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**UNIVERSITATEA DE MEDICINĂ ȘI FARMACIE „CAROL DAVILA”,
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ȘCOALA DOCTORALĂ
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CONSERVATIVE TREATMENT IN RENAL TUMORS OF THE SOLITARY SURGICAL KIDNEY AND RECURRENCES

SUMMARY OF THE DOCTORAL THESIS

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1. INTRODUCTION

Renal tumors have always posed a significant challenge to modern medicine, lying at the intersection between the imperative need for safe oncological decision-making and the desire to preserve the function of a vital organ. With the refinement of surgical techniques and an improved understanding of renal pathophysiology, the focus has progressively shifted from absolute radicalism to meticulous conservation—particularly in complex, high-stakes cases such as tumors in a solitary kidney or recurrent tumors. This fundamental transition reflects not only an evolution in medical technology but also a paradigm shift in therapeutic philosophy: preserving the patient's quality of life has become as important as achieving oncological control.

The importance of conservative treatment in renal tumors has increased considerably with the emergence of advanced imaging technologies, the development of robotic surgery, and the integration of artificial intelligence in interventional medicine. In the context of a solitary kidney or tumor recurrence, each therapeutic decision must carefully balance risks and benefits, considering the extreme vulnerability of the remaining renal function. Preservation of healthy parenchyma is no longer an abstract ideal, but a vital necessity requiring detailed anatomical knowledge, sophisticated preoperative planning, and execution with maximal surgical precision.

The topic of conservative treatment of renal tumors in solitary kidneys and tumor recurrences directly addresses this challenge by clinically, technically, and technologically analyzing the most current therapeutic approaches. The relevance of this work is further emphasized by the rapid advancement of artificial intelligence, three-dimensional imaging, and preoperative simulation technologies, which are continuously redefining the standards of nephron-sparing surgery—making the preservation of renal function feasible even in cases that previously necessitated total organ sacrifice.

The purpose of this thesis is to examine, based on retrospective data and updated scientific literature, how modern conservative treatment techniques can be successfully applied in highly complex cases—solitary kidneys and tumor recurrences—and to identify the factors that influence long-term functional and oncological outcomes. The major objectives include describing the historical evolution of the concept of nephron-sparing surgery, conducting an in-depth analysis of surgical strategies and non-surgical alternatives, and exploring the impact of emerging technologies on the planning, execution, and monitoring of treatment.

The methodology employed is based on three retrospective studies conducted on a cohort of 188 partial nephrectomy cases, among which a significant subgroup included patients with a surgically solitary kidney and tumor recurrences. Clinical, technical, and imaging data were correlated to assess functional and oncological outcomes, identifying predictive models and key variables that influence the success of conservative treatment.

The structure of the thesis is designed to provide a coherent and progressive perspective on the topic addressed. The first chapter presents general aspects of renal tumors and the evolution of conservative treatment, including definitions, current classifications, epidemiological data, and essential diagnostic elements. The second chapter focuses on the practical aspects of conservative treatment applied in cases of solitary kidneys and recurrences, analyzing surgical techniques, strategies for preserving renal function, minimally invasive alternatives, and the impact of new technologies on clinical outcomes. The second part of the thesis focuses on conservative treatment of renal tumors managed surgically in a tertiary referral center. This section aims to correlate the author's findings with data from classical literature.

Through this approach, the thesis aims to highlight not only the current achievements of modern medicine in the field of nephron-sparing surgery but also future directions for development, offering a comprehensive overview of a specialty undergoing continuous and remarkable transformation.

2 CHAPTER 1 – General Aspects

2.1 History of Conservative Surgical Treatment

2.1.1 The First Renal Interventions

The earliest interventions on the kidney were not merely bold surgical acts by pioneers, but true manifestations of scientific evolution and desperate attempts to treat pathologies that had previously been fatal. In the 19th century, surgery was characterized by the absence of imaging diagnostics, rudimentary anesthesia, and the emergence of aseptic techniques—all of which made any major operation a high-risk and often lethal endeavor.

During this era, in 1869, Gustav Simon performed the first successful radical nephrectomy, completely removing a diseased kidney from a patient—an intervention considered at that time to be a remarkable act of surgical pioneering. The choice of radical surgical treatment was motivated not only by the lack of alternative therapeutic options but also by the prevailing belief that complete eradication of the affected organ was the only way to prevent disease progression and save the patient's life.

At the end of the 19th century, Ludwig Czerny envisioned a more conservative approach. The first partial nephrectomy described in the medical literature was performed in 1887. Although this intervention had extremely limited applicability at the time, it opened the door to what would later become a fundamental direction in oncologic surgery: preserving organ function when oncologically feasible. However, this vision was well ahead of its time. In an era lacking imaging techniques capable of detecting small tumors, with underdeveloped pathological anatomy and poor control of postoperative complications, conservative surgery could not become a standard practice. Most surgeons continued to opt for radical nephrectomies, considered safer from an oncological standpoint. (1)

2.2 Definition, Classification, and Epidemiology

2.2.1.1 Definition of Renal Tumors

Through their diversity, renal tumors illustrate the complexity of pathological processes that can affect the renal tissue and highlight the need for a clear differentiation between benign and malignant lesions, both morphologically and functionally. The

differences between these categories are not merely theoretical but carry direct implications for prognosis, therapeutic strategy, and long-term patient monitoring.

