ORIGINAL ARTICLE

OUTCOMES OF THE FIRST 100 ADRENALECTOMIES IN A SINGLE CENTER: RETROSPECTIVE COHORT STUDY

Tek Merkezde İlk 100 Adrenalektominin Sonuçları: Retrospektif Kohort Çalışması

Emre HEPSEN[1], Adem SANCI[1], Metin YIGMAN[1], Kubilay SARIKAYA[1], Alper GOK[1], Semih Yasar SARGIN[1], Erman CAKAL[2]

[1]Ankara Etlik City Hospital,
Clinic of Urology,
Ankara,
Türkiye.
[2]Ankara Etlik City Hospital, Clinic of Endocrinology and Metabolism ,
Ankara,
Türkiye.

Emre HEPŞEN, MD.
(https://orcid.org/0000-0002-4634-5114)
✉dremrehepsen@gmail.com
Adem SANCI, MD.
(https://orcid.org/0000-0003-2229-8234)
✉dr.adem88@hotmail.com
Metin YIĞMAN, Assoc. Prof. Dr.
(https://orcid.org/0000-0003-1217-8458)
✉m.yigman@hotmail.com
Kubilay SARIKAYA, Assoc. Prof. Dr.
(https://orcid.org/0000-0003-1734-2392)
✉drkubilay.sarikaya76@outlook.com
Alper GÖK, Prof. Dr.
(https://orcid.org/0000-0001-6874-4151)
✉alper_gok@hotmail.com
Semih Yaşar SARGIN, Prof. Dr.
(https://orcid.org/0009-0002-1029-3989)
✉seysarn@gmail.com
Erman ÇAKAL, Prof. Dr.
(https://orcid.org/0000-0003-4455-7276)
✉ermancakal@hotmail.com

Contact:
MD. Emre HEPŞEN
Ankara Etlik City Hospital,
Clinic of Urology, Ankara, Türkiye.

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ABSTRACT

Objective: We aimed to evaluate the first 100 adrenalectomy cases in our clinic by analyzing preoperative indications, perioperative outcomes, postoperative follow-up, and final histopathological findings.

Material and Methods: This retrospective study included patients who underwent laparoscopic (LA) or open adrenalectomy (OA). Surgical indications were determined after multidisciplinary evaluation including endocrinology, based on clinical assessment, hormonal analyses, and imaging findings.

Results: LA was attempted in 96 patients and completed in 94, with conversion to OA in 2 cases (2.1%). Among 34 patients with Cushing syndrome (CS), 33 had benign adenomas and one (2.9%) had adrenocortical carcinoma (ACC). Among 29 patients with primary aldosteronism (PA), 28 had adenomas and one (3.4%) was suspicious for ACC. Among 18 patients with suspected pheochromocytoma (Pheo), pathology confirmed Pheo in 16 patients; LA was completed in 15 cases. One patient with a 6-cm ACC underwent LA, whereas two patients with tumors measuring 9 cm and 18 cm underwent OA. Among four who underwent LA for suspicious lesions, three were benign and one had a 12-cm mature teratoma. Nine had adrenal cysts, and three were diagnosed with myelolipoma (ML). The largest adrenal mass resected laparoscopically was a 14-cm ML.

Within hormonally active tumors, Pheo patients had larger tumors, longer operative time, higher intraoperative fluid aspiration, higher hemoglobin decrease, and longer drain removal time (p=0.007). OA cases had significantly larger tumors, higher-risk pathologies and worse perioperative outcomes compared with completed LA procedures.

Antihypertensive requirements improved after adrenalectomy in hormonally active tumors: 77% in CS, 89.7% in PA, and 94.4% in Pheo.

Conclusion: Adrenalectomy can be performed safely with appropriate patient selection and multidisciplinary management. Surgical approach should be individualized according to tumor characteristics and suspected pathology.

Keywords: *Adrenal Tumor; Adrenalectomy; Laparoscopic Adrenalectomy*

ÖZET

Amaç: Kliniğimizde gerçekleştirilen ilk 100 adrenalektomi olgusunu; preoperatif endikasyonlar, perioperatif sonuçlar, postoperatif takip bulguları ve histopatolojik sonuçlar açısından değerlendirilmesini amaçladık.

Gereç ve Yöntemler: Retrospektif çalışmaya laparoskopik (LA) veya açık adrenalektomi (AA) uygulanan hastalar dahil edildi. Cerrahi endikasyonlar; klinik değerlendirme, hormonal analizler ve görüntüleme bulgularına dayanarak endokrinoloji ile multidisipliner konsey sonrası belirlendi.

