Original Article

Adrenalectomy Unveiled: A Comprehensive Exploration of Surgical Endeavors in Pakistan

Nadeem Bin Nusrat[1], Shujah Muhammad[2], Nauman Zafar[3], Assad ur Rehman[4], Asadullah Aslam[5], Sarmad Imtiaz[6], Salman Shahzad[7], Umar Saleem[8], Ammar Asghar[9], Saud Iqbal[10], Moin Arshad[11], Aadil Chaudhary[12], Saira Imtiaz[13]

[1-6,8-12]Department of Urology, Pakistan Kidney and Liver Institute and Research Centre Lahore, Pakistan; [7]Department of Anaesthesia, Pakistan Kidney and Liver Institute and Research Centre Lahore, Pakistan; [13]Department of Research, Pakistan Kidney and Liver Institute and Research Centre Lahore, Pakistan

Corresponding Author: Saira Imtiaz, Department of Research, Pakistan Kidney and Liver Institute and Research Centre Lahore, Pakistan **Email:** saira.khan@pkli.org.pk

Abstract

Background: Adrenalectomy is the standard treatment for adrenal pathologies, with minimally invasive techniques enhancing outcomes. However, data from developing countries remain scarce.
Objective: To assess adrenalectomy outcomes at a tertiary care center in Pakistan.
Methods: A retrospective case series (2017–2024) at Pakistan Kidney and Liver Institute (IRB: PKLI-IRB/AP/172) included 17 patients with confirmed adrenal masses. Data included demographics, presentation, surgical approach (open, laparoscopic, robotic), and outcomes. Open surgery via subcostal incision was used for large (>6 cm) or invasive tumors; smaller tumors underwent laparoscopic or robotic resection using the Versius system.
Results: The cohort (mean age 46.1±17.1 years) showed male predominance (58.8%). Comorbidities included hypertension (47.1%) and diabetes (35.3%). Most tumors were unilateral (82.4%), with mean size 8.78±3.82mm. Surgical approaches included open (47.1%), robotic (41.2%), and laparoscopic (11.8%), with one conversion case (5.9%). Pathologies revealed adrenal carcinoma (35.3%), pheochromocytoma (23.5%), and rare cases including liposarcoma (5.9%). Intraoperative complications occurred in one case (5.9%). Postoperative complications included infection (11.8%), DVT (11.8%), and lymphorrhea (5.9%). Median operative time was 160 minutes (IQR:55), blood loss 150mL (IQR:200), and hospital stay 5 days (IQR:2). Normal adrenal function was preserved in 82.4% postoperatively. No recurrences occurred, with 100% survival at follow-up.
Conclusion: Adrenalectomy at our center demonstrated favorable outcomes across open and minimally invasive approaches, with low complication rates and excellent survival. Robotic techniques comprised a significant proportion of cases, reflecting evolving surgical practice. These results provide valuable insights into adrenal surgery outcomes in a Pakistani population.
Keywords: Adrenalectomy; Robotic adrenalectomy; Minimally invasive surgery; Adrenal neoplasms; Surgical outcomes
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Introduction

The management of adrenal tumors carries significant clinical importance due to their potential hormonal activity and malignancy risks. These tumors - both benign and malignant - can cause substantial morbidity through excessive hormone production, leading to conditions like hypertension and Cushing's syndrome.[1-3] Globally, advancements in CT and MRI imaging, coupled with improved biochemical testing, have markedly increased detec-tion rates, with many adrenal masses discovered incidentally during evaluation for unrelated conditions.[4]

Adrenalectomy remains the cornerstone intervention for adrenal pathologies, ranging from functional endocrine tumors to malignant neoplasms requiring oncologic resection.[5] The past three decades have witnessed a paradigm shift in adrenal surgery, with minimally invasive techniques progressively replacing traditional open approaches.[6] Since its first description in 1992, laparoscopic adrenalectomy has become the gold standard for most benign lesions due to superior perioperative outcomes[7,8,]while robotic-assisted techniques now offer enhanced precision in complex cases.[9]