Benign renal tumors are usually characterized by an orderly cellular proliferation that largely preserves the histological characteristics of the normal tissue of origin. These formations exhibit a well-organized architecture, clearly defined margins, and do not show a tendency to invade adjacent tissues or to spread via the lymphatic or vascular systems. From a biological perspective, the cells of benign tumors retain their normal functions to some extent and do not develop severe genetic mutations that would confer aggressive behavior. A particularly illustrative example is the renal angiomyolipoma: this benign tumor, composed of vascular, smooth muscle, and adipose elements, can reach considerable size but remains localized without metastasizing—although it may cause serious complications if its fragile vessels rupture. (5)

2.2.2 Clinical Symptoms

The clinical presentation of renal tumors is complex and multifaceted, and a thorough understanding of both local and systemic symptoms is essential for early diagnosis and proper disease management. Although today the majority of renal tumors are discovered incidentally, the classical symptomatology of Virchow's Triad and paraneoplastic manifestations remain relevant in the assessment of renal oncology patients. (31)

Virchow's Triad, consisting of gross hematuria, flank pain, and a palpable abdominal mass, represents the typical manifestation of renal tumors in advanced stages, although the complete incidence of this triad has significantly declined due to advances in imaging technology.

2.3 Diagnosis of Renal Tumors

2.3.1 Imaging Modalities

The use of high-performance imaging techniques such as ultrasound, computed tomography (CT), and magnetic resonance imaging (MRI) is indispensable in the diagnosis of renal tumors, with each of these modalities serving a specific and complementary role in the diagnostic process, lesion characterization, and staging. The selection of the imaging method depends on the clinical context, patient characteristics, and the need for diagnostic accuracy. In modern clinical practice, these investigations are often employed in combination to achieve a comprehensive assessment. (21,22)

Abdominal ultrasound is typically the first-line imaging modality used to evaluate the kidneys, due to its wide availability, low cost, and absence of radiation exposure.

Contrast-enhanced computed tomography (CT) is the method of choice for the diagnosis and staging of renal tumors. CT allows for a detailed evaluation of the kidney, the pelvicalyceal collecting system, renal vessels, perirenal tissues, and regional lymph nodes.

Magnetic resonance imaging (MRI) is particularly useful in cases where CT is contraindicated, such as in patients with iodine-based contrast allergies or with severe renal insufficiency, which precludes the use of iodinated contrast agents. MRI provides excellent soft tissue resolution and superior characterization of complex lesions, especially cystic tumors or endophytic masses.

2.3.2 Histopathological Classification and Staging

2.3.2.1 WHO 2022 Classification of Renal Tumors

The 2022 WHO Classification of Renal Tumors marks a major advancement in the refinement of histopathological categories, integrating for the first time, in a systematic manner, genetic and molecular data into routine diagnostic practice. This approach reflects a paradigm shift in renal oncology—from a purely morphological classification to a molecularly integrated one, in which the identification of genetic mutations and gene fusions becomes essential for establishing the final diagnosis, predicting prognosis, and selecting targeted therapies. The newly introduced subtypes are not merely theoretical entities but clinically significant pathologies, requiring in-depth understanding by the modern clinician. (10,43)

2.3.2.2 TNM Staging System

The TNM system is a standardized method for cancer staging used to evaluate the local extent of the tumor (T), the involvement of regional lymph nodes (N), and the presence of distant metastases (M). In the context of renal cancer, this staging framework provides essential information for treatment selection and prognostic estimation, based on tumor size, its invasion into surrounding tissues, and lymph node involvement.

CHAPTER 2 – Nephron-Sparing Treatment of Renal Tumors

3.1 Surgical Treatment of Renal Tumors

3.1.1 Open Partial Nephrectomy

Open partial nephrectomy, also referred to as classic partial nephrectomy, is one of the oldest and most established surgical methods for the conservative treatment of renal tumors, particularly in cases involving a solitary kidney or tumor recurrence. Despite the advent of modern minimally invasive approaches, this technique continues to play a crucial role in the therapeutic arsenal of the urologic surgeon, especially in complex cases requiring direct visualization and meticulous control of renal anatomical structures.

3.1.2 Robot-Assisted Laparoscopic Partial Nephrectomy

The DaVinci robotic system was developed to overcome the limitations of conventional laparoscopic techniques and to provide surgeons with the tools necessary to perform procedures with unmatched precision, in a safer and more controlled manner. In the context of partial nephrectomy—particularly for tumors in solitary kidneys or recurrent tumors—this system offers strategic advantages that fundamentally reshape the paradigm of nephron-sparing surgery.

3.2 Non-Surgical Alternatives

In the management of recurrent renal tumors, especially in patients with a solitary kidney where surgical reintervention may be associated with significant technical challenges and a serious threat to the remaining renal function, non-surgical alternatives such as cryoablation and radiofrequency ablation represent valuable therapeutic options tailored to carefully selected cases. These minimally invasive techniques allow for the destruction of tumor tissue without the need for extensive parenchymal resection, thereby preserving renal function and reducing the overall morbidity associated with treatment.

