

Laparoscopic Adrenalectomy In The Management Of Adrenal Neoplasms: Clinical Outcomes And Diagnostic Considerations

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Abstract

Adrenal neoplasms represent a diagnostically and therapeutically challenging group of endocrine disorders. The introduction of minimally invasive surgical techniques and modern imaging modalities has significantly improved treatment outcomes; however, optimal patient selection and perioperative management remain critical factors influencing surgical success. Objective. To evaluate the clinical effectiveness and safety of laparoscopic adrenalectomy based on a prospective analysis of diagnostic and surgical outcomes in patients with adrenal neoplasms. Methods. A prospective clinical study included 125 patients with adrenal tumors examined between 2024 and 2025. Diagnostic evaluation consisted of hormonal assessment and multidetector computed tomography (MDCT) angiography with three-dimensional reconstruction. Laparoscopic adrenalectomy was performed in 50 patients. Clinical, hormonal, and morphological outcomes were analyzed, including postoperative recovery and complications. Results. Hormonally active tumors were identified in 78% of operated patients. Laparoscopic adrenalectomy was successfully completed in all cases without conversion to open surgery. Postoperative recovery was characterized by early mobilization and short hospitalization (5–7 days). Restoration of hormonal function occurred within 3–30 days in 96% of patients, while lifelong hormone replacement therapy was required in 4%. Histological examination revealed pheochromocytoma in 44%, ACTH-independent Cushing’s syndrome in 30%, aldosteroma in 16%, and adrenocortical adenomas in 10% of cases. Conclusions. Laparoscopic adrenalectomy is a safe and highly effective method for the treatment of adrenal neoplasms. Early diagnosis using modern imaging techniques combined with multidisciplinary perioperative management significantly improves clinical outcomes and reduces postoperative complications.

Keywords: Adrenal neoplasms; laparoscopic adrenalectomy; minimally invasive surgery; hormonally active adrenal tumors; pheochromocytoma.

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1. Introduction

Adrenal neoplasms represent a heterogeneous group of pathological conditions characterized by considerable variability in biological behavior, hormonal activity, and clinical presentation. The widespread implementation of high-resolution imaging techniques, including multidetector computed tomography (MDCT), magnetic resonance imaging (MRI), and advanced angiographic reconstruction, has significantly increased the detection rate of adrenal tumors over the past decades. As a result, the incidence of incidentally discovered adrenal masses, commonly referred to as adrenal incidentalomas, has steadily increased in modern clinical practice.

Despite advances in diagnostic imaging and endocrine evaluation, the optimal management strategy for patients with adrenal neoplasms remains a subject of ongoing debate. While laparoscopic adrenalectomy is currently considered the standard surgical approach for most benign and hormonally active tumors, not all detected adrenal lesions require surgical intervention. The decision-making process depends on multiple factors, including tumor size, hormonal activity, radiological characteristics, growth dynamics, and the presence of comorbid conditions. Consequently, accurate preoperative assessment plays a decisive role in determining treatment strategy and minimizing surgical risks.

Modern imaging modalities, particularly MDCT angiography with three-dimensional reconstruction, allow detailed evaluation of tumor morphology, vascular anatomy, and relationships with adjacent organs. These parameters are essential for predicting technical complexity, estimating the risk of intraoperative complications, and selecting the most appropriate surgical approach. Previous studies have emphasized that insufficient preoperative assessment may lead to unnecessary surgery in benign conditions or delayed intervention in potentially malignant lesions.

In addition to anatomical assessment, hormonal activity of adrenal tumors significantly influences both clinical presentation and perioperative management. Functional tumors such as cortisol-producing adenomas, pheochromocytomas, and aldosterone-producing

neoplasms are frequently associated with severe metabolic and cardiovascular complications, requiring careful endocrine preparation prior to surgery. Therefore, integration of radiological, laboratory, and clinical data is essential for individualized treatment planning.

The present study aims to analyze the diagnostic and clinical determinants influencing surgical decision-making in patients with adrenal neoplasms and to evaluate the outcomes of laparoscopic adrenalectomy within a modern imaging-guided treatment algorithm. Particular attention is paid to the role of MDCT angiography in preoperative assessment, patient selection for surgery, and optimization of surgical outcomes.

