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# Transient Decline and Recovery of Renal Function Following Unilateral Adrenalectomy for Primary Aldosteronism

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## ABSTRACT

**Introduction:** A transient decline in the estimated glomerular filtration rate (eGFR) is frequently observed following adrenalectomy for primary aldosteronism (PA), reflecting the unmasking of aldosterone-mediated renal injury previously concealed by glomerular hyperfiltration. The temporal pattern of this decline and its associated preoperative predictors remain poorly characterized.

**Methods:** We retrospectively analyzed 38 consecutive patients with confirmed PA who underwent unilateral adrenalectomy. Serial changes in eGFR and serum creatinine were evaluated using the Friedman test with Durbin-Conover post-hoc comparisons. Correlations between postoperative renal function and preoperative clinical and biochemical variables were assessed using Spearman's rank correlation and the Mann-Whitney U test.

**Results:** A statistically significant overall difference in eGFR was observed during the first three postoperative months ($\chi^2$: 9.04, p=0.03), driven by a significant decline at month 3 relative to both the preoperative baseline (p=0.03) and postoperative day 1 (p=0.003). When the 6-month measurement was incorporated, the overall difference was no longer significant ($\chi^2$: 6.52, p=0.16). The eGFR decline at month 3 was significantly more pronounced in patients with spontaneous hypokalemia (-22.2% vs. -4.76%, p=0.04). Month 6 eGFR was negatively correlated with baseline aldosterone concentration, aldosterone-to-renin ratio, and age, and was positively correlated with preoperative eGFR and systolic blood pressure.

**Conclusion:** Adrenalectomy for PA was associated with a transient decline in eGFR at postoperative month 3, with values approaching baseline by month 6, and with no evidence of persistent deterioration. Spontaneous hypokalemia and a higher aldosterone burden identify patients at greater risk of postoperative decline in renal function.

**Keywords:** Primary aldosteronism, adrenalectomy, glomerular filtration rate, renal function, hypokalemia

## Introduction

Primary aldosteronism (PA) is a common cause of secondary hypertension. Conn's syndrome is characterized by autonomous aldosterone overproduction that is independent of renin-angiotensin regulation. The main causes of PA include aldosterone-producing adenomas and bilateral adrenal hyperplasia, while rarer forms are associated with genetic mutations. Among these, an aldosterone-producing adenoma is the most common and is generally located on one side of the adrenal gland. Unilateral adrenalectomy is the treatment of choice for patients with lateralized PA and represents the only potentially curative intervention (1).

Chronic aldosterone overproduction exerts direct nephrotoxic effects independent of its hemodynamic actions (which include glomerular hypertension); these effects include tubular injury and progressive renal fibrosis. Consequently, individuals with PA are more prone to chronic kidney disease (CKD) and have an elevated risk of worsening kidney function compared to those with essential hypertension, even when their blood pressure levels are similar (2,3). Notably, the true extent of aldosterone-mediated renal damage may remain underestimated in the preoperative setting, as concurrent hemodynamic adaptations to chronic aldosterone excess, most importantly, glomerular hyperfiltration, can partially mask underlying renal dysfunction, rendering standard measures of kidney function deceptively reassuring (3).

Despite the growing body of evidence characterizing postoperative decline in estimated glomerular filtration rate (eGFR) in PA, data from centers where renal function is preserved or improved after adrenalectomy remain limited. Furthermore, most published studies originate from East Asian cohorts, and population-specific differences in PA phenotype, duration of disease at diagnosis, and preoperative management may substantially influence postoperative renal outcomes. However, whether these findings are generalizable to other ethnic groups, including

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Turkish patients, remains unclear. Therefore, the present study aimed to evaluate changes in eGFR following unilateral adrenalectomy for PA and to identify preoperative clinical and biochemical factors associated with postoperative renal function in a Turkish institutional cohort.

## Methods

### Study Population

We retrospectively reviewed the medical records of patients with PA who underwent unilateral adrenalectomy between September 2020 and February 2026. Initially, 46 patients were enrolled in the study. After excluding patients with autonomous cortisol co-secretion and those with insufficient clinical data, the final study population comprised 38 patients. The study was conducted in accordance with the ethical standards of the 1975 Declaration of Helsinki and was approved by the Local Ethics Committee of University of Health Sciences Türkiye, Başakşehir Çam and Sakura City Hospital (decision number: 48, date: 21.01.2026). The ethics committee waived the requirement for informed consent due to the retrospective nature of the study and the use of anonymized data.