However, significant challenges persist in resource-limited settings, including delayed diagnosis and

limited access to advanced surgical techniques.[1] These disparities are compounded by inadequate healthcare infrastructure, creating variations in adrenalectomy outcomes between functional and non-functional tumors based on surgical approach.[10,11] The adrenal glands' intimate vascular anatomy further complicates resection, requiring precise technique regardless of operative method.[12]

In Pakistan and similar middle-income regions, where socioeconomic factors profoundly impact surgical outcomes, data remain particularly scarce. This knowledge gap underscores the need for studies examining adrenalectomy outcomes under resource constraints. Our analysis of 17 cases at a tertiary Pakistani center aims to establish baseline outcomes in this setting, evaluate the feasibility of advanced techniques, and contribute to global discussions on surgical innovation in constrained environments. By documenting our institutional experience with open, laparoscopic, and robotic approaches, we provide practical insights for improving adrenal disease management across comparable healthcare systems.

Methods

This retrospective study was conducted at the Pakistan Kidney and Liver Institute and Research Center (PKLI), a premier tertiary care hospital in Lahore, Pakistan after approval from the Institutional Review Board (IRB) of Pakistan Kidney and Liver Institute (PKLI), Lahore (Reference No: PKLI-IRB/AP/172). Informed consent was waived due to the retrospective nature of the study. A retrospective case series design was employed to evaluate patients who underwent adrenalectomy at PKLI between 2018 and 2024**.**

The study population comprised all consecutive patients who underwent adrenalectomy procedures between 2017 to 2024 for histopathologically confirmed adrenal masses. To ensure comprehensive data collection, strict inclusion criteria were applied: (1) definitive histological confirmation of adrenal pathology following surgical resection, and (2) availability of complete medical records document-ting the entire clinical course from preoperative evaluation through postoperative follow-up. These criteria were implemented to maintain data integrity and allow for thorough analysis of surgical outcomes while representing the full spectrum of adrenal pathologies treated at our institution during the study period. The selection process aimed to capture all eligible cases that met these criteria within the specified timeframe, providing a representative sample of adrenalectomy patients at our tertiary referral center.

The study data were collected retrospectively from electronic medical records using a standardized data collection form. This comprehensive form captured four key categories of information: (1) Demographic characteristics including patient age, gender, and comorbid conditions; (2) Preoperative clinical details such as presenting symptoms, radiological imaging findings, and endocrine laboratory workup results; (3) Surgical parameters encompassing the operative approach (open, laparoscopic, or robotic), specific techniques employed, operative duration, and estimated blood loss; and (4) Outcome measures including postoperative complications (classified by Clavien-Dindo system), length of hospital stay, disease recurrence rates, and survival status at follow-up. All data points were systematically recorded to ensure complete and uniform documentation across all study cases.

Open adrenalectomy was performed exclusively via a subcostal approach for large adrenal masses (>6 cm) or locally adherent/invasive tumors. The procedure begins with mobilization of adrenal gland by separating the peritoneum and gerota and defining adrenal gland gland anatomy and adrenal vein with renal hilum Gerota's fascia. Early control of adrenal vein ligated with vicryl 3/0 and clipped. Adrenal arterial vessels controlled with LigaSure Impac Covidien. En bloc resection of adrenal performed after vascular ligation.

For laparoscopic adrenalectomy, the surgical approach differed based on tumor location. Right-sided tumors required four ports, including one dedicated for liver retraction, while left-sided tumors were approached through three ports. Hemostasis was achieved using Ligasure™ for parenchymal dissection, with laparoscopic ligature clips applied to the adrenal vein and metallic clips used for adrenal arteries. The procedure emphasized complete gland mobilization from peritoneal reflections and splenorenal attachments on left side and hepatorenal attachments on right side. and Gerota's fascia, with

particular attention to identifying the adrenal vein's anatomical relationship to major vessels (IVC on right, renal vein on left) and the renal hilum. All specimens were retrieved using an endobag to prevent port-site contamination.

