patient migration was predominantly from the private to the public sector for reinterventions, supporting the role of the public healthcare system in managing complex cases.

From a temporal perspective, most reinterventions were recorded early, within the same year as the initial procedure, suggesting the presence of a significant number of early postoperative failures. Subsequently, the number of reinterventions decreased during the pandemic period and increased moderately in the following years, indicating that the evolution of these cases was influenced by both clinical factors and disruptions within the healthcare system.

The recurrence rate was higher in men (5.03% vs. 3.81%) and increased with age, peaking in the 70–79 age group (6.26%), with the association being statistically significant. Among comorbidities, only diabetes mellitus and benign prostatic hyperplasia were significantly associated with recurrence.

The length of hospital stay was influenced by both the surgical approach and the type of healthcare facility. In public hospitals, open surgery was associated with longer hospitalizations, although with a trend toward progressive reduction over time, while laparoscopic procedures consistently showed shorter durations. In the private sector, the

length of stay was significantly shorter for both types of intervention, reflecting organizational differences and more efficient care pathways. From an economic perspective, laparoscopic reinterventions were associated with higher costs than open procedures, particularly in the public sector, highlighting the financial implications of minimally invasive techniques.

Overall, the results of Study I indicate that the management of recurrent inguinal hernia in Romania is characterized by the predominance of the open approach, a concentration of cases in the public sector and university centres, unequal access to minimally invasive techniques, and the presence of significant differences between types of healthcare facilities.

5.5. Discussions

The analysis indicates an estimated recurrence rate of inguinal hernia in Romania ranging between 0.58% and 4.88%, a variation determined both by the actual heterogeneity of cases and by the limitations of the administrative data used. The peak of early reinterventions suggests a possible early technical failure; however, this may also include other situations, such as procedures for bilateral hernias or postoperative complications. Comparison with international data is limited by methodological differences, highlighting the need to interpret the results within the specific context of the healthcare system analyzed.

With regard to clinical factors, diabetes mellitus and benign prostatic hyperplasia were significantly associated with recurrence, emphasizing the role of metabolic factors and intra-abdominal pressure in the failure of surgical repair.

The study also highlights important differences between the public and private sectors, with public hospitals managing the majority of cases, including complex and recurrent ones, thereby assuming a central role within the healthcare system. Access to laparoscopic surgery remains uneven, being concentrated in large centres, while current reimbursement mechanisms do not sufficiently support the use of minimally invasive techniques. In this context, optimizing the management of recurrent inguinal hernia requires systemic measures, such as the adjustment of funding policies, the expansion of training in laparoscopic surgery, and the development of a national hernia registry to enable standardized outcome evaluation and reduce disparities in care.

5.6. Study Limitations

- ▶ Use of reintervention as an indirect indicator of recurrence, with potential underestimation of the true incidence
- ▶ Lack of detailed clinical data regarding surgical technique and operator-dependent

factors

- ▶ Inability to differentiate between true recurrence and other early reinterventions (e.g., postoperative complications)
- ▶ Absence of unit-level data, limiting the analysis of institutional variations
- ▶ Possible influence of unassessed factors on the results
- ▶ Inherent heterogeneity of administrative data based on the DRG system
- ▶ Limited international comparisons due to methodological and reporting differences

5.7 Conclusions

- The estimated recurrence rate of inguinal hernia in Romania ranges between 0.58% and 4.88%, influenced by the limitations of administrative data
- Recurrences occur predominantly early, suggesting an important role of technical factors
- The risk of recurrence increases with age and is higher in men
- Among comorbidities, only diabetes mellitus and benign prostatic hyperplasia are significantly associated with recurrence
- The public healthcare system manages the majority of cases and functions as the main referral centre for recurrent and complex cases
- There is asymmetric patient migration from the private to the public sector for reinterventions
- Private hospitals have shorter lengths of stay, reflecting short-stay care models
- Laparoscopic surgery is associated with shorter hospitalization but higher costs
- Access to laparoscopy is unequal, being concentrated in large and university centres
- The current reimbursement system does not sufficiently support the use of minimally invasive techniques
- Optimization of management requires:
 - implementation of a national hernia registry
 - adjustment of funding mechanisms
 - expansion of training in laparoscopic surgery