### Diagnosis PA

Before screening for PA, medications known to interfere with the renin-angiotensin-aldosterone system were either discontinued for the appropriate wash-out period or switched to non-interfering alternatives. Serum potassium levels were normalized in all patients via replacement therapy before blood sampling to prevent false-negative results. After ensuring adequate sodium intake for several days, participants were screened using morning, seated measurements of serum or plasma aldosterone and plasma renin activity (PRA). A positive screening result was defined as an aldosterone level ≥10 ng/dL (by immunoassay), a PRA ≤1 ng/mL/h, and an aldosterone-to-PRA ratio >20 (4). Confirmatory testing was omitted in patients with overt biochemical evidence of autonomous aldosterone production, defined as a PRA below 0.2 ng/mL/h in conjunction with a plasma aldosterone concentration exceeding 20 ng/dL. In the remaining patients with a positive screening result who did not fulfill these criteria, intravenous saline infusion test was performed to establish the diagnosis of PA (4). Adrenal vein sampling (AVS) was performed in patients who did not meet the criteria for a high pretest probability of unilateral aldosterone-producing adenoma. These included patients aged 35 years or older and those whose computed tomography (CT) demonstrated normal adrenal morphology, bilateral adrenal abnormalities, or non-specific findings such as lesions of 1.0 cm or smaller or bilateral gland thickening (4). For patients in whom bilateral adrenal venous sampling was unsuccessful, the decision for surgical lateralization was based on a combination of CT findings and the contralateral suppression index, calculated as the ratio of the aldosterone-to-cortisol ratio in the successfully cannulated adrenal vein relative to that in the inferior vena cava sample (5). A markedly suppressed ratio on the successfully cannulated side, together with a unilateral adenoma identified on CT, was considered indicative of contralateral aldosterone hypersecretion and supported lateralization to the contralateral non-cannulated side.

Tumor localization was confirmed in all participants using preoperative cross-sectional imaging, including abdominal CT or magnetic resonance imaging (MRI).

Histopathological examination of the surgical specimens from all 38 patients confirmed adrenocortical adenoma.

### Measurement of Clinical Data

Collected clinical data included age, sex, body mass index (BMI) (kg/m$^2$), duration of hypertension, preoperative systolic and diastolic blood pressure, number of antihypertensive medications (excluding mineralocorticoid receptor antagonists), and preoperative hypokalemia. All patients with preoperative hypokalemia were rendered normokalemic before surgery. Smoking, diabetes mellitus, and hyperlipidemia were additionally recorded as potential covariates known to influence renal function. The eGFR was calculated using the CKD-EPI 2021 creatinine-based equation. Plasma aldosterone concentration was measured by radioimmunoassay. Postoperative eGFR was assessed on day 1 and at 1, 3, and 6 months following adrenalectomy. The percentage change in eGFR from baseline was calculated as [(postoperative eGFR-preoperative eGFR)/preoperative eGFR] × 100, with negative values indicating a decline and positive values indicating an improvement relative to the preoperative baseline. Of the 38 patients who underwent adrenalectomy, 29 (76.3%) attended the postoperative month 3 visit and were included in serial eGFR analyses at that time point. The remaining 9 patients did not present for scheduled follow-up and were therefore excluded from the month-3 analyses.

Biochemical and blood pressure outcomes were classified according to the Primary Aldosteronism Surgical Outcome consensus criteria. Complete biochemical success was defined as the correction of hypokalemia (if present preoperatively) and normalization of the aldosterone-to-renin ratio based on local laboratory reference intervals. Partial biochemical success was defined as correction of hypokalemia, with a persistently elevated aldosterone-to-renin ratio and a ≥50% reduction in baseline plasma aldosterone concentration relative to preoperative values. Absent biochemical success was defined as persistent hypokalemia or a persistently elevated aldosterone-to-renin ratio without a meaningful reduction in aldosterone concentration (6).

Postoperative blood pressure response was classified into three categories: complete clinical response, defined as a blood pressure below 140/90 mmHg without any antihypertensive medication; partial clinical response, defined as a reduction in the number or dose of antihypertensive agents with a blood pressure remaining at or above 140/90 mmHg; and absent clinical response, defined as a blood pressure of 140/90 mmHg or higher with an unchanged or increased antihypertensive medication requirement (6).