Bulgular: LA 96 hastaya başlandı ve 94'ünde tamamlandı; 2 olguda (%2,1) AA'ye konversiyon gerekti. Cushing sendromu (CS) tanılı 34 hastanın 33'ünde benign adenom, 1'inde (%2,9) adrenokortikal karsinom (ACC) saptandı. Primer aldosteronizm (PA) tanılı 29 hastanın 28'inde adenom, 1'inde (%3,4) ACC şüphesi mevcuttu. Feokromositoma (Pheo) ön tanısı ile opere edilen 18 hastanın 16'sında patoloji Pheo ile uyumlu bulundu; 15'inde laparoskopik cerrahi tamamlandı. 6 cm'lik ACC olgusu laparoskopik olarak tamamlanırken, 9 cm ve 18 cm tümörlü iki olguda AA tercih edildi. Şüpheli lezyon nedeniyle LA yapılan dört hastanın üçünde benign adenom, birinde 12 cm matür teratom saptandı. Dokuz hastada adrenal kist, üç hastada miyelolipom (ML) izlendi; LA yapılarak çıkarılan en büyük kitle 14 cm'lik ML idi. Hormonal aktif tümörler içinde Pheo grubunda tümör boyutu, operasyon süresi, aspire edilen sıvı miktarı, hemoglobin düşüşü ve dren çekilme süresi daha yüksekti (p=0.007). AA uygulanan hastalarda tümör boyutu daha büyük ve riskli patolojilerden oluşmakla birlikte perioperatif sonuçlar daha olumsuzdu. Antihipertansif gereksinimde düzelme CS'de %77, PA'da %89,7 ve Pheo'da %94,4 oranında saptandı.

Sonuç: Uygun hasta seçimi ve multidisipliner yaklaşım ile adrenalektomi güvenle uygulanabilir. Cerrahi yöntem, tümör özellikleri ve olası patolojiye göre bireyselleştirilmelidir.

Anahtar Kelimeler: *Adrenal Tümör; Adrenalektomi; Laparoskopik Adrenalektomi*

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INTRODUCTION

Adrenalectomy is indicated for hormonally active adrenal tumors such as Cushing syndrome (CS), primary aldosteronism (PA) (Conn syndrome), and pheochromocytoma (Pheo), as well as for malignant lesions including adrenocortical carcinoma (ACC) and selected benign tumors such as adrenal cysts and myelolipomas (ML) (1,2). Laparoscopic transabdominal adrenalectomy (LA) is currently considered the standard surgical approach; however, open adrenalectomy (OA) is recommended for large tumors and lesions with a high suspicion of malignancy (3,4). As a tertiary center routinely performing adrenal surgery, we aimed to analyze the first 100 adrenalectomy cases in our institution with respect to preoperative indications, perioperative outcomes, postoperative follow-up, and final histopathological findings. This study reflects our early institutional experience with adrenalectomy and provides an overview of the initial outcomes achieved at our center.

MATERIAL AND METHODS

This retrospective study included the first 100 patients who underwent LA or OA at the urology department of Etlik City Hospital between February 2023 and February 2026. Patients who underwent concomitant ipsilateral adrenalectomy during surgery for renal malignancy and those who underwent adrenalectomy for adrenal metastases from multi-organ metastatic disease were excluded from the study.

The study was conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all patients, and the study protocol was approved by the institutional ethics committee (Date: 24/03/2026. No: AEŞH-BADEK2-2026-292). Clinical data were collected retrospectively from hospital records.

All patients were evaluated preoperatively by the endocrinology department for hormonal activity. Biochemical and hormonal assessments included serum cortisol, adrenocorticotropic hormone (ACTH), plasma renin and aldosterone levels. A 1-mg dexamethasone suppression test was performed when clinically indicated. In selected patients, adrenal venous sampling (AVS) was performed by interventional radiology to determine lateralization of hormone secretion. Plasma and urinary catecholamines and metanephrines were measured in patients with suspected Pheo.

All patients underwent contrast-enhanced computed tomography (CT) or magnetic resonance imaging. Adrenal masses with unenhanced CT attenuation > 10 Hounsfield units (HU) and an absolute percentage washout<50% at 15 minutes after contrast administration were considered suspicious for malignancy. Tumor size and growth were evaluated by comparison with previous imaging when available. Patients with suspected ACC underwent 18fluorodeoxyglucose Positron emission tomography (18FDG PET)/CT scan, and Gallium-68 DOTATATE PET/CT was performed in selected patients with suspected Pheo.