2. Methods

Study Design and Patient Population. This prospective observational study was conducted at the Department of Endocrine Surgery of the Republican Specialized Scientific and Practical Medical Center of Endocrinology named after Academician Yo.Kh. Turakulov (Tashkent, Republic of Uzbekistan). The study included patients diagnosed with adrenal neoplasms between January 2024 and August 2025.

A total of 125 patients with adrenal tumors were examined and evaluated using a standardized diagnostic protocol. The study design focused on assessing clinical, radiological, and endocrine parameters influencing surgical decision-making and treatment outcomes. Among the examined patients, laparoscopic adrenalectomy was performed in 50 (40%) cases, while conservative management or follow-up strategies were applied in the remaining patients based on clinical indications.

The study was conducted in accordance with institutional ethical standards and the principles of the Declaration of Helsinki. All patients provided informed consent for diagnostic and surgical procedures.

Diagnostic Evaluation. All patients underwent comprehensive clinical and laboratory assessment. The diagnostic algorithm included evaluation of clinical symptoms, hormonal activity, and imaging

characteristics of adrenal lesions.

Hormonal assessment included measurement of adrenocorticotrophic hormone (ACTH), cortisol, aldosterone, renin, metanephrine, normetanephrine, dehydroepiandrosterone sulfate (DHEA-S), testosterone, thyroid-stimulating hormone, and free thyroxine when clinically indicated. Additional laboratory testing included serum glucose, electrolytes (sodium, potassium, calcium), urea, and creatinine levels.

Radiological evaluation was primarily based on multidetector computed tomography (MDCT) angiography with three-dimensional reconstruction. Imaging analysis allowed assessment of tumor size, density, anatomical localization, vascular relationships, and potential invasion into adjacent structures. These parameters were used to determine surgical feasibility and operative risk.

MDCT angiography was performed in 123 (98.4%) patients using modern high-resolution imaging systems. Three-dimensional visualization enabled accurate differentiation between adrenal tumors and adjacent renal or vascular structures and significantly improved preoperative planning.

Indications for Surgical Treatment. Indications for laparoscopic adrenalectomy were determined according to contemporary surgical and endocrine criteria and included:

- hormonally active adrenal tumors regardless of size;
- hormonally inactive tumors exceeding 3 cm in diameter with growth tendency;
- suspected malignant adrenal neoplasms;
- selected cases of ACTH-independent hypercortisolism.

Surgery was not performed in 75 (60%) patients due to advanced malignant disease with metastases, severe comorbid conditions, unclear hormonal origin of hypertension, or patient refusal of surgical intervention.

Surgical Technique and Perioperative Management. All surgical procedures were performed using a standard transperitoneal laparoscopic approach. Adrenalectomy was carried out with careful preservation of surrounding structures and early identification and ligation of the

central adrenal vein. Particular attention was paid to maintaining capsule integrity and minimizing manipulation of hormonally active tumors.

Postoperative management included monitoring of hormonal status, electrolyte balance, and hemodynamic parameters. Hormone replacement therapy was administered when indicated until functional recovery of the contralateral adrenal gland.

Statistical Analysis. Descriptive statistical analysis was performed to evaluate demographic, clinical, and surgical variables. Quantitative data are presented as absolute values and percentages. Comparative analysis was used to assess relationships between tumor characteristics, hormonal activity, and clinical outcomes.

3. Results

Patient Characteristics and Surgical Distribution. A total of 125 patients with adrenal neoplasms were evaluated during the study period. Surgical treatment in the form of laparoscopic adrenalectomy was performed in 50 (40%) patients, whereas 75 (60%) patients were managed conservatively due to advanced malignant disease, severe comorbid conditions, unclear hormonal activity, or patient refusal of surgery.

Among the operated patients, right-sided adrenal tumors were identified in 27 (54%) cases and left-sided lesions in 23 (46%). Female patients predominated (39 patients, 78%), while male patients accounted for 11 (22%) cases. The majority of patients belonged to the working-age population (18–45 years), representing 60% of the surgical cohort.