### Statistical Analysis

Continuous variables were tested for normality using the Shapiro-Wilk test and expressed as median [interquartile range (IQR)] or mean ± standard deviation, as appropriate. Categorical variables are reported as frequencies and percentages. Serial changes in eGFR and serum creatinine levels across postoperative time points were evaluated using the Friedman test. Two separate analyses were performed: the first included four time points (preoperative, postoperative day 1, and postoperative months 1 and 3), and the second included the 6-month time point. Post-hoc pairwise comparisons were conducted using the Durbin-Conover test, which is specifically designed to follow the Friedman test and incorporates an internal adjustment for multiple comparisons. Correlations between clinical and biochemical variables were assessed using Spearman's rank correlation coefficient. Differences between categorical groups were evaluated using the Mann-Whitney U test. A two-sided p value <0.05 was considered statistically significant for all analyses. Statistical analyses were performed using Jamovi (version 2.6).

## Results

A total of 38 participants were included in this study. Of these, 25 (65.8%) were female and 13 (34.2%) were male. The median age at diagnosis was 48.5 years (IQR: 44.5-56.0). The median BMI was 29.9 (IQR: 26.4-32.6). The median duration of hypertension was 10.0 years (IQR: 4.75-15.0). The median number of antihypertensive medications was 3 (IQR: 2-3). The baseline systolic and diastolic blood pressures were 146 mmHg (IQR: 136–160) and 87 mmHg (IQR: 80.3-92.0), respectively. The median baseline heart rate was 77 bpm (IQR: 70.8-86.3 bpm). Spontaneous hypokalemia was observed in 20 patients (52.6%). The median total clinical follow-up duration was 35.5 months (IQR: 19.8-50.3). The baseline clinical characteristics of the study cohort are presented in Table 1.

AVS was performed in 27 patients; successful bilateral cannulation was achieved in 13 patients, yielding a median lateralization index of 14.0 (IQR: 2.0-43.0). Given the limited number of patients with complete AVS data, the lateralization index was not included as a study variable in further analyses.

Of the 38 patients, 24 (63.2%) underwent laparoscopic adrenalectomy and 14 (36.8%) underwent robotic adrenalectomy. No patient required a postoperative blood transfusion. Detailed perioperative renal function data and 3-month biochemical outcomes are shown in Table 2.

The Friedman test applied to four time points (preoperative, postoperative day 1, and postoperative months 1 and 3) revealed a statistically significant overall difference in eGFR ($\chi^2$: 9.04, df: 3, p=0.03). Post-hoc pairwise comparisons using the Durbin-Conover test demonstrated that eGFR at postoperative month 3 was significantly lower than both the preoperative baseline (p=0.03) and the postoperative day 1 value (p=0.003). No significant difference was observed between the preoperative and postoperative day 1 eGFR (p=0.35), preoperative and postoperative month 1 eGFR (p=0.43), or postoperative day 1 and month 1 eGFR (p=0.09).

When the 6-month eGFR measurement was incorporated into the analysis, the overall Friedman test was no longer statistically significant ($\chi^2$: 6.52, df: 4, p=0.16). Accordingly, no individual pairwise comparisons reached statistical significance at this stage, including the comparisons between preoperative and postoperative month 3 eGFR (p=0.06), and between postoperative day 1 and month 3 eGFR (p=0.02). Postoperative changes in eGFR are shown in Figure 1.

Serum creatinine levels did not differ significantly across the four time points by the Friedman test ($\chi^2$: 5.28, df: 3, p=0.153). However, post-hoc Durbin-Conover pairwise comparisons revealed that serum creatinine at postoperative month 3 was significantly higher than at postoperative day 1 (p=0.03), mirroring the pattern observed for eGFR. No significant difference was detected in any other pairwise comparison of serum creatinine (all p>0.05).

When the 6-month creatinine measurement was incorporated into the analysis, the overall Friedman test result was no longer statistically significant ($\chi^2$: 5.02, df: 4, p=0.28); no individual pairwise comparison reached statistical significance, including the comparison between postoperative day 1 and month 3 creatinine levels (p=0.05). These findings are consistent with the eGFR results and further support the conclusion that the transient rise in serum creatinine observed at postoperative month 3 resolved by month 6, with no sustained impairment of renal function following adrenalectomy. Postoperative changes in serum creatinine levels are shown in Figure 2.