6. STUDY II

Impact of Preoperative (Patient-Dependent) Risk Factors on the Occurrence of Hernia Recurrence: A Monocentric Study

6.1. Introduction

Repair of abdominal hernias is one of the most frequently performed surgical procedures, and recurrence remains a significant issue for both the patient and the surgeon [1]. Globally, more than 20 million inguinal hernia repairs are performed annually [12], with a major economic impact estimated at approximately 10 billion dollars in the United States [91]. Recurrence rates range between 15–20% for incisional hernias [92] and 1–15% for inguinal hernias [93]. Recurrence is influenced by multiple factors, including patient characteristics, surgical technique, and postoperative complications [58,83]. The use of prosthetic meshes aims to provide support and promote tissue integration [1,94]; however, the healing process may be affected by collagen imbalance, thereby increasing the risk of recurrence [5,19].

6.2. Working Hypothesis and Specific Objectives

The hypothesis of the present study is based on the premise that hernia recurrence is not a random phenomenon, but rather the result of the interaction between individual preoperative factors and the biological mechanisms involved in tissue healing. It is assumed that certain patient characteristics, such as age, body mass index, and the presence of comorbidities, influence the ability of the abdominal wall to support the prosthetic material and increase the risk of recurrence. Furthermore, medical history, including previous surgical interventions, may contribute to the development of an unfavourable tissue environment. In this context, the study aims to evaluate the impact of these factors and is based on the hypothesis that their identification allows for patient risk stratification and the optimization of surgical management through an individualized approach.

6.3. Materials and methods

The present retrospective study included 108 adult patients who underwent surgery for recurrent inguinal, umbilical, or incisional hernia between 2012 and 2022 at the “Dr. Carol Davila” Clinical Hospital of Nephrology in Bucharest. All procedures were performed using tension-free techniques with synthetic prosthetic materials, and the selection of the surgical method was adapted to patient characteristics and the surgeon’s experience. Demographic data, comorbidities, and clinical factors (including body mass index, diabetes, smoking

status, and oncological history) were analysed in relation to the occurrence of recurrence. Patients with follow-up of less than one year, emergency interventions, or parastomal hernias were excluded.

In a subgroup of 28 patients, intraoperative biopsies were collected to evaluate prosthetic material integration, analysed by stereomicroscopy and histological examination (hematoxylin–eosin), in order to assess the relationship between the mesh and the host tissue. Statistical analysis included descriptive and inferential methods, using normality tests (Anderson–Darling) and the Chi-square test to evaluate associations between risk factors and recurrence, with a significance threshold of $p < 0.05$. The results were interpreted in a clinical context, with the aim of identifying relevant predictors of hernia recurrence.

6.4. Results

The analysis of sex distribution revealed a clear pattern: recurrent inguinal hernias were markedly predominant in men, whereas ventral hernias, particularly umbilical, infraumbilical, and supraumbilical types, were more frequent in women. Age distribution showed a progressive increase in the number of cases with advancing age, with a peak in the 70–79-year interval, supporting the role of tissue aging, comorbidities, and surgical history in the occurrence of recurrence. From a technical perspective, the open approach was predominant in the treatment of recurrences, reflecting a preference for established techniques in complex cases, although a selective use of laparoscopy was also observed.

The profile of postoperative complications was dominated by seroma and chronic abdominal pain, followed by wound infection, suggesting the importance of inflammatory processes and deficient tissue integration in the mechanisms of recurrence. The analysis of comorbidities showed that obesity, diabetes mellitus, arterial hypertension, and atrial fibrillation were significantly associated with hernia recurrence, whereas smoking, benign prostatic hyperplasia, and a history of oncological treatment did not reach the threshold of statistical significance.