Demographic data, comorbidities, medication use, body mass index (BMI), and blood pressure measurements were recorded. Clinical features suggestive of CS were also assessed.

Surgical indication was determined after multidisciplinary evaluation involving endocrinology and urology specialists. Preoperative preparation protocols were managed by endocrinologists. Patients with CS received perioperative steroid coverage. Patients with PA were treated with spironolactone, antihypertensive therapy, and potassium supplementation when required. Patients with Pheo received preoperative alpha-blockade and volume expansion.

Surgical notes and patient follow-up records were reviewed retrospectively to evaluate operative time, aspirated fluid volume (intraoperative suction volume), hemoglobin decrease, drain removal day, and perioperative complications classified according to the Clavien-Dindo (CD) grading system. Histopathological findings were recorded. Postoperative outpatient follow-up data were reviewed to assess blood pressure control and antihypertensive medication requirements. Patients were categorized according to preoperative diagnosis as CS, PA, Pheo, ACC, suspicious adrenal tumor, adrenal cyst, and ML. Outcomes were compared according to preoperative diagnostic groups and surgical approach (LA vs OA).

Statistical Analyses

Statistical analyses were performed using SPSS version 25.0 (IBM Corp., Armonk, NY, USA). Continuous variables were presented as mean ± standard deviation or median (interquartile range) according to data distribution, while categorical variables were expressed as frequencies and percentages. Normality of distribution was assessed using the Shapiro-Wilk test.

Comparisons among more than two diagnostic groups were performed using one-way analysis of variance (ANOVA) or the Kruskal-Wallis test, as appropriate. When an overall statistically significant difference was identified, post-hoc pairwise comparisons were conducted using the Tukey test after ANOVA and Dunn's test with Bonferroni correction after the Kruskal-Wallis test. For comparisons between two groups, the Student's t-test was used for normally distributed variables, whereas the Mann-Whitney U test was used for variables that did not show a normal distribution. Comparisons between laparoscopic and open adrenalectomy groups were performed using the Mann-Whitney U test due to the small sample size of the open surgery group. Categorical variables were compared using the chi-square test.

Correlation analyses were performed using Pearson or Spearman correlation coefficients. A two-sided p value<0.05 was considered statistically significant.

RESULTS

The demographic characteristics of the 100 patients who underwent adrenalectomy, including sex, age, BMI, tumor size, and tumor laterality, are presented in Table 1.

When patients were grouped according to preoperative diagnosis, demographic features, operative approach, pathology results, and antihypertensive medication outcomes are presented in Table 2.

There was no significant difference in patient age among diagnostic groups (p=0.446). Although there was female predominance in the CS group and only male patients in the ML group, sex distribution did not differ significantly between groups after Bonferroni correction (p=0.011). Tumor laterality did not differ significantly among diagnostic groups (p=0.17).

Among 34 patients with a preoperative diagnosis of CS, 33 had benign adenomas, while one patient (2.9%) with a 5-cm tumor was diagnosed with adrenocortical carcinoma (ACC). Among 29 patients with presumed primary aldosteronism, 28 had benign adenomas and one patient (3.4%) with 3-cm tumor was diagnosed as suspicious for ACC.

Among 18 patients operated with a preoperative diagnosis of Pheo, pathology confirmed Pheo in 16 patients, whereas two patients had benign adenomas. Pheochromocytoma of the Adrenal Gland Scaled (PASS) score ≥4 was observed in 10 of 16 patients (62.5%). Four patients had hereditary syndromes Multiple Endocrine Neoplasia Type 2A (MEN2A), Von Hippel-Lindau disease (VHL) and two Neurofibromatosis Type 1 (NF1) cases. Conversion to OA was required in one NF-1 patient with a 7-cm tumor due to intraoperative hypertensive crises. OA was initially preferred in two patients: one because of a large 13-cm tumor and the other due to severe cardiac comorbidity with an ejection fraction of 20% following two previous myocardial infarctions. Among 18 patients with suspected Pheo, LA was completed in 15 patients.

All three patients operated with a preoperative diagnosis of ACC were confirmed histopathologically. One patient with a 6-cm tumor underwent LA, whereas two patients with tumors measuring 9 cm and 18 cm underwent OA.