Tumor Size Distribution. Tumor size analysis demonstrated a predominance of medium-sized adrenal neoplasms. Lesions measuring up to 5 cm accounted for the largest proportion of cases, indicating that most tumors were detected at a stage suitable for minimally invasive surgical management (fig.1).

- up to 1.5 cm — 9 patients (18%);
- up to 3 cm — 11 patients (22%);
- up to 5 cm — 17 patients (34%);
- up to 7 cm — 9 patients (18%);
- larger than 7 cm — 4 patients (8%).

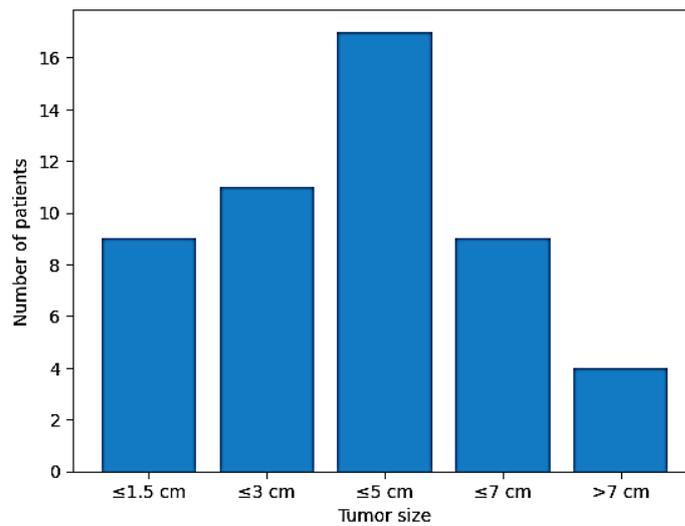


Figure 1. Distribution of adrenal tumor sizes among operated patients.

The predominance of tumors measuring between 3 and 5 cm reflects improved diagnostic capabilities associated with widespread use of modern imaging techniques.

Hormonal Activity of Adrenal Tumors. Preoperative endocrine evaluation demonstrated that hormonally active tumors constituted the majority of surgically treated cases. Elevated hormonal activity was detected in 39 (78%) patients, while hormonal levels were within normal limits or demonstrated subclinical elevation in 10 (20%) cases. Reduced hormonal activity was observed in only one patient (2%).

The high prevalence of hormonally active tumors correlated with the presence of systemic manifestations, including arterial hypertension, metabolic disturbances, and endocrine-related complications.

Morphological Findings. Histological examination revealed predominance of hormonally active adrenal tumors. ACTH-independent Cushing’s syndrome was diagnosed in 15 (30%) patients, pheochromocytoma in 22 (44%), adrenocortical adenomas in 5 (10%), and aldosteroma in 8 (16%) cases. Combined morphological variants were identified in 14% of observations (fig.2).