Intraoperative evaluation of the prosthetic material revealed, in a significant number of cases, deficiencies in integration and mesh migration, particularly observed in umbilical, inguinal, and infraumbilical hernias. Microscopic analysis demonstrated clear differences between well-integrated meshes and those that were poorly integrated or non-integrated. Areas of deficient integration showed persistent inflammation, disorganized collagen architecture, and a predominance of immature type III collagen, suggesting a delay in the tissue remodelling process. In contrast, well-integrated meshes were associated with a

reduced inflammatory infiltrate, dense and well-organized connective tissue, and a predominance of mature type I collagen, indicating effective healing and superior biological stability. In certain cases, even in the presence of good tissue integration, mesh migration suggested the contribution of additional mechanical factors, such as insufficient fixation or excessive strain on the abdominal wall.

The use of stereomicroscopy and polarized light microscopy enabled a detailed evaluation of mesh architecture and collagen distribution, highlighting the differences between adequate and deficient tissue integration. Well-integrated meshes were characterized by a continuous, mature, and well-organized fibro-collagenous matrix, whereas partially integrated or non-integrated meshes retained their initial reticular structure, with separation zones at the implant–tissue interface and insufficiently matured collagen. Overall, the results support the concept that hernia recurrence is the consequence of the interaction between patient-related biological factors, the quality of tissue healing, and the mechanical stability of the prosthetic material, underscoring the importance of an integrated approach in the evaluation and management of these patients.

6.5. Discussions

The results indicate that hernia recurrence is not merely a technical failure, but rather the outcome of the interaction between the prosthetic material and the patient’s biological response. Although the use of “tension-free” meshes has reduced recurrence rates [38,76], tissue integration remains essential, with success depending primarily on the quality of healing and tissue remodelling [95,96]. Collagen plays a key role in this process, with the transition from type III to type I collagen representing an indicator of effective healing [97,98]. The deficient integration observed in the study, characterized by persistent inflammation and poor collagen organization, supports the concept that impaired tissue remodelling promotes recurrence. At the same time, comorbidities such as obesity, diabetes, and cardiovascular disease contribute to this process by affecting perfusion and cellular healing mechanisms [99,100].

The use of stereomicroscopy and polarized light microscopy highlighted clear differences between adequate and deficient mesh integration, demonstrating that collagen organization directly reflects the stability of the reconstruction. Overall, the results support the multifactorial nature of hernia recurrence and the need for an integrated approach, aimed both at optimizing patient-related risk factors and at the appropriate selection of the surgical technique.

6.6. Study Limitations

- ▶ Retrospective design, dependent on the accuracy and completeness of available data, with the possibility of variations in the quality of the collected information
- ▶ Absence of a control group, allowing the identification of associations without establishing direct causal relationships
- ▶ Single-centre nature and variability of surgical techniques, reflecting the particularities of clinical practice and operator experience
- ▶ Moderate sample size and lack of standardized long-term follow-up, with potential underestimation of late recurrences
- ▶ Predominantly qualitative morphological analysis, performed on a subgroup of patients, which may limit the generalizability of conclusions regarding tissue integration

6.7. Conclusions

- Statistical analysis revealed significant associations between hernia recurrence and obesity ($p = 0.001$), diabetes mellitus ($p = 0.003$), arterial hypertension ($p = 0.003$), and atrial fibrillation ($p = 0.044$), while smoking and benign prostatic hyperplasia did not demonstrate statistical significance
- Tissue integration of the mesh differed significantly between cases, with well-integrated meshes characterized by mature, organized connective tissue and a predominance of type I collagen, whereas poorly integrated meshes showed persistent inflammation and a predominance of type III collagen
- Polarized light microscopy highlighted clear differences in birefringence corresponding to the degree of collagen maturation, allowing differentiation between areas of organized (mature) collagen and those with immature, poorly structured collagen
- Stereomicroscopy enabled three-dimensional evaluation of the implant–tissue interface, demonstrating complete integration through the disappearance of the mesh’s reticular architecture and, in contrast, deficient integration through the persistence of filaments and the presence of separation spaces
- The results support the conclusion that hernia recurrence is associated both with patient-related systemic factors and with the quality of collagen organization and tissue integration of the prosthetic material