The median percentage change in eGFR from baseline to postoperative month 3 was -6.0% (IQR: -15.0 to +1.0). No significant correlations were observed between the 3-month percentage change in eGFR and any of

**Table 1. Baseline clinical characteristics of the study cohort (n=38)**

| Variable | Value |
|---|---|
| Demographics | |
| Sex: female, n (%) | 25 (65.8%) |
| Sex: male, n (%) | 13 (34.2%) |
| Age at diagnosis (years) | 48.5 [44.5–56.0] |
| Body mass index (kg/m$^2$) | 29.9 [26.4–32.6] |
| Clinical follow-up duration (months) | 35.5 [19.8–50.3] |
| Hypertension and medications | |
| Duration of hypertension (years) | 10.0 [4.75–15.0] |
| Antihypertensive medications<br>ACEi/ARB<br>Diuretics<br>Dihydropyridine CCB<br>Non-dihydropyridine CCB<br>Beta-blocker<br>MRA | 24 (64.9%)<br>13 (35.1%)<br>24 (64.9%)<br>12 (32.4%)<br>11 (29.7%)<br>3 (8.1%) |
| Spontaneous hypokalemia, n (%) | 20 (52.6%) |
| Diabetes mellitus, n (%) | 8 (21.1%) |
| Dyslipidemia, n (%) | 5 (13.2%) |
| Smoking | 8 (21.1%) |
| Baseline hemodynamics | |
| Systolic BP (mmHg) | 146 [136–160] |
| Diastolic BP (mmHg) | 87 [80.3–92.0] |
| Heart rate (bpm) | 77 [70.8–86.3] |
| Aldosteron (ng/dL) | 50.0 [29.5–68.2] |
| PRA (ng/mL/h) | 0.33 [0.28–0.60]. |
| ARR | 99.2 [54.4–195.0]. |

Data expressed as median [interquartile range] or n (%). ACEi: Angiotensin-converting enzyme inhibitor, ARB: Angiotensin II receptor blocker, CCB: Calcium channel blocker, MRA: Mineralocorticoid receptor antagonist, BP: Blood pressure, bpm: Beats per minute, PRA: Plasma renin activity, ARR: Aldosterone-to-renin ratio, IQR: Interquartile range

**Table 2. Perioperative renal function and postoperative outcomes**

| Variable | n | Median (IQR) |
|---|---|---|
| Renal function-eGFR (mL/min/1.73 $m^2$) | | |
| Preoperative | 38 | 78.0 (67.3-106.0) |
| Postoperative day 1 | 38 | 82.5 (65.3-106.0) |
| Postoperative month 1 | 29 | 83.0 (66.0-103.0) |
| Postoperative month 3 | 29 | 77.0 (60.0-98.0) |
| Postoperative month 6 | 35 | 86.0 (62.5-102.0) |
| Renal function-serum creatinine (mg/dL) | | |
| Preoperative | 38 | 0.860 (0.660-1.000) |
| Postoperative day 1 | 38 | 0.840 (0.652-1.080) |
| Postoperative month 1 | 29 | 0.890 (0.715-1.080) |
| Postoperative month 3 | 29 | 0.940 (0.735-1.190) |
| Postoperative month 6 | 35 | 0.920 (0.735-1.090) |
| 3-month postoperative biochemical and clinical parameters | | |
| Aldosterone (ng/dL) | 29 | 9.43 (5.15-19.3) |
| PRA (ng/mL/h) | 29 | 1.03 (0.700-2.59) |
| ARR | 29 | 9.70 (3.46-33.5) |
| Systolic BP (mmHg) | 29 | 130 (120-145) |
| Diastolic BP (mmHg) | 29 | 80 (70-90) |
| Serum potassium (mmol/L) | 29 | 4.80 (4.69-5.04) |

IQR: Interquartile range, eGFR: Estimated glomerular filtration rate, PRA: Plasma renin activity, ARR: Aldosterone-to-renin ratio, BP: Blood pressure

the following: age at diagnosis, sex, baseline eGFR, baseline aldosterone concentration, PRA, or aldosterone-to-renin ratio (all p>0.05). It was significantly greater in patients with spontaneous hypokalemia than in those without spontaneous hypokalemia [-22.2% (IQR: -33.5 to -10.7) vs -4.76% (IQR: -11.95 to +5.61), p=0.04].