4 PERSONAL CONTRIBUTION

4.1 Working Hypothesis and Objectives

The fundamental principle of modern renal tumor treatment is the maximal preservation of renal parenchyma. Partial nephrectomy (PN) is no longer merely a crude technique for tumor excision but rather a complex therapeutic concept aimed at preserving long-term renal function. This concept has profound implications for patient prognosis, which depends significantly on the ability to prevent postoperative chronic kidney disease (CKD) and its associated comorbidities, primarily cardiovascular complications.

In the current era of rapid advancements in urologic surgery, the treatment of renal tumors has undergone substantial transformation, with minimally invasive approaches becoming more frequent than conventional interventions.

The hypothesis of this thesis was based on the premise that robotic technology yields outcomes comparable to, or even superior to, those of open surgery. Additionally, it is believed that robot-assisted laparoscopic techniques reduce hospital stay duration, minimize blood loss and postoperative complications, while maintaining equivalent oncological radicality.

The main objectives of this thesis are:

1. To perform a comparative evaluation of functional and oncological outcomes between open partial nephrectomy and robot-assisted laparoscopic partial nephrectomy.
2. To conduct a retrospective analysis of a cohort of patients who underwent surgery via both open and robotic approaches.
3. To determine prognostic factors influencing postoperative functional outcomes: clamping time, loss of functional parenchyma, and recovery.
4. To identify any specific advantages associated with minimally invasive robot-assisted laparoscopic procedures.
5. To formulate conclusions and practical recommendations based on the obtained data.

In order to conduct this thesis, I performed three retrospective, observational, non-randomized studies on a sample of 188 patients who underwent nephron-sparing surgery for renal tumors via either open/classical partial nephrectomy or robot-assisted laparoscopic partial nephrectomy.

Across the three studies, the following parameters were evaluated: intraoperative findings, intra- and postoperative complications classified according to the Clavien-Dindo system, and renal function evolution assessed through serum creatinine and estimated glomerular filtration rate (eGFR), both in the immediate postoperative period and at the 6-month follow-up.

The intraoperative data collected included:

- Clamping time
- Requirement for suturing breaches of the pelvicalyceal system
- Estimated blood loss / need for blood transfusions
- Use of intraoperative ultrasound

Postoperative follow-up involved monitoring of:

- Blood loss requiring transfusions
- Complications based on the Clavien-Dindo classification
- Serum creatinine and eGFR
- Length of hospital stay

1. Study I – Incidence of Benign Tumors Among Patients Treated Surgically With a Nephron-Sparing Approach

A retrospective, observational, non-randomized study was conducted on a cohort of 30 patients who underwent surgery for renal masses, either through open partial nephrectomy or robot-assisted laparoscopic partial nephrectomy. All patients were diagnosed histopathologically with benign renal tumors and were treated in a tertiary care center.

Inclusion criteria: Patients who underwent open or robot-assisted laparoscopic partial nephrectomy and were diagnosed with benign renal tumors.

Exclusion criteria: No enrolled patients were excluded from the study.

Objectives:

- The primary objective of the study was to identify the percentage of patients who underwent nephron-sparing surgery for benign renal tumors.
- The secondary objective was to describe the demographic, clinical, and biological characteristics of the patients (descriptive statistical analysis), comparing intraoperative and immediate postoperative outcomes.

1.1.1 Introduction

Benign renal tumors such as oncocytoma and angiomyolipoma (AML) (Fig. 1) present significant diagnostic challenges, as their radiologic features may mimic those of malignant tumors. Oncocytoma is a benign epithelial tumor, while AML is a mesenchymal tumor composed of adipose tissue, smooth muscle, and blood vessels (22,152,153) (Fig. 2). Advances in minimally invasive surgery, particularly the robot-assisted technique, have facilitated nephron-sparing procedures—especially in patients with a solitary kidney or bilateral conditions (6,154). Even experienced radiologists, faced with the limitations of CT and MRI—such as protocol variability, pseudo-enhancement in small or centrally located lesions, and lack of standardized criteria—cannot definitively determine the benign or malignant nature of renal tumors (153,155).

1.1.2 Materials and Methods

We conducted a retrospective study of 188 partial nephrectomies performed between 2019 and 2024, including 148 robotic procedures and 40 open surgeries. The surgical

approach (robotic vs. open) was selected based on patient comorbidities, history of prior abdominal surgeries, tumor location, and the preferences of both the surgeon and the patient. Open surgery was performed via subcostal lumbotomy, with resection of the 12th rib in sporadic cases (an anterior transperitoneal approach was used in two cases), and arterial clamping was applied (Figs. 3, 4). Robotic partial nephrectomy was performed transperitoneally using the DaVinci Xi system, with arterial clamping (Fig. 5) and tumor excision by enucleoresection or enucleation. Preoperative data (age, comorbidities, renal function) and postoperative outcomes were analyzed using SPSS 22.0; a p value < 0.05 was considered statistically significant.