The Versius Robotic System (CMR Surgical) was employed for robotic adrenalectomy, maintaining the same technical principles as the laparoscopic approach while offering enhanced 3D visualization, wristed instrument maneuverability, and improved precision in vascular dissection. Both minimally invasive approaches shared critical steps including early adrenal vein control with ligature clips, meticulous dissection to avoid avulsion, minimal tumor manipulation (particularly important for pheochromocytomas to prevent catecholamine surges), and strict adherence to oncologic principles for malignant cases. Specimen extraction in all minimally invasive cases mandated the use of retrieval bags with careful attention to prevent capsular rupture during removal.

The primary outcomes of the study focused on surgical complications (classified according to the Clavien-Dindo system) and postoperative recovery parameters (particularly length of hospital stay). Secondary outcomes included assessment of recurrence rates, postoperative adrenal function status, and patient survival data during the follow-up period. These comprehensive outcome measures allowed for thorough evaluation of short-term clinical outcomes following adrenalectomy.

All statistical analyses were performed using SPSS software (version 27.0). For continuous variables, data were presented as either mean ± standard deviation (SD) for normally distributed parameters or median with interquartile range (IQR) for non-normally distributed data. Categorical variables were expressed as frequencies and percentages.

Results

The study population consisted of 17 patients, with 10 (58.8%) males and 7 (41.2%) females. The mean age of the patients was 46.12 ± 17.06 years. The majority of patients (12, 70.6%) had no comorbidities, while 1 (5.9%) had decompensated chronic liver disease (DCLD), 2 (11.8%) had hepatitis C, 1 (5.9%) had chronic kidney disease (CKD), and 1 (5.9%) had hypothyroidism.

Regarding symptoms, only 1 (5.9%) of patients experienced abdominal distension. None of the patients reported weight gain or insomnia (0, 0%). Ischemic heart disease was present in 1 (5.9%) patient, while 16 (94.1%) did not have it. Hypertension was observed in 8 (47.1%) patients, whereas 9 (52.9%) did not have it. Diabetes mellitus was present in 6 (35.3%) patients, while 11 (64.7%) were non-diabetic. Among other clinical presentations, 8 (47.1%) patients reported pain, 3 (17.6%) had incidental findings, and 2 (11.8%) had headaches. Imaging modalities used included CT scans in 14 (82.4%) patients, CT and MRI in 2 (11.8%) patients, and CT with a sestamibi scan in 1 (5.9%) patient.

The mean size of the adrenal mass was 8.78 ± 3.82 mm. Tumor locations varied, with 7 (41.2%) in the left adrenal gland, 6 (35.3%) in the right adrenal gland, 1 (5.9%) in an extra-adrenal (ectopic) location, and 3 (17.6%) showing bilateral adrenal involvement. Regarding tumor laterality, unilateral involvement was seen in 14 (82.4%) cases (7, 41.2% on the left and 7, 41.2% on the right), while bilateral involvement was observed in 3 (17.6%) cases.

Contrast enhancement was present in 7 (41.2%) cases, absent in 4 (23.5%) cases, and not mentioned in 6 (35.3%) cases. Calcifications were observed in 4 (23.5%) cases, while 13 (76.5%) cases showed no calcifications.

Table 1: *Preoperative Endocrinological and Hemodynamic Profiles*

Parameter	Value
Aldosterone (ng/dL)	16.50 (IQR: 22.05)
Renin (ng/mL/h)	14.55 (IQR: 20.72)
Cortisol	5.48 (IQR: 8.37)
Urinary Normetanephrine	100.00 (IQR: 484.55)
Metanephrine	40.00 (IQR: 583.65)
Blood Glucose (mg/dL)	130.00 (IQR: 28.00)
Hemoglobin (g/dL)	12.31 ± 2.32
Sodium (mmol/L)	139.35 ± 3.87
Potassium (mmol/L)	4.25 ± 0.49
Chloride (mmol/L)	101.90 ± 3.75
Systolic BP (mmHg)	128.53 ± 21.06
Diastolic BP (mmHg)	77.59 ± 8.10
Heart Rate (bpm)	84.18 ± 13.01