Although eGFR did not differ significantly from baseline values by postoperative month 6, the 6-month eGFR was negatively correlated with baseline aldosterone concentration (r: -0.52, p=0.003) and aldosterone-to-renin ratio (r: -0.39, p=0.02), and positively correlated with preoperative eGFR (r: 0.51, p=0.002). Additionally, the 6-month eGFR was positively correlated with baseline systolic blood pressure (r: 0.37, p=0.02) and negatively correlated with age at diagnosis (r: -0.5, p=0.002). The results are shown in Table 3.

At the 3-month follow-up, 14 patients (36.8%) achieved a complete blood-pressure response. A partial blood pressure response was observed in 22 (57.9%) patients. Two patients (5.2%) showed no blood pressure response. Preoperatively, spontaneous hypokalemia was present in 20 (52.6%) patients. Following adrenalectomy, serum potassium levels normalized in all patients without potassium supplementation. Biochemical outcomes were assessed at postoperative month 3 in 29 patients; complete biochemical response was achieved in 20 (69.0%), partial biochemical response in 7 (24.1%), and no biochemical response in 2 (6.9%). A repeated-measures analysis of variance was performed to compare patients who achieved complete biochemical remission with those who did not and to assess whether eGFR and creatinine differed according to biochemical remission status. For eGFR, no significant between-subjects effect of remission status was observed in either the four-time-point (preoperative, day 1, month 1, month 3; p=0.62) or

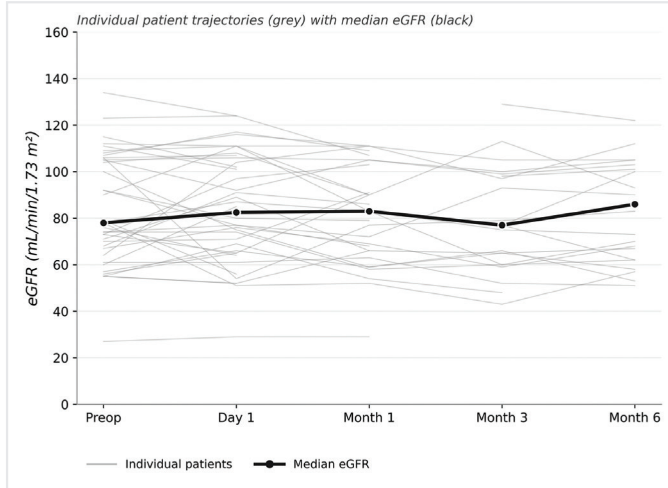


**Figure 1.** Individual patient trajectories of estimated glomerular filtration rate (eGFR) following unilateral adrenalectomy for primary aldosteronism. Grey lines represent individual patients; the black line represents the group median. eGFR is expressed in mL/min/1.73 $m^2$

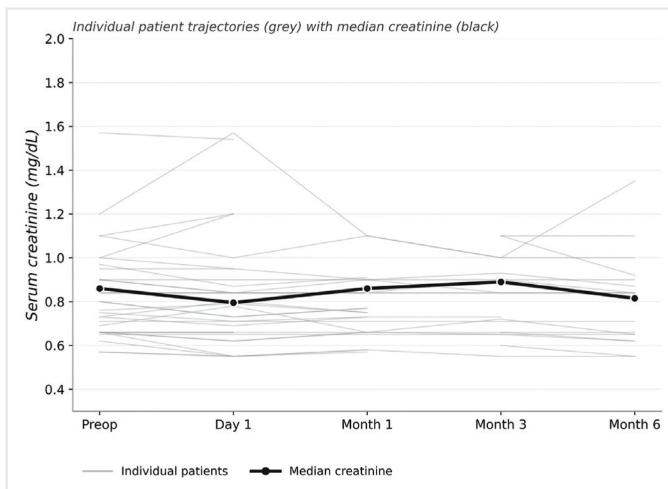


**Figure 2.** Individual patient trajectories of serum creatinine following unilateral adrenalectomy for primary aldosteronism. Grey lines represent individual patients; the black line represents the group median. Serum creatinine is expressed in mg/dL