7. Conclusions and Personal Contributions

7.1. Conclusions

Study I

The national study conducted demonstrates that the recurrence of inguinal hernia in Romania falls within a range comparable to that reported in the international literature; however, its precise estimation is limited by the characteristics of administrative data and the absence of a dedicated national registry. The discrepancy between coded recurrences and total reinterventions suggests the presence of systematic underreporting, as well as methodological variability that must be taken into account when interpreting the results.

The temporal distribution of reinterventions shows a predominant concentration in the early postoperative period, supporting the role of technical factors and tissue healing in the occurrence of recurrence. At the same time, the evolution in the number of reinterventions throughout the analysed period reflects the influence of external factors, such as disruptions in the healthcare system during the pandemic, followed by a gradual recovery of surgical activity.

The analysis of surgical practice at the national level highlights the predominance of the open approach, while minimally invasive techniques remain insufficiently utilized. This distribution indicates the presence of persistent disparities in access to resources, expertise, and infrastructure, as well as an uneven implementation of laparoscopic surgery, particularly outside university centres.

The demographic profile of patients is consistent with known epidemiological data, with inguinal hernia predominantly affecting males and being more frequent at advanced ages. The progressive increase in recurrence risk with age, followed by an apparent decrease at the extremes of age, suggests both the influence of biological factors and the existence of clinical selection mechanisms regarding the indication for reintervention.

Sex-related differences indicate a higher susceptibility to recurrence among male patients, in accordance with the anatomical and biomechanical particularities of this pathology. Moreover, the similar temporal pattern of recurrences in both sexes, with early predominance, suggests common mechanisms involved in postoperative failure.

One of the most relevant findings of the study is the central role of the public healthcare system in the management of inguinal hernia, as it manages the majority of cases and disproportionately assumes responsibility for recurrent patients. Patient migration occurs predominantly from the private to the public sector at the time of reintervention,

indicating that public hospitals function as the main referral structure for complex cases and therapeutic failures.

The geographical distribution of interventions and recurrences highlights a concentration of surgical activity in major university centers, particularly in cities such as Bucharest, Cluj, Mureș, and Timiș. This pattern reflects both the increased treatment capacity of these institutions and their role in managing complex cases from neighboring regions, underscoring the existence of regional disparities in access to specialized surgical care.

The analysis of comorbidities suggests that not all associated conditions equally influence the risk of recurrence. In particular, metabolic disorders and conditions that lead to increased intra-abdominal pressure appear to have a more significant impact on postoperative failure, whereas other common comorbidities did not demonstrate a significant association.

The length of hospital stay highlights clear differences depending on the surgical approach and the type of healthcare facility. Laparoscopic interventions are consistently associated with shorter hospitalization periods, and private hospitals show significantly reduced lengths of stay compared to public institutions, reflecting the existence of different organizational models and “short-stay” care pathways.

From an economic perspective, the results indicate that laparoscopic interventions involve higher costs compared to open procedures, particularly in the public sector. This discrepancy suggests that current reimbursement mechanisms do not fully reflect the complexity and resources required for minimally invasive surgery, which may indirectly influence the degree of adoption of these techniques.

Overall, the study demonstrates that the management of recurrent inguinal hernia in Romania is characterized by structural differences between healthcare sectors, regional inequalities, and limitations related to the organization of the healthcare system. In this context, the implementation of a national hernia registry, the optimization of reimbursement mechanisms, and the expansion of training programs in laparoscopic surgery represent essential directions for reducing disparities and improving the quality of surgical care at the national level.

Study II

The monocentric study conducted demonstrates that hernia recurrence represents the result of a complex interaction between patient-related biological factors, the particularities of the surgical technique, and the mode of tissue integration of the prosthetic material. The

analysis of clinical and morphological data confirms that postoperative evolution is not determined exclusively by the surgical act, but directly reflects the patient's biological status and healing capacity.