Table 1. Baseline demographic and tumor characteristics of patients undergoing adrenalectomy (n=100)

Age (years) (mean ± SD)	51.3 ± 11.6
Male, n (%)	31 (31%)
Female, n (%)	69 (69%)
BMI (kg/m²)	31.6 ± 6.9
Tumor size (cm)	4.35 ± 2.97
Right n (%)	49 (49%)
Left n (%)	51 (51%)

Abbreviations: BMI: body mass index, SD: standard deviation

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Table 2. Patient characteristics, operative approach, pathological findings, and antihypertensive outcomes according to preoperative diagnosis (n=100)

					Histopathology								
Preliminary Diagnosis	n	Age (years) (mean ± SD)	Male/ Female	Right/ Left	Adenoma n	ACC n (%)	PASS ≥4 n (%)	LA n	COAn	POAn	Pre-op AH n (%)	Reduced AH n (%)	Discontinued AH n (%)
CS	34	44.8 ± 10.6	5/29	17/17	33	1 (34/ 2.9%)		34	0	0	26 (34/ 76.5%)	10 (26/ 38.5%)	10 (26/ 38.5%)
PA	29	46.1 ± 9.8	11/18	12/17	27	1 (29/ 3.4%)		29	0	0	29 (29/ 100%)	10 (29/ 34.5%)	16 (29/ 55.2%)
Pheo	18	48.7 ± 12.3	9/9	13/5	2/ 16 Pheo	0	10 (16/ 62.5%)	15	1	2	18 (18/ 100%)	2 (18/ 11.1%)	15 (18/ 83.3%)
ACC	3	52.3 ± 8.4	1/2	2/1	0	3		1	0	2	1	0	0
Suspicious lesion	4	47.5 ± 11.2	0/4	1/3	3/ 1 Teratoma	0		4	0	0	3	0	0
Adrenal cyst	9	45.6 ± 13.1	2/7	3/6	9	0		8	1	0	1	0	0
ML	3	49.0 ± 6.2	3/0	1/2	3	0		3	0	0	1	0	0
		p=0.446	p=0.011*	p=0.17									

*: The difference was not statistically significant after Bonferroni correction
Abbreviations: CS: Cushing syndrome, PA: primary aldosteronism, Pheo: pheochromocytoma, ACC: adrenocortical carcinoma, ML: myelolipoma, PASS: pheochromocytoma of the adrenal gland scaled score, LA: laparoscopic transabdominal adrenalectomy, COA: conversion to open adrenalectomy, POA: primary open adrenalectomy, AH: antihypertensive, SD: standard deviation

Among four patients who underwent LA due to suspicious imaging findings or tumor growth, three had benign adenomas and a 12-cm left adrenal mass in a 22-year-old female patient was diagnosed as a mature adrenal teratoma (Figure 1a). Nine patients had adrenal cysts; LA was completed in eight patients, while one patient with a 15-cm cyst required conversion to OA.

LA was attempted in 96 patients and was successfully completed in 94, while conversion to OA was required in 2 cases (2.1%).

All three patients with preoperative diagnosis of ML had histopathologically confirmed ML. The largest adrenal mass resected laparoscopically in our series was a 14-cm left adrenal ML in a 56-year-old male patient (Figure 1b).

Among 26 patients with CS receiving antihypertensive therapy preoperatively, medication dose or number decreased in 10 patients (38.5%), while 10 patients (38.5%) no longer required antihypertensive therapy postoperatively. All 29 patients with PA were receiving antihypertensive therapy preoperatively. After adrenalectomy, 10 patients (34.5%) discontinued spironolactone but continued other antihypertensives, whereas 16 patients (55.2%) required no antihypertensive therapy. Among 18 patients with Pheo, antihypertensive therapy decreased in 2 patients (11.1%), while 15 patients (83.3%) became normotensive after adrenalectomy. In hormonally inactive tumors, no change in antihypertensive therapy was observed in six patients receiving treatment preoperatively.

Among 94 patients with completed LA, perioperative outcomes are summarized in table 3. Tumor size was significantly larger in hormonally inactive tumors compared with hormonally active tumors ($p<0.001$). Within hormonally active tumors, tumor size differed significantly between groups, with larger tumors observed in Pheo patients ($p<0.001$). Operative time also differed significantly, being longest in Pheo cases ($p=0.001$). Aspirated fluid volume, hemoglobin decrease, and drain removal time were significantly higher in Pheo compared with other hormonally active tumors ($p=0.001$, $p=0.001$, and $p=0.007$, respectively). Tumor size showed a weak positive correlation with aspirated fluid volume ($r= 0.27$, $p=0.008$) andoperative time ($r=0.30$, $p=0.003$).