**Table 3. Predictors of postoperative eGFR at 6 month**

| Variable | eGFR 6 month | |
|---|---|---|
| | Spearman's r | p value |
| Age at diagnosis (years) | -0.5 | 0.002 |
| BMI (kg/$m^2$) | 0.14 | 0.41 |
| Systolic BP (mmHg) | 0.37 | 0.02 |
| Preoperative eGFR | 0.51 | 0.002 |
| Baseline aldosterone (ng/dL) | -0.52 | 0.003 |
| Baseline PRA (ng/mL/h) | 0.1 | 0.57 |
| Baseline ARR | -0.39 | 0.02 |

eGFR: Estimated glomerular filtration rate, BMI: Body mass index, BP: Blood pressure, PRA: PPlasma renin activity, ARR: Adosterone-to-renin ratio the five-time-point (preoperative, day 1, month 1, month 3, month 6; p=0.36) comparison. Similarly, no significant between-subjects effect of remission status on serum creatinine was observed in either the four-time-point (p=0.24) or the five-time-point (p=0.24) comparison. Detailed results are presented in Table 4.

## Discussion

In the present study, unilateral adrenalectomy for PA was associated with a transient decline in eGFR at postoperative month 3, with values approaching preoperative levels by month 6, and with no evidence of persistent deterioration in renal function. A parallel pattern was observed for serum creatinine, which showed a transient increase at month 3 that was no longer evident by month 6. The magnitude of postoperative eGFR at month 6 was significantly correlated with the baseline aldosterone concentration, aldosterone-to-renin ratio, preoperative eGFR, baseline systolic blood pressure, and age at diagnosis, highlighting the role of the preoperative disease burden in determining renal outcomes. With respect to clinical outcomes, complete blood pressure response was achieved in 36.9% of patients and complete biochemical remission was achieved in 69% of patients, with serum potassium normalizing in all patients with preoperative hypokalemia.

In PA, excess aldosterone alters kidney hemodynamics and structure. After adrenalectomy, many patients experience a decrease in eGFR. Across studies, this is consistently interpreted as unmasking pre-existing renal damage rather than as new surgical kidney injury. Excess aldosterone promotes sodium retention, volume expansion, and glomerular hypertension through afferent arteriolar vasoconstriction, resulting in sustained glomerular hyperfiltration (7,8). Hyperfiltration and glomerular hypertension can mask a true reduction in kidney function preoperatively by maintaining normal or elevated eGFR despite structural damage (3,7). Long-term aldosterone exposure causes renal fibrosis, glomerular sclerosis, and microvascular lesions, leading to CKD even when eGFR appears normal (8-10). In this study, the transient decline in eGFR observed at postoperative month 3, with values approaching preoperative levels by month 6, is consistent with the well-established pathophysiological consequences of aldosterone excess on renal hemodynamics. The nadir observed at month 3 is consistent with the timeline reported in the literature because the renin-angiotensin-aldosterone system requires weeks to months to re-equilibrate after abrupt withdrawal of autonomous aldosterone secretion, and tubular adaptation to the altered hemodynamic milieu is similarly gradual. Notably, the absence of a persistent eGFR decline by month 6 distinguishes our cohort from series reporting sustained postoperative renal function impairment. It may reflect a relatively small degree of irreversible structural renal damage induced by aldosterone in our patients at the time of surgery. This interpretation is supported by the relatively preserved preoperative eGFR and potassium levels in our cohort, compared with those in previously published series, suggesting that surgical intervention was undertaken at an earlier stage of aldosterone-mediated renal injury, before the development of irreversible fibrotic changes.

**Table 4. eGFR and serum creatinine according to biochemical remission status**

| Variable | No remission median (IQR) | Complete remission median (IQR) |
|---|---|---|
| eGFR (mL/min/1.73 m$^2$) | | |
| Preoperative | 89.0 (69.5–105.0) | 92.0 (72.0–107.5) |
| Postoperative day 1 | 89.0 (76.2–98.8) | 97.0 (68.5–111.0) |
| Postoperative month 1 | 83.0 (69.0–90.0) | 86.5 (66.5–106.0) |
| Postoperative month 3 | 75.0 (62.5–96.0) | 77.0 (62.5–88.0) |
| Postoperative month 6 | 90.0 (73.0–103.0) | 80.5 (62.2–103.0) |
| Serum creatinine (mg/dL) | | |
| Preoperative | 0.775 (0.665–0.937) | 0.830 (0.635–0.975) |
| Postoperative