The demographic profile of patients included in the study is characterized by a predominance of middle-aged and elderly individuals, with a concentration of cases in the later decades of life, supporting the role of tissue aging and the accumulation of risk factors in the occurrence of recurrence. Sex-based distribution reveals a distinct pattern, with recurrent inguinal hernias being predominant in men, while ventral hernias, particularly umbilical and infraumbilical types, are more frequent in women, suggesting the influence of sex-specific anatomical and biomechanical factors.

The analysis of recurrence types shows a predominance of inguinal hernias, followed by ventral defects, particularly at the umbilical and infraumbilical levels, reflecting both the higher incidence of these pathologies and the particular vulnerability of these regions of the abdominal wall. Age-group distribution highlights a progressive increase in the frequency of recurrences with advancing age, with a peak in the later decades of life, suggesting a cumulative effect of tissue degradation and associated comorbidities.

Regarding the surgical approach, the results demonstrate the predominance of open techniques in the management of hernia recurrences, while laparoscopic surgery is used selectively, particularly in carefully selected reinterventions. This distribution reflects the complexity of recurrent cases, in which local changes, adhesions, and previous interventions influence the choice of surgical technique. At the same time, an increasing trend in the use of minimally invasive approaches in reinterventions can be observed, suggesting a progressive adaptation of surgical practice.

The analysis of postoperative complications highlights the important role of inflammatory processes and tissue healing in the occurrence of recurrence. Complications such as seroma, infection, or persistent inflammatory reaction suggest the presence of deficient tissue integration of the prosthetic material, which may compromise the stability of the parietal reconstruction.

A key finding of the study is the identification of preoperative risk factors with a significant impact on hernia recurrence. In particular, obesity, diabetes mellitus, and cardiovascular pathology were associated with an increased risk of recurrence, emphasizing the decisive role of metabolic imbalances and impaired microcirculation in the healing process. In contrast, factors such as smoking or benign prostatic hyperplasia did not demonstrate a significant independent association, suggesting that their influence is rather

indirect or dependent on interaction with other factors.

Microscopic analysis revealed clear structural differences between well-integrated prosthetic meshes and those with deficient integration. Effective integration is characterized by a mature, organized, and stable fibro-collagenous matrix, in which type I collagen predominates and the inflammatory response is minimal. In contrast, insufficient integration is associated with disorganized collagen architecture, predominance of type III collagen, and persistence of an inflammatory infiltrate, features that reflect an incomplete healing process.

Stereomicroscopic and polarized light evaluation allowed a detailed characterization of the relationship between the prosthetic material and the host tissue, highlighting the importance of the three-dimensional organization of collagen in the stability of parietal reconstruction. These methods demonstrated that the success of the intervention does not depend solely on the presence of the prosthetic material, but on its capacity to be integrated into a coherent and mature tissue matrix.

Overall, the results of the study support the hypothesis that hernia recurrence is determined by disruption of biological healing processes, particularly through alteration of the balance between mature and immature collagen and through deficient integration of the prosthetic material. In this context, patient comorbidities play an essential role, influencing both the inflammatory response and the capacity for tissue remodelling.

In conclusion, Study II demonstrates that hernia recurrence cannot be explained exclusively by technical factors, but represents the expression of a complex interaction between the patient's biological status and local healing mechanisms. These findings support the need for thorough preoperative evaluation and a personalized approach, aimed both at optimizing risk factors and at selecting a surgical strategy tailored to the individual patient profile.

7.2. Personal contributions

Study I

The personal contribution consists in conducting an original national-level analysis of inguinal hernia recurrence in Romania, based on a large cohort of patients followed over a five-year period. The author was involved in all stages of the research, from study design and methodological framework to data analysis and interpretation of the results.

A novel aspect is represented by the use of a methodology adapted to the specific characteristics of the DRG database, whereby recurrence was estimated using two complementary approaches. This strategy allowed the delineation of a realistic range of

recurrence, despite the inherent limitations of administrative data, contributing to a more rigorous population-level evaluation of the phenomenon.