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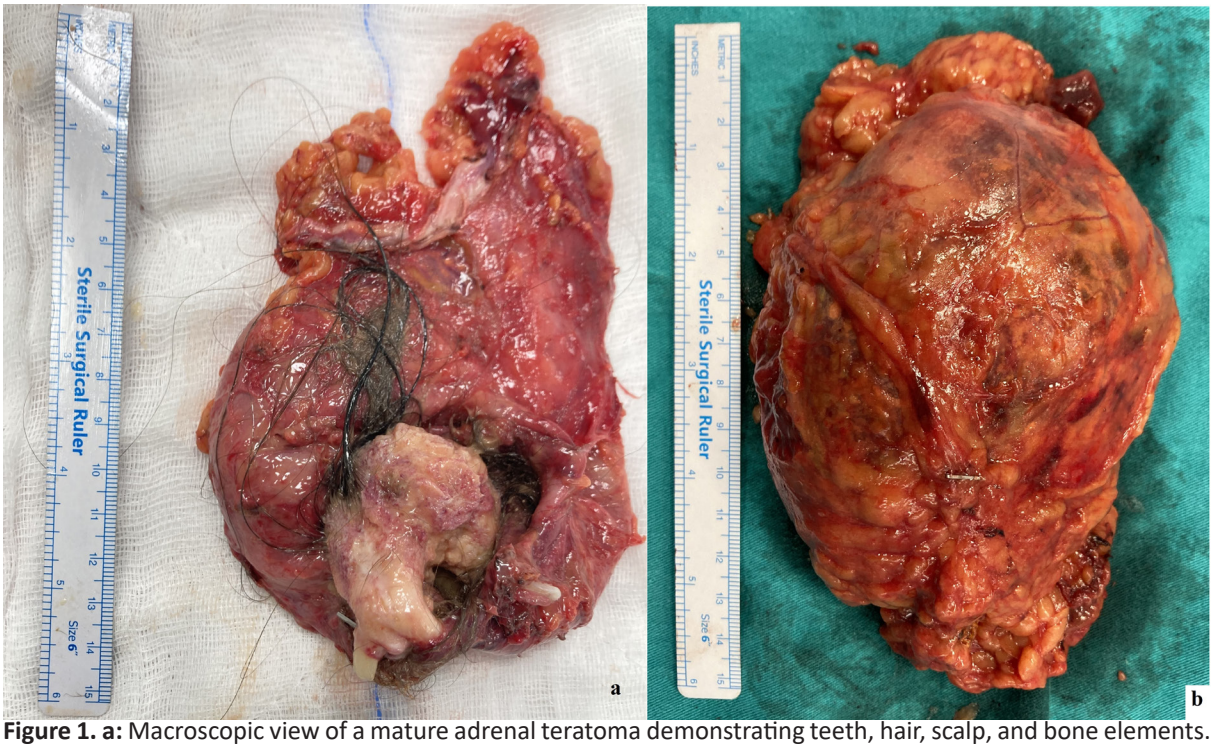

Figure 1. a: Macroscopic view of a mature adrenal teratoma demonstrating teeth, hair, scalp, and bone elements. **b:** Macroscopic view of a giant, 14-cm adrenal myelolipoma.

Patients with CS had significantly higher BMI values compared with other hormonally active tumors (36.2 ± 7.5 vs 29.9±5.2 kg/m², p<0.001).

Among LA patients, one patient in the CS group required erythrocyte transfusion (CD grade II). One patient with a preoperative diagnosis of CS was found to have ACC on final histopathology and died one month postoperatively due to pneumonia following a cerebrovascular event (CD grade V). One Pheo patient required transfusion (CD grade II). No other complications above CD grade I were observed.

Among the 15 patients with completed LA for suspected Pheo, pathology revealed benign adenoma in 2 patients, while 13 patients were confirmed as Pheo. PASS score ≥4 was observed in 7 of these 13 patients (54%) (Table 3).

The patient who required conversion to OA and the two patients who underwent primary OA were all histopathologically confirmed as Pheo, and PASS score ≥4 was observed in all three patients. One of these patients required erythrocyte transfusion and was classified as CD grade II.

Among patients who underwent surgery with a preoperative diagnosis of ACC, one of the two patients who underwent OA required erythrocyte transfusion (CD grade II). Tumor size, operative, perioperative, and BMI data of patients who underwent OA are summarized in Table 4.