1.1.3 Results

The patients included in the study underwent nephron-sparing surgery for renal masses of varying sizes. Preoperative imaging (CT, MRI, ultrasound) was used for surgical planning; however, a definitive diagnosis of benignity could not be established prior to surgery. Benign tumors were confirmed in 30 cases: 18 oncocytomas (16 robotic, 2 open procedures) and 12 angiomyolipomas (9 robotic, 3 open). One large AML ($8 \times 5.5 \times 5$ cm; 250 g) was diagnosed preoperatively. Benign tumors represented 16% (Figs. 6, 7) of all partial nephrectomies. Robotic surgery was utilized in 83.3% of benign cases. Oncocytoma occurred more frequently in male patients (75%), while AML was more common in females (72.7%). Robotic procedures were associated with reduced blood loss and shorter hospital stays.

1.1.4 Discussion

Benign renal tumors accounted for 16% of all partial nephrectomies in our study, including 18 oncocytomas and 12 AMLs. Although these lesions were predominantly managed via the robotic approach—reflecting the growing popularity of robot-assisted laparoscopic partial nephrectomy for small renal masses—preoperative imaging remained limited in reliably distinguishing benign from malignant lesions. (156) Indeed, only one case of AML was definitively diagnosed preoperatively, confirming previous reports regarding the imperfect specificity of cross-sectional imaging. (157–159) Consequently, partial nephrectomy often serves both diagnostic and therapeutic purposes, enabling definitive histopathological confirmation while preserving renal function when malignancy cannot be ruled out.

The importance of distinguishing benign from malignant renal tumors is critical, given that many small, solid, incidentally discovered tumors can appear similar on imaging studies. For instance, a large oncocytic tumor may mimic the radiologic features of clear cell renal cell carcinoma. The therapeutic decision—between surgical excision and active surveillance—largely depends on diagnostic accuracy. In this context, image-guided percutaneous biopsy (ultrasound- or CT-guided) has gained ground in recent years, aiding in the diagnosis of ambiguous lesions and helping avoid potentially unnecessary surgical interventions in cases of benign tumors. (5)

1.1.5 Conclusions

Nephron-sparing surgery should be prioritized, as it offers both therapeutic and diagnostic benefits. Patients must be informed about the possibility of benign pathology, potential tumor growth, and the availability of non-surgical treatment options.

Conservative surgical treatment, including minimally invasive techniques such as robot-assisted laparoscopy, can be successfully employed even in emergency situations. Partial nephrectomy can yield optimal outcomes in cases of ruptured, hemorrhagic angiomyolipomas and in patients with bilaterally functional kidneys, but especially in imperative cases. These findings support partial nephrectomy as the standard of care for small renal masses of indeterminate pathology, serving both diagnostic and curative purposes. The establishment of a national imaging protocol and the integration of artificial intelligence may improve diagnostic accuracy, which in turn could reduce the frequency of surgical treatments that might otherwise be considered excessive in certain cases.

1.2 Study II – Partial Nephrectomy for Malignant Renal Tumors in Patients with a Solitary Kidney – A Retrospective Study

We conducted a retrospective, observational, non-randomized study on a sample of 24 patients with a solitary surgical kidney who were diagnosed with malignant renal tumors or with tumor recurrences following previous nephron-sparing procedures. These patients underwent surgical or re-surgical intervention. The sample is representative of a population with malignant renal tumors diagnosed and treated in a tertiary care center.

Inclusion criteria: Patients with a solitary surgical kidney and recurrences in the same kidney.

Exclusion criteria: No patients enrolled in the study were excluded.

1.2.1 Introduction

Nephron-sparing surgery represents the treatment of choice for patients with tumors in a solitary kidney, where preservation of renal function is essential to prevent chronic kidney disease and the need for dialysis (87, 167, 168). The importance of maximal renal parenchymal preservation in the treatment of tumors in a solitary kidney can only be fully understood by analyzing the multidimensional impact that loss of renal function has on general health status, survival, and patient quality of life. Parenchymal preservation is not merely a secondary objective of surgery, but a fundamental priority, equal in importance to the complete excision of the tumor, as without adequate renal function, even a cancer-free patient may rapidly deteriorate into a severe medical condition requiring renal replacement therapies (106).

First and foremost, renal function is essential for maintaining internal homeostasis. The kidney is not just a passive filter for metabolic waste; it actively regulates circulating blood volume, arterial pressure, acid-base balance, the levels of vital electrolytes (sodium, potassium, calcium, phosphorus), and stimulates the production of erythropoietin, a hormone necessary for red blood cell formation. The loss of functional renal parenchyma simultaneously affects all these processes, triggering a pathological domino effect: refractory hypertension, severe anemia, life-threatening electrolyte imbalances, and accumulation of metabolic toxins (uremia), resulting in systemic dysfunction across all vital organs.

In a patient with a solitary kidney, this vulnerability is significantly heightened (107). There is no compensatory renal reserve to offset functional loss. Therefore, any parenchymal damage—whether surgical, ischemic, or secondary to other insults—directly reduces the kidney's filtration capacity and accelerates progression toward end-stage chronic kidney disease.