Furthermore, the study provides an original contribution through the characterization of surgical practice at the national level, highlighting structural differences between the public and private sectors. The author performed a comparative analysis of activity volume, types of interventions, and models of care organization, emphasizing the predominant role of the public system in case management, particularly for complex and recurrent cases.

An important contribution is represented by the analysis of the geographical distribution of cases and the role of university centres, demonstrating the concentration of interventions and recurrences within these institutions. At the same time, the evaluation of patient migration between the private and public sectors constitutes an original element, highlighting the existence of a predominant flow toward the public system in the case of reinterventions.

In addition, the study includes a detailed analysis of length of hospital stay, temporal trends, and differences between surgical approaches, as well as an evaluation of the economic implications of reinterventions. These aspects provide a practical perspective on how resources are utilized within the healthcare system.

Taken together, these findings represent a personal contribution consisting in providing a comprehensive overview of the management of recurrent inguinal hernia in Romania, with both clinical and health policy relevance.

Study II

The personal contribution consists in performing a detailed clinical and morphological analysis of hernia recurrence, with emphasis on the identification of preoperative risk factors and on understanding the biological mechanisms involved in the failure of surgical treatment. The author was actively involved in patient selection, data collection, analysis of results, and their interpretation in a clinical context.

An original element of the study is the correlation of clinical data with histopathological evaluations, allowing the relationship between the patient's biological status and the quality of tissue healing to be highlighted. Microscopic analysis provided relevant information regarding the mode of integration of the prosthetic material, differentiating between effective and deficient integration.

Furthermore, the personal contribution includes the use of polarized light techniques for the characterization of collagen structure, highlighting the differences between mature and immature collagen and their role in the stability of the abdominal wall. This approach

enabled a deeper understanding of the tissue remodelling mechanisms involved in recurrence.

The study also brings relevant contributions in identifying preoperative risk factors associated with recurrence, emphasizing the importance of metabolic comorbidities and conditions that influence the healing process. The integrated interpretation of these factors, in correlation with the observed histological changes, represents an important contribution to the multidimensional understanding of hernia recurrence.

Through these findings, the personal contribution lies in advancing the understanding of the biological mechanisms underlying recurrence and in highlighting the need for a personalized patient approach that integrates both clinical factors and tissue-specific characteristics.

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List of Published Scientific Papers

1. Tigora A, Paic V, Garofil DN, Bratucu MN, Zurzu M, Nuta D, Popa F, Surlin V, Patrascu S, Strambu V, et al. Preoperative Risk Factors in Hernia Recurrence: A Single-Center Study. *Journal of Mind and Medical Sciences*. 2024; 11(1):146-155.

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(Original Research Article Derived from the Chapters 2: 2.1-2.3. pages 20-25; 6: 6.1-6.7. pages 64-87, 103-114)

ISI-Indexed Journal (Web of Science) with Impact Factor 1,6 Q2

2. Tigora A, Radu PA, Garofil DN, Bratucu MN, Zurzu M, Paic V, Ioan RG, Surlin V, Margaritescu D, Badoiu SC, et al. Modern Perspectives on Inguinal Hernia Repair: A Narrative Review on Surgical Techniques, Mesh Selection and Fixation Strategies. *Journal of Clinical Medicine*. 2025; 14(14):4875.

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(Review Article Derived from the Chapters 1; 1.1-1.6. pages 1-20)

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3. Tigora A, Garofil D, Zurzu M, Paic V, Bratucu M, Popa F, Surlin V, Ramboiu S, Marinescu D, Strambu V, et al. Inguinal Hernia Recurrence in Adults in Romania: A Five-Year Nationwide Analysis of Surgical Practice and Health System Disparities. *Medicina*. 2026; 62(2):391.

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(Original Research Article Derived from the Chapters 5; 5.1-5.7. pages 30-63)

ISI-Indexed Journal (Web of Science) with Impact Factor 2,4 – Q1