Six cases who underwent OA were associated with significantly larger tumor size compared to 94-completed LA procedures (mean 10.2 ± 4.9 vs 4.5 ± 2.1 cm, p=0.002). Operative time was significantly longer in the OA group (mean 150.0 ± 22.4 vs 78.6 ± 18.9 minutes, p<0.001). Similarly, aspirated fluid volume was markedly higher in patients who underwent OA (mean 483.3 ± 153.2 vs 145.3 ± 63.8 mL, p<0.001). Median hemoglobin decrease was significantly higher in the OA group (1.6 [1-3.2] vs 3.1 [1.7-3.5] g/dL, p=0.003) The mean drain removal time was significantly longer in the OA group (4.67 ± 0.82 vs 2.84 ± 0.65 days, p=0.007) (Table 5).

DISCUSSION

Adrenal incidentalomas represent a heterogeneous group of lesions with varying functional status and pathological features.

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Table 3. Completed laparoscopic cases, n=94; Operative and perioperative outcomes according to adrenal pathology

	Preliminary Diagnosis (n)	Tumor size (cm) (mean ± SD)	Operative time (min) (mean ± SD)	Aspirated fluid (mL) (mean ± SD)	Hb decrease (g/dL) median [IQR]	Drain removal (day) (mean ± SD)	AP use (n)	CD Grade (n)	BMI (kg/m²) (mean ± SD)	PASS ≥4 n (%)
Hormonally active	CS (34)	3.79 ± 0.88	72.1 ± 11.5	114.9 ± 57.2	1.7 (1-3.1)	2.73 ± 0.63	7	2(1) 5(1)	36.2 ± 7.5	-
	PA (29)	2.34 ± 1.01	74.5 ± 17.6	129.1 ± 52.2	1.6 (1-2.2)	2.76 ± 0.69	3	1	29.9 ± 3.5	-
	Pheo (15)	4.00 ± 1.20	97.3 ± 25.4	220.0 ± 132.0	2.2 (1.6-3.2)	3.27 ± 0.46	0	2(1)	26.4 ± 4.5	7 (13/%54)
	-	p<0.001	p=0.001	p=0.001	p=0.001	p=0.007	-	-	p<0.001	
Hormonally inactive	ACC (1)	6	120	300	2.1	4	0	1	18.6	-
	Suspicious lesion (4)	6.75 ± 3.59	88.8 ± 22.5	200.0 ± 61	1.3 (1.1-1.7)	2.75 ± 0.50	1	1	34.6 ± 8.1	-
	Adrenal cyst (8)	6.38 ± 1.77	71.3 ± 10.9	118.8 ± 29.1	1.1 (1-1.4)	2.50 ± 0.53	1	1	30.0 ± 4.8	-
	ML (3)	9.67 ± 5.13	95.0 ± 22.9	183.3 ± 14.4	1.3 (1.1-1.5)	3.33 ± 0.58	0	1	31.3 ± 2.4	-
	-	p<0.001	-	-	-	-	-	-	-	-

Abbreviations: CS: Cushing syndrome, PA: primary aldosteronism, Pheo: pheochromocytoma, ACC: adrenocortical carcinoma, ML: myelolipoma, Hb: hemoglobin, AP: antiplatelet, CD: Clavien-Dindo grade, BMI: body mass index, PASS: pheochromocytoma of the adrenal gland scaled score, SD: standard deviation, IQR: Interquartile Range

Table 4. Open surgery cases, n=6; Operative and perioperative outcomes according to adrenal pathology

	POAn	COAn	Tumor size (cm) (mean ± SD)	Operative time (min) (mean ± SD)	Aspirated fluid (mL) (mean ± SD)	Hb decrease (g/dL) median [IQR]	Drain removal (day) (mean ± SD)	AP use (n)	CD Grade, (n)	BMI (kg/m²) (mean ± SD)	PASS ≥4 n (%)
Pheo	2	1	7.7 ± 5.0	140 ± 17.3	350 ± 86.6	2.5 (2-3.3)	4.33 ± 0.58	1	2 (1)	24.8 ± 3.0	3 (%100)
ACC	2	0	13.5 ± 6.4	165 ± 21.2	600 ± 141.4	3.2 (3-3.5)	5.50 ± 0.71	0	2 (1)	27.7 ± 10.6	
Adrenal cyst	0	1	15	130	750 ml	1.7	4	0	1	23.9	

Abbreviations: Pheo: pheochromocytoma, ACC: adrenocortical carcinoma, POA: primary open adrenalectomy, COA: conversion to open adrenalectomy, Hb: hemoglobin, AP: antiplatelet, CD: Clavien-Dindo grade, BMI: body mass index, PASS: pheochromocytoma of the adrenal gland scaled score