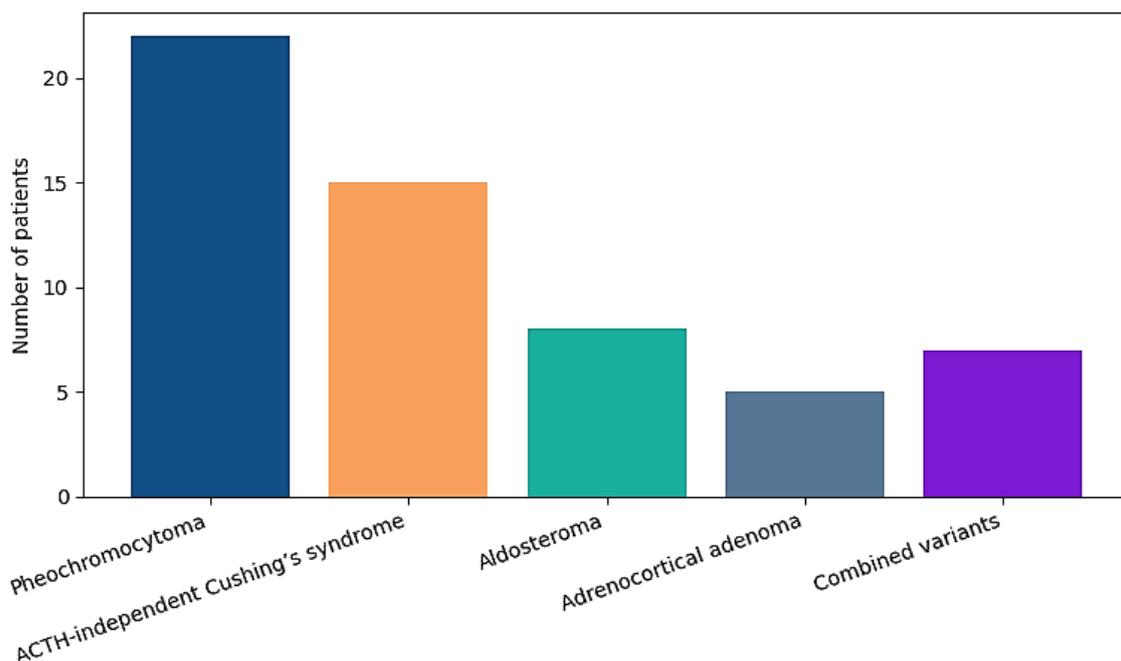


Figure 2. Histological distribution of adrenal neoplasms in operated patients.

These findings demonstrate the clinical relevance of hormonal screening and support the surgical indication for hormonally active adrenal lesions.

Perioperative and Early Postoperative Outcomes. All adrenalectomies were performed laparoscopically without conversion to open surgery. The minimally invasive approach allowed early patient mobilization and reduced postoperative pain. The duration of hospital stay ranged from 5 to 7 days depending on the severity of preoperative endocrine disturbances and recovery of contralateral adrenal function.

Recovery of hormonal activity following surgery and hormone replacement therapy occurred:

- within 3–5 days in 24 patients (48%);
- within 14–30 days in 24 patients (48%);
- lifelong hormone replacement therapy was required in 2 patients (4%).

Clinical improvement following adrenalectomy included normalization of blood pressure, improvement in glucose metabolism, reduction of body weight in patients with hypercortisolism, and regression of dermatological manifestations associated with endocrine disorders.

Imaging and Surgical Planning Outcomes. Preoperative MDCT angiography with three-dimensional reconstruction provided precise assessment of tumor localization and its relationship to major vascular structures, enabling accurate surgical planning in the majority of cases.

The availability of high-resolution imaging significantly reduced intraoperative uncertainty and facilitated safe performance of minimally invasive procedures even in anatomically complex cases.

4. Discussion

The present study demonstrates that laparoscopic adrenalectomy represents a safe and clinically effective approach for the management of adrenal neoplasms when appropriate preoperative diagnostic assessment and patient selection are applied. The obtained results confirm the current paradigm shift toward minimally invasive endocrine surgery, where laparoscopic techniques have largely replaced open procedures due to reduced surgical trauma, shorter hospitalization, and improved postoperative recovery.

Since the first report of laparoscopic adrenalectomy by Gagner et al., minimally invasive adrenal surgery has progressively evolved into the preferred treatment modality for benign and hormonally active adrenal tumors. Large clinical series have consistently demonstrated lower intraoperative blood loss, decreased postoperative pain, and shorter recovery time compared with conventional open adrenalectomy, without compromising oncological safety in selected patients [2,3,8,11]. The absence of conversion to open surgery in the present study further supports the feasibility of the laparoscopic approach when adequate preoperative planning is performed.

One of the most important findings of this study is the high proportion of hormonally active tumors (78%) among operated patients. This percentage exceeds the rates reported in general population-based studies, where hormonally active lesions account for approximately 15–25% of adrenal incidentalomas [1-7,14-19]. Such discrepancy may be explained by referral bias, as specialized endocrine surgical centers typically receive patients with clinically manifest endocrine disorders requiring operative treatment. The observed improvement in metabolic and cardiovascular parameters after tumor removal confirms the systemic impact of hormone-secreting adrenal tumors, consistent with reports by Young et al. and Reincke, who demonstrated significant reversibility of endocrine and metabolic disturbances following removal of the hyperfunctioning adrenal gland [9-13,20-24].

The role of modern imaging techniques, particularly multidetector computed tomography (MDCT) with three-dimensional reconstruction, deserves special consideration. Accurate visualization of tumor size, vascular anatomy, and spatial relationships with adjacent organs allowed optimization of surgical strategy and reduction of intraoperative risks. Previous studies have emphasized that advanced imaging significantly improves preoperative decision-making and reduces complication rates during adrenal surgery [7,14]. In the present study, MDCT angiography enabled reliable identification of tumor characteristics even in anatomically complex cases, contributing to favorable surgical outcomes.

Tumor size distribution in the operated cohort also reflects contemporary trends in adrenal tumor detection. The predominance of lesions measuring 3–5 cm indicates earlier diagnosis due to widespread implementation of

high-resolution imaging modalities. According to international data, tumors larger than 6 cm are associated with increased suspicion for malignancy and higher surgical complexity [10,11]. In our series, only 8% of tumors exceeded this threshold, which partly explains the low complication rate and favorable postoperative course.

Morphological findings demonstrated a predominance of pheochromocytomas and ACTH-independent cortisol-secreting tumors. The high frequency of pheochromocytoma (44%) underscores the importance of comprehensive hormonal screening prior to surgery, as inadequate preoperative evaluation may lead to severe hemodynamic instability during tumor manipulation. Similar observations have been reported by Irvin et al. and Henry et al., emphasizing the necessity of multidisciplinary perioperative management involving endocrinologists, anesthesiologists, and surgeons [11,16,24].

Intraoperative challenges observed in individual cases highlight the continued importance of surgical experience and team coordination. Even with minimally invasive techniques, vascular involvement or unrecognized hormonal activity may result in potentially life-threatening situations. Reports by Tessier et al. and Mitchell et al. indicate that rare but severe complications during adrenalectomy are frequently associated with insufficient preoperative hormonal assessment or unexpected anatomical variations [22,23]. The favorable outcomes in the present study demonstrate that timely intraoperative decision-making and experienced anesthesiology support remain critical components of safe adrenal surgery.

Overall, the findings of this study confirm that successful management of adrenal neoplasms depends not solely on surgical technique but on an integrated diagnostic and therapeutic strategy. Early detection, comprehensive endocrine evaluation, modern imaging technologies, and minimally invasive surgical approaches collectively contribute to improved clinical outcomes. The results also emphasize the need for increased awareness and earlier screening among patients with resistant hypertension or metabolic disorders, as delayed diagnosis remains a significant limiting factor in achieving optimal treatment results.

5. Conclusions

Laparoscopic adrenalectomy represents an effective and

safe surgical approach for the treatment of adrenal neoplasms when combined with comprehensive preoperative diagnostic assessment and appropriate patient selection. In the present study, minimally invasive adrenalectomy demonstrated high clinical efficacy, allowing successful surgical treatment in 98% of operated patients with low complication rates and rapid postoperative recovery.

The predominance of hormonally active tumors among operated patients highlights the importance of thorough endocrine evaluation, as removal of hormone-secreting lesions resulted in significant clinical improvement, including stabilization of arterial pressure, normalization of metabolic parameters, and regression of endocrine-related symptoms. Recovery of hormonal balance occurred within 3–30 days in the majority of patients, while lifelong hormone replacement therapy was required only in a limited number of cases (4%).

Preoperative multidetector CT angiography with three-dimensional reconstruction proved to be a critical component of surgical planning, enabling precise assessment of tumor localization and anatomical relationships, thereby reducing intraoperative risks and facilitating safe laparoscopic intervention.

The results of this study confirm that early diagnosis, modern imaging technologies, and minimally invasive surgical techniques collectively improve treatment outcomes in patients with adrenal neoplasms. Further improvement in clinical results may be achieved through earlier detection strategies and multidisciplinary management of patients with suspected hormonally active adrenal tumors.

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