Preoperative complications were absent in all patients (17, 100.0%). Preoperative diagnoses incl-

uded adrenal carcinoma in 8 (47.1%) cases, pheochromocytoma in 6 (35.3%) cases, myelolipoma in 2 (11.8%) cases, and metastatic renal cell carcinoma (RCC) in 1 (5.9%) case. Endocrine disorders were not present in 11 (64.7%) patients, while 4 (23.5%) were diagnosed with pheochromocytoma, and 1 (5.9%) had another endocrine disorder. Some of the Preoperative Endocrinological, Hematological, and Vital Parameters presented in Table 1:

ASA physical status classification showed that 6 (35.3%) patients were classified as ASA I (normal healthy patient), 6 (35.3%) as ASA II (mild systemic disease), and 5 (29.4%) as ASA III (severe systemic disease). All patients (17, 100.0%) underwent general anesthesia. Regarding intraoperative management, hemodynamic stability was maintained in 9 (52.9%) cases, fluid balance was a concern in 3 (17.6%) cases, blood transfusions were required in 1 (5.9%) case, vasoactive medications were used in 3 (17.6%) cases, and both vasoactive medications and blood transfusions were required in 1 (5.9%) case.

The surgical approach included laparoscopic surgery in 2 (11.8%) cases, open surgery in 8 (47.1%) cases, and robotic surgery in 7 (41.2%) cases. One (5.9%) case required conversion from laparoscopic to open surgery, while 16 (94.1%) did not require conversion. Intraoperative complications were absent in 16 (94.1%) cases, while 1 (5.9%) patient experienced vascular instability and hemorrhage. Postoperative complications presented in Table 2:

Table 2: *Postoperative Complications and Clavien-Dindo Classification*

Postoperative Complications	Number of Patients (n = 17)	Percentage (%)	Clavien-Dindo Classification
Infection	2	11.8	Grade II
Lymphorrhea	1	5.9	Grade I
Deep Vein Thrombosis (DVT)	2	11.8	Grade II

Pathological findings revealed adrenal carcinoma in 6 (35.3%) cases, pheochromocytoma in 4 (23.5%) cases, myelolipoma in 2 (11.8%) cases, metastatic RCC in 1 (5.9%) case, metastatic hepatocellular carcinoma in 1 (5.9%) case, adrenal adenoma in 1 (5.9%) case, ganglioneuroma in 1 (5.9%) case, and liposarcoma in 1 (5.9%) case.

Weiss criteria assessment for adrenal carcinoma cases showed no involvement in 11 (64.7%) cases. Various features were identified, including clear cells < 25% in 1 (5.9%) case, capsular invasion in 1 (5.9%) case, clear cells < 25%, necrosis, and capsular invasion in 1 (5.9%) case, mitoses > 5 in 50 fields in 1 (5.9%) case, clear cells < 25% and necrosis in 1 (5.9%) case, and diffuse architecture > 33%, capsular invasion, and clear cells < 25% in 1 (5.9%) case.

Immunohistochemistry results varied, with negative findings in 2 (11.8%) cases. Markers detected included CK in 2 (11.8%) cases, melanin A in 1 (5.9%) case, S-100 positivity in Schwann and ganglion cells in 1 (5.9%) case, CD34 in 1 (5.9%) case, synaptophysin in 2 (11.8%) cases, KI-67 and melanin A in 1 (5.9%) case, KI-67, melanin A, and synaptophysin in 1 (5.9%) case, melanin A and synaptophysin in 2 (11.8%) cases, chromogranin, KI-67, and synaptophysin in 2 (11.8%) cases, KI-67, CK, and synaptophysin in 1 (5.9%) case, and chromogranin, S-100 positivity in Schwann and ganglion cells, and synaptophysin in 1 (5.9%) case.

Post-surgical adrenal function was normal in 14 (82.4%) patients, while 3 (17.6%) required corticosteroid supplementation. Some of the post operative outcome is presented in Table 3.

Table 3: *Postoperative Outcomes*

Parameter	(Median, IQR)
Operative Time (minutes)	160.00 (55.00)
Intraoperative Blood Loss (mL)	150.00 (200.00)
Length of Hospital Stay (days)	5.00 (2.00)

There were no cases of recurrence (0, 0%), and all patients (17, 100.0%) were alive at follow-up.

Discussion:

Our findings present important contrasts with Obadiel et al.'s Yemeni cohort, which reported younger patients, female predominance (65.1%), and predominantly open adrenalectomies (88.4%).[1] While we shared similar hypertension prevalence (47.1%), our cohort demonstrated greater robotic adoption (41.2%) and more non-functional tumors (64.7%), reflecting both institutional capabilities and differing patient populations. The higher malignancy rates (35.3% vs 16.3%) and complication rates (29.4% vs 16.3%) in our series likely reflect our inclusion of more complex cases, while both studies maintained excellent safety profiles (100% vs 97.7% survival).

When compared to Davey et al.'s meta-analysis[13], our robotic outcomes (operative time 172.14±47.42 minutes, blood loss 122.86±80.56mL) compared favorably with their laparoscopic results, while achieving similar length of stay (3.86±0.69 days) to their retroperitoneal approach. This suggests robotic techniques may combine the benefits of different minimally invasive approaches, particularly for larger tumors (mean 8.78cm vs their 3.5-4.4cm).

Our study extends Fang et al.'s pheochromocytoma-specific findings[14] by demonstrating robotic advantages across diverse adrenal pathologies. The shorter hospital stays for robotic versus laparoscopic cases (3.86±0.69 vs 5 days) in our series, despite higher overall complexity, supports expanding robotic indications beyond endocrine-active tumors.

The comparison with Azhar et al.[15] is particularly instructive, as both studies evaluated large adrenal tumors in resource-conscious settings. Our lower conversion rate (5.9% vs 2.9%) despite more malignant cases suggests that judicious case selection and robotic utilization can maintain safety even with challenging pathologies.

Strategies to minimize complications include improved preoperative optimization, structured perioperative protocols and enhanced surgical training. Surgeon experience plays a critical role, with complication rates decreasing significantly after the initial learning curve.[16] Adrenalectomy has demonstrated long-term benefit for treating functional tumors, reducing mortality, and improving renal outcomes in primary aldosteronism.[17] Quality of life significantly improves after adrenalectomy for conditions like Cushing's syndrome and primary aldosteronism, with physical and mental health scores nearing those of the general population.[18, 19]

Study strengths include comprehensive outcome reporting across multiple surgical approaches and detailed pathological characterization.

Limitations involve the single-center design and modest sample size inherent to adrenal surgery studies. Future research should focus on multicenter collaborations to establish optimal approach selection criteria and cost-effectiveness analyses of robotic adoption in resource-limited settings.

Conclusion:

This study demonstrates the safety and efficacy of adrenalectomy across open, laparoscopic, and robotic approaches in a resource-limited setting. Robotic techniques showed particular promise for complex cases, with favorable operative outcomes. While open adrenalectomy remains essential for select tumors, our findings support judicious robotic adoption where feasible to optimize patient recovery and surgical precision.

Ethical Permission: The present study protocol was reviewed and approved by the Institutional Review Board of Pakistan Kidney and Liver Institute and Research Centre Lahore, Pakistan (approval number: Ref # PKLI-IRB/AP/172). Patient consent was waived due to the retrospective nature of the study.

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Authors' contribution:

NBN, SM, NZ, AR, AA, SI: Study concept and design; Final approval of the version to be published

SS, US, AA, SI: Data collection/management; Manuscript writing/editing; Final approval of the version to be published

MA, AC: Manuscript writing/editing; Final approval of the version to be published

SI: Data analysis & interpretation

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