Table 5. Comparison of operative and perioperative outcomes between laparoscopic (n=94) and open (n=6) adrenalectomy

	n	Tumor size (cm) (mean ± SD)	Operative time (min) (mean ± SD)	Aspirated fluid (mL) (mean ± SD)	Hb decrease (g/dL) median [IQR]	Drain removal (day) (mean ± SD)
Completed Laparoscopic Cases	94	4.5 ± 2.1	78.6 ± 18.9	145.3 ± 63.8	1.6 [1-3.2]	2.84 ± 0.65
Open Surgery Cases	6	10.2 ± 4.9	150.0 ± 22.4	483.3 ± 153.2	3.1 [1.7-3.5]	4.67 ± 0.82
		p=0.002	p<0.001	p<0.001	p=0.003	p=0.007

Abbreviations: Hb: hemoglobin, SD: standard deviation, IQR: Interquartile Range

In the general population, functioning lesions such as CS, PA, and Pheo each account for approximately one-fifth of cases, whereas nonfunctioning incidentalomas constitute the largest subgroup (5). However, in adrenalectomy series, the distribution differs due to surgical selection. Final histopathological analyses typically demonstrate a predominance of benign cortical adenomas (30-50%), followed by Pheo (20-25%), while benign lesions such as ML and adrenal cysts account for a smaller

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proportion (~10%). ACC remains uncommon (2-10%) but is relatively overrepresented in surgical cohorts (6). In our series of 100 adrenalectomy patients, hormonally active lesions-particularly CS and PA-were the most common indications for surgery, whereas ML and ACC were among the least frequent pathologies, consistent with the literature.

The significant female predominance observed in our CS subgroup (85.3%) is consistent with previous reports demonstrating that cortisol-producing adrenal adenomas occur more frequently in women, with a reported female-to-male ratio ranging from 4:1 to 13:1 (7).

Patients with CS had significantly higher BMI values compared with those with other hormonally active adrenal tumors. This finding is consistent with the well-established metabolic effects of chronic hypercortisolism, as previous studies have shown that obesity and weight gain occur in approximately 70-85% of patients with CS (8).

In our surgical cohort, ACC was identified in 2.9% of patients with a preoperative diagnosis of CS and in 3.4% of patients with presumed PA. While the finding in the CS subgroup is clinically plausible due to the frequent association of ACC with cortisol excess (6), aldosterone-producing ACC is rare (6,9). Therefore, the relatively higher proportion observed in our primary aldosteronism subgroup likely reflects referral and surgical selection bias in a tertiary adrenal surgery cohort rather than the true prevalence.

In our series, the preoperative diagnosis of Pheo was confirmed histopathologically in 88.9% of cases, which is consistent with previously published series reporting high but not absolute diagnostic concordance (10). The discrepancy likely reflects the possibility of false-positive metanephrine results and imaging overlap with other benign adrenal lesions. PASS ≥4 was observed in 62.5% of pheochromocytomas in our series, including 7 of 13 laparoscopic cases and all 3 open cases. A systematic review and meta-analysis showed that while PASS ≥4 was present in 97% of malignant pheochromocytomas, it was also found in a substantial number of benign tumors, yielding a specificity of only 68% and a positive predictive value of 31% (11). Therefore, the relatively high rate of PASS ≥4 in our series may reflect case selection and the limited specificity of the score rather than a truly high malignant potential.

A hereditary syndrome was identified in 25% of Pheo patients in our cohort, including MEN2A, VHL, and NF1, which is consistent with the literature reporting a hereditary background in approximately one-third of Pheo/paraganglioma cases (12).

We also identified a rare case of mature adrenal teratoma in a 22-year-old woman, accounting for approximately 0.13% of adrenal tumors, which is consistent with its exceptionally rare occurrence in the literature. These tumors typically exhibit benign behavior and are associated with a favorable prognosis following complete surgical resection (13).

The largest adrenal mass resected laparoscopically in our series was a giant, 14-cm adrenal myelolipoma. This finding supports previous reports indicating that tumor size alone should not preclude a minimally invasive approach in selected benign lesions, although larger tumors are associated with increased operative complexity (1). The male-only distribution observed in our small ML subgroup is likely related to the limited number of cases rather than a true epidemiological difference (14).

When hormonally active tumors were analyzed, Pheo cases demonstrated larger tumor size, longer operative time, and increased perioperative morbidity, consistent with their higher vascularity and intraoperative hemodynamic fluctuations due to catecholamine release (15). The observed increase in blood loss in Pheo cases may be partially explained by the larger tumor size, as a significant correlation between tumor size and intraoperative blood loss was demonstrated.