Maximal preservation of renal parenchyma in solitary kidney tumor surgery is the cornerstone of a medical approach that not only treats the disease but also safeguards the patient's future (110). This philosophy requires technical excellence, a profound understanding of renal pathophysiology, and an ethical responsibility in every surgical decision made (83).

1.2.2 Materials and Methods

Between January 2019 and December 2024, 24 patients with a solitary surgical kidney, including 7 with tumor recurrences, underwent nephron-sparing surgery through either open (Fig. 9) or robot-assisted laparoscopic approaches (Fig. 10) for localized renal tumors. Patients selected for conservative surgical intervention were preoperatively diagnosed using CT or MRI imaging. All patient data were recorded in tables, including age, sex, R.E.N.A.L. nephrometry score, estimated blood loss, and length of hospital stay. Follow-up data were subsequently collected at 6-month postoperative evaluations.

1.2.3 Results

Twenty-four patients met the inclusion criteria: 17 underwent initial partial nephrectomy on a solitary kidney, and 7 had tumor recurrence on a solitary kidney. The median age was 67 years in the recurrence group and 63 years in the initial partial nephrectomy group. The male-to-female ratio was 2:1. The number of open surgeries (13) was comparable to the number of robot-assisted laparoscopic procedures (11). The mean serum creatinine was slightly higher in patients with recurrence (2.98 mg/dL), and the eGFR was slightly lower (39 mL/min/1.73 m²), compared to 1.67 mg/dL and an eGFR of 49 in the group managed by open surgery. In both groups, serum creatinine and eGFR values showed recovery from the immediate postoperative renal function deficit by the 6-month follow-up. Clamp time and blood loss were greater in the recurrence group. Tumor sizes were larger in the initial nephrectomy group, with an average diameter of 4.95 cm. The average length of hospital stay was shorter in the recurrence group (5.71 days) compared to patients without recurrence (8 days), likely due to a higher number of complications in the initial intervention group. One patient required extended hospitalization and transfer to the nephrology department due to postoperative anuria, which resolved progressively after one hemodialysis session, rehydration, and nephrological management (urine output of 200/400/800/2000 mL). The patient was discharged with a serum creatinine of 1.29 mg/dL. Only one positive surgical margin was recorded across both cohorts, occurring in the initial surgery group.

1.2.4 Discussions

Surgical treatment of patients with a solitary surgical kidney and tumor recurrences involves a significantly more complex approach compared to initial interventions. The differences lie not only in the planning process but also in the associated risks and the expected functional and oncological outcomes (169,176,177). Tumor recurrences arise in a context of profound post-surgical anatomical changes; adhesions make dissection considerably more difficult than during the first intervention. These adhesions involve not only the renal parenchyma but also the pelvicalyceal system and the renal pedicle, significantly increasing the risk of massive hemorrhage or iatrogenic injury (Fig. 11, 12).

The philosophy of nephron-sparing surgery is to preserve as much functional renal parenchyma as possible to minimize impairment of renal function; in cases of recurrence,

every millimeter preserved becomes vital (169,178,179). These challenges often lead surgeons to opt for open partial nephrectomy, which offers meticulous control over renal anatomical structures (2). Once the learning curve for robotic partial nephrectomy has been overcome, the outcomes can be comparable to those achieved in standard cases, even in complex settings such as tumor recurrences (180) (Fig. 13, 14).

The final surgical decision was made based on the preferences of both the surgeon and the patient, after thorough discussion of all risks and benefits (3). The significance level (α) of the study was set at 0.05; therefore, p -values less than 0.05 were considered statistically significant.

1.2.5 Conclusions

In cases of renal tumors in a solitary surgical kidney, as well as in recurrences, partial nephrectomy can be safely performed with optimal functional and oncologic outcomes. Both robotic-assisted laparoscopic and open surgical approaches, in the hands of an experienced surgeon, can yield comparable results, and the choice of technique should be made in mutual agreement with the patient.

Renal tumor recurrences in a solitary kidney represent a major challenge from both technical and oncological perspectives. Postoperative anatomical changes, abnormal vascularization, adhesions, and increased risks of hemorrhage or iatrogenic injury render these surgeries significantly more complex compared to the resection of primary tumors.

The therapeutic approach for patients with renal tumors in a solitary kidney and recurrences must be individualized, involving rigorous case selection, integration of modern technologies, and full utilization of the surgical team's expertise.

2 Study III – Conservative Treatment of Renal Tumors

A retrospective, observational, non-randomized study was conducted on a sample of 152 patients diagnosed with malignant renal tumors who underwent surgical intervention. The cohort is representative of a population diagnosed and treated for malignant renal tumors in a tertiary referral center.

Inclusion criteria: Patients with malignant renal tumors, solitary surgical kidney, and tumor recurrences in a solitary kidney, treated by either robotic-assisted laparoscopic partial nephrectomy or open surgery.

Exclusion criteria: Patients lost to follow-up.

2.1.1 Introduction

According to the European Association of Urology (EAU) guidelines, partial nephrectomy (PN) represents the standard of care for localized T1a renal tumors, even in imperative indications such as solitary kidney, bilateral tumors, or pre-existing chronic kidney disease (167,168,181). PN can also be successfully performed in T1b and even selected T2 tumors, depending on their complexity. Recent studies suggest that it is a feasible option even for tumors larger than 7 cm (82,168,182) (Fig. 15). In patients with a solitary kidney, nephron-sparing surgery is crucial to prevent the need for dialysis (36,182,183).

Although robot-assisted partial nephrectomy (RPN) offers significant advantages such as increased precision, reduced blood loss, and faster postoperative recovery, open partial nephrectomy (OPN) remains indispensable in specific scenarios—particularly in patients with complex tumor anatomy or those with extensive prior abdominal surgeries (120,121,177).

In cases involving multiple tumors (Fig. 16,17), endophytic tumors (Fig. 18,19), or tumors located in the renal sinus (Fig. 20,21), the use of intraoperative ultrasound (Fig. 22–26) becomes imperative. It provides real-time guidance even when the tumor presents no external deformity on the kidney surface.

The kidney appears normal. Intraoperative ultrasound in partial nephrectomy represents one of the most significant technical innovations that has revolutionized conservative surgical treatment, offering advantages in safety and precision previously unattainable by traditional open or conventional laparoscopic surgery. In robotic surgery, the integration of ultrasound optimizes decisions regarding the type of vascular clamping and facilitates the identification of clear resection margins. Intraoperative ultrasound contributes to improved oncological and functional outcomes by reducing the risk of postoperative renal insufficiency. The use of intraoperative ultrasound should be considered standard in complex cases of conservative renal surgery.

The aim of this study was to retrospectively collect up-to-date data in an observational, non-randomized manner, based on a sample of 152 patients diagnosed with malignant renal tumors who underwent surgical treatment via partial nephrectomy. This sample is representative of a population of patients with malignant renal tumors treated in a tertiary care center.

2.1.2 Materials and Methods

Between January 2019 and December 2024, 152 patients underwent partial nephrectomy for localized renal tumors. Of these, 110 patients underwent robot-assisted laparoscopic partial nephrectomy, and 42 patients were treated through open surgery. Patients were divided into two groups:

- **Group A**, consisting of patients with a solitary surgical kidney and tumor recurrences in the solitary kidney,
- **Group B**, consisting of patients with a functional contralateral kidney.

A multiple univariate binomial logistic regression model was constructed, taking into account the following oncological criteria:

- **Age** (younger patients tend to present with more aggressive tumors),
- **Sex** (male patients are generally more prone to aggressive tumors),
- **Type of surgery** (open vs. robotic),
- **Clamping time** (vascular maneuvers may affect recurrence risk),
- **Tumor stage (T stage)** (more advanced stages are associated with higher recurrence risk),
- **Presence of multiple tumors** (which may increase recurrence risk),
- **Use of intraoperative ultrasound** (which may aid in achieving oncologically adequate resections).

It should be noted that the number of predictors selected was also influenced by the limited size of the study sample.

2.1.3 Results

Renal function was assessed using serum creatinine levels and eGFR values immediately postoperatively and at the 6-month follow-up. Postoperative creatinine and eGFR values revealed significant differences between the analyzed groups. Patients with a solitary kidney demonstrated decreased postoperative renal function (177) (immediate postoperative creatinine: 1.76 mg/dl vs. 0.94 mg/dl; $p<0.001$, and baseline eGFR: 46 ml/min/1.73 m² vs. 83 ml/min/1.73 m²; $p<0.001$). However, a significant improvement in renal function was observed at the 6-month follow-up, with a decrease in creatinine (from 1.75 to 1.46 mg/dl; $p<0.01$) and an increase in eGFR (from 46.2 to 51.8 ml/min/1.73 m²; $p=0.02$). The elevated values immediately post-surgery are attributed to operative stress and edema of the remaining renal parenchyma. These findings support the hypothesis that nephron-sparing surgery, even in patients with a solitary kidney, can yield favorable functional outcomes. (177)

In the group with a functioning contralateral kidney, no significant changes were observed in creatinine or eGFR, confirming the stability of renal function in the presence of compensatory contralateral parenchyma. (106,178,184)

Among patients with a solitary kidney, the complication rate was significantly higher (25% vs. 5%; $p=0.004$), reflecting the increased complexity of these cases. This was further supported by longer hospital stays (7.33 vs. 5.32 days; $p=0.024$), a higher transfusion requirement (17% vs. 3%; $p=0.022$), and greater intraoperative blood loss (203 ml vs. 125 ml; $p=0.011$). (89)

The use of intraoperative ultrasound in nephron-sparing surgery enables precise localization of endophytic tumors, minimizing the loss of functional renal parenchyma during resection. (179,182,183) It also plays a critical role in cases involving multiple or irregular tumors by accurately identifying tumor margins. (25,91,95)

A notable finding in this study is the significantly more frequent use of intraoperative ultrasound in the solitary kidney group (75% vs. 10%; $p<0.001$), underscoring the pivotal role of this modality in maximizing parenchymal preservation and guiding tumor excision in endophytic, hilar, or multifocal cases.

2.1.4 Discussions

The limitations of our study include its retrospective nature and the absence of long-term postoperative follow-up. Another limitation is the relatively small number of patients with renal tumors in a solitary kidney or with recurrences in a solitary kidney, as these cases are exceedingly rare.

The results of this study highlight differences between patients treated with robotic partial nephrectomy and those who underwent open surgery. Differences were also observed between patients with a solitary kidney and those with bilateral functional kidneys. The aim of this study was to assess the impact of the surgical approach on postoperative renal function, complication rates, and oncologic outcomes.

Intraoperative ultrasound proves to be especially valuable in cases of complex tumors (RENAL score, high nephrometry), where the shape, size, and location of the tumor complicate the selection of safe resection margins. In such scenarios, ultrasound aids in real-time surgical planning, reducing the risk of local recurrence as well as the unnecessary sacrifice of renal function. (92)

An additional benefit of intraoperative ultrasound is the detection of multifocal tumors. While preoperative imaging modalities such as CT or MRI can identify multiple lesions, smaller nodules may remain undetected. During surgery, ultrasound allows for a thorough examination of the entire renal parenchyma and facilitates the identification of additional nodules requiring excision, contributing to a more comprehensive oncologic approach.

In robotic surgery, the integration of intraoperative ultrasound aligns perfectly with the modern workflow. Robotic instruments can manipulate compatible ultrasound probes without significantly interrupting the procedure. This enables the surgeon to switch quickly between standard endoscopic and ultrasound images without leaving the console, maintaining focus and optimizing operative time.

A multicenter study published in *European Urology Focus* in 2024 demonstrated that the use of AI integrated with intraoperative fluorescence imaging (ICG Augmented Reality technology) enabled precise identification of tumor margins and the vascular anatomy of the remaining parenchyma. Surgeons who utilized this technology achieved a significantly lower rate of positive margins (from 10% to 4%) and a shorter warm ischemia time by 18%. This innovation represents a major step toward intelligent, visually-assisted surgery, where operative decisions are guided not only by experience but also by real-time, objectively processed data.

2.1.5 Conclusions

The results of this study support the feasibility and safety of conservative treatment (partial nephrectomy) for localized renal tumors, even in patients with a solitary kidney or complex renal tumors.

The degree of intraoperative ultrasound utilization should be increased, as it plays a critical role in reducing the rate of positive surgical margins and in maximizing the preservation of healthy renal parenchyma.

3. GENERAL CONCLUSIONS

- Partial nephrectomy represents the treatment of choice for localized renal tumors, ensuring optimal oncological and functional outcomes and playing a key role in preventing the progression to chronic kidney disease. These nephron-sparing procedures are imperative in challenging cases such as bilateral tumors, multifocal tumors, tumors in solitary kidneys, and tumor recurrences. Achieving the "trifecta" should be a standard objective during partial nephrectomy.
- During preoperative assessment, the use of an anatomical scoring system to determine the complexity of the surgical intervention is essential, providing the surgeon with an indispensable tool in selecting the optimal surgical approach and strategy, tailored to each patient's individual characteristics.
- In complex cases with imperative indications, such as sinus extension, multifocal tumors, or even venous involvement, surgical treatment is recommended in a tertiary

referral center by highly experienced surgeons, with the goal of performing a nephron-sparing procedure and avoiding dialysis.

- Preoperative imaging evaluation is critically important in conservative renal surgery. Due to interobserver variability, we consider the development and implementation of a national imaging protocol to be necessary. This should include AI-assisted imaging and 3D reconstruction, which can enhance diagnostic accuracy and provide additional information about intrarenal vascular anatomy.
- The use of intraoperative ultrasound in nephron-sparing surgery can extend the indications for surgical intervention in cases with a high degree of complexity and difficulty.
- In our study, partial nephrectomy—whether performed via open surgery (through a lumbar or anterior transperitoneal approach) or via robot-assisted laparoscopy—can achieve optimal outcomes. The decision regarding surgical approach is based on the surgeon's expertise and the complexity of the case.
- The rate of low-grade (Clavien-Dindo grade I–III) postoperative complications in patients with a solitary kidney was higher than in those with a functional contralateral kidney, although no statistically significant difference was observed regarding severe complications (grade IV–V).
- **4. ORIGINALITY AND INNOVATIVE CONTRIBUTIONS OF THE THESIS**
- This doctoral thesis is the result of a clinical research endeavor aimed at defining and improving conservative treatment strategies for localized renal tumors, especially in difficult and complex scenarios: high nephrometry score or multifocal tumors, solitary surgical kidneys, and tumor recurrences.
- The analysis includes a systematic review of recent specialized literature and encompasses three retrospective studies conducted on a cohort of 188 patients treated with partial nephrectomy. A significant number of these patients presented anatomical and oncological particularities that required individualized therapeutic decisions.
- The first study addressed the issue of benign tumors that were surgically treated through partial nephrectomy, highlighting the challenges of preoperative imaging-based diagnosis. The results showed that, despite the use of modern imaging modalities (CT, MRI, ultrasound), differentiating benign from malignant lesions remains significantly challenging, often resulting in uncertain diagnoses. Thus, partial nephrectomy serves not only a curative role but also a diagnostic one. An incidence of 16% benign tumors was observed in the cohort analyzed, predominantly oncocytomas and angiomyolipomas.
- The second study evaluated the outcomes of conservative treatment in patients with a solitary surgical kidney, including cases of tumor recurrence. The study emphasized the technical challenges posed by post-surgical anatomical changes in recurrences, such as adhesions and an increased risk of hemorrhagic or iatrogenic complications. It was demonstrated that, in the hands of an experienced surgeon, both open and robot-assisted laparoscopic approaches can offer comparable functional and oncological results.
- The third study aimed to conduct a comparative analysis of renal function and oncological outcomes in two distinct groups of patients: those with a solitary kidney (including recurrences) and those with a functional contralateral kidney. The study analyzed the impact of the surgical approach (robotic vs. open), the use of intraoperative ultrasound, and tumor complexity. The study confirmed the advantages of robotic surgery in terms of reduced blood loss, shorter hospital stay, and faster recovery and social-professional reintegration, while open surgery was reserved for cases of extreme complexity.

- The use of intraoperative ultrasound, significantly more frequent in the solitary kidney group (75% vs. 10%), was associated with superior preservation of renal parenchyma and a reduced risk of positive surgical margins.
- The data obtained from these three studies strongly support the feasibility and safety of conservative treatment for localized renal tumors, even in highly complex and difficult cases. Through the implementation of tailored surgical techniques assisted by modern technologies (robotics, intraoperative ultrasound), it is possible to achieve functional and oncologic outcomes equivalent to those of radical surgery, with added benefits in terms of quality of life and prevention of chronic kidney disease.
- The personal contribution of the author lies not only in the execution of these studies and the detailed analysis of clinical data, but also in the development of an integrative national strategy for the management of patients with solitary surgical kidneys and tumor recurrences—an especially vulnerable category with a high risk of progression to chronic kidney disease and, consequently, dialysis. The proposed strategy includes the following essential steps:

Development and Implementation of a National Imaging Protocol Including:

- Use of standardized imaging assessment protocols;
- Integration of artificial intelligence to improve diagnostic accuracy.

Referral of Diagnosed Patients to a Specialized Tertiary Center, Providing:

- Access to modern technologies (intraoperative ultrasound, robotic surgery);
- Highly experienced surgeons with advanced expertise in partial nephrectomy;
- Access to multidisciplinary expertise (urologist, nephrologist, oncologist);
- Possibility of selecting a personalized therapeutic plan (interventional or conservative/non-surgical).

The Role of the Tertiary Center Does Not End with the Surgical Intervention, but Extends into Postoperative Recovery, especially in patients with acute kidney injury, who require specialized intensive care and nephrological treatment. This must be followed by structured monitoring and, when necessary, continued multidisciplinary treatment—urological, nephrological, or oncological—tailored to the individual needs of each patient.

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Lista cu lucrări științifice publicate

1. Stelian Ianiotescu, Constantin Gingu, Irina Balescu, Nicolae Bacalbasa*, Ioanel Sinescu
Repeat robotic nephron-sparing surgery for metachronous multifocal tumors in a solitary kidney: a case report, *JML*,
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4 PERSONAL CONTRIBUTION - 4.3 Study II – Partial nephrectomy in malignant tumors in patients with a solitary kidney – retrospective pag 50-72
2. Stelian Ianiotescu, Constantin Gingu, Alexandru Iordache, Adrian Preda, Osama Salloum, Irina Balescu*, Nicolae Bacalbasa, Ioanel Sinescu
Optimizing outcomes of partial nephrectomy in patients with tumors in solitary kidneys: a non-systematic review, *JML*,
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4 PERSONAL CONTRIBUTION - 4.3 Study II – Partial nephrectomy in malignant tumors in patients with a solitary kidney – retrospective pag 50-72
3. Stelian Ianiotescu, Constantin Gingu, Irina Cecilia Balescu, Nicolae Bacalbasa *, Cristian Balalau, Ioanel Sinescu
The Incidence of Oncocytoma and Angiomyolipoma in Patients Undergoing Nephron-Sparing Surgery for Small Renal Masses, *JMMS-3599193* - ISSN (Online): 3079-3939
4 PERSONAL CONTRIBUTION - 4.2 Study I – Incidence of benign tumors among patients who were surgically and conservatively treated, pages 37–49
4. Stelian Ianiotescu ¹, Constantin Gingu ^{2,3}, Mihai Dobra^{2,3}, Andrei Andresanu^{2,3}, Alexandru Iordache², Alexandru Dick^{2,3}, Irina Balescu^{4,*}, Nicolae Bacalbasa^{4,5,6}, Cristian Balalau^{4,7}, Ioanel Sinescu^{2,3}

Outcomes of Partial Nephrectomy in Patients with Tumors in Solitary Kidneys: A Retrospective Comparative Analysis of Open and Robotic Approaches, JMMS-3599193 - ISSN (Online): 3079-3939

4 PERSONAL CONTRIBUTION - 4.3 Study II – Partial nephrectomy in malignant tumors in patients with a solitary kidney – retrospective pag 50-72