Comparison between LA and OA demonstrated that LA was associated with shorter operative time, lower blood loss, and faster recovery (1,2). However, OA was more commonly performed in patients with larger tumors and higher-risk pathologies, reflecting appropriate surgical selection (3,4).

LA was initiated in 96 patients, and conversion to OA was required in 2 cases (2.1%), including one Pheo and one adrenal cyst. This conversion rate is consistent with published LA series, where the rates are generally below 5% (16,17). Conversion in Pheo reflects increased technical difficulty and hemodynamic instability.

According to current adrenal tumor guidelines, LA

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may be considered for adrenal tumors ≤6 cm with radiological suspicion of malignancy in the absence of local invasion, particularly depending on the surgeon's experience (2,6). In contrast, OA is recommended for tumors with a high risk of malignancy because of the increased risk of local recurrence and peritoneal dissemination when performed laparoscopically. Achieving negative surgical margins and avoiding tumor capsule rupture are crucial in such cases (2,4,18). In line with these recommendations, we completed the LA in one patient with a preoperative suspicion of ACC measuring 6 cm, whereas OA was performed in two patients with ACC measuring 9 cm and 18 cm, respectively.

In our PA cohort, 10 patients (34.5%) discontinued spironolactone therapy after adrenalectomy but continued other antihypertensive medications, while 16 patients (55.2%) no longer required any antihypertensive treatment. Previous studies have demonstrated that adrenalectomy in hormonally active adrenal tumors, particularly unilateral PA, significantly improves blood pressure control and reduces antihypertensive medication burden. Surgical treatment of unilateral aldosterone-producing adenomas has been reported to result in partial clinical success-defined as improved blood pressure control or reduced medication burden-in approximately 50-60% of patients, while normalization of blood pressure without antihypertensive medication occurs in about 27-37% of cases, yielding an overall clinical improvement rate approaching 90% according to Primary Aldosteronism Surgical Outcome (PASO)-based analyses (19,20).

In CS, hypertension is a common manifestation of cortisol excess and typically improves after successful adrenalectomy. Previous studies have reported normalization or significant improvement of hypertension in approximately 39-87% of patients following surgical treatment of cortisol-secreting adrenal tumors, although persistent hypertension may remain in a subset of patients due to long-standing vascular remodeling or coexisting essential hypertension (21). In our cohort of 26 patients with CS, antihypertensive medication requirements decreased in 10 patients (38.5%), while another 10 patients (38.5%) no longer required antihypertensive therapy after adrenalectomy. Overall, improvement or resolution of hypertension was observed in 77% of patients, which falls within the range reported in the literature.

In Pheo, removal of the catecholamine-secreting tumor usually results in rapid improvement in blood pressure control due to elimination of catecholamine excess. Surgical series have demonstrated normalization of blood pressure in approximately 70-80% of patients, while a proportion of patients may continue to require antihypertensive therapy due to long-standing vascular changes or coexisting essential hypertension (22). In our study, antihypertensive medication requirements decreased in 2 patients (11.1%), while 15 patients (83.3%) became normotensive and no longer required antihypertensive therapy following adrenalectomy. Overall, improvement or resolution of hypertension was observed in 94.4% of patients, consistent with previously reported outcomes.

Taken together, these findings demonstrate that adrenalectomy in hormonally active adrenal tumors leads to substantial improvement in blood pressure control and reduction in antihypertensive medication requirements. However, complete normalization of blood pressure may vary depending on tumor type, duration of hypertension, and underlying cardiovascular comorbidities. These results highlight the importance of timely diagnosis and appropriate surgical management in improving long-term cardiovascular outcomes.

This study has several limitations. First, its retrospective, single-center design may have introduced selection bias and may limit the generalizability of the findings. Second, the unequal group sizes, particularly the relatively small number of patients who underwent open adrenalectomy, reduced the statistical power of subgroup analyses. Finally, because the study reflects our institution's early experience with adrenalectomy, perioperative outcomes may have been influenced by learning-curve effects. Nevertheless, this study provides a comprehensive evaluation of perioperative, pathological, and follow-up outcomes in a relatively large single-center adrenalectomy cohort.

CONCLUSION

Adrenalectomy can be performed safely and effectively

with appropriate patient selection and multidisciplinary management. The choice of surgical approach should be individualized according to tumor characteristics, suspected pathology, and surgical expertise. In appropriately selected patients, LA offers advantages such as shorter operative time, reduced blood loss, and faster postoperative recovery. Our findings are consistent with the literature. Further prospective studies with larger cohorts are needed to confirm these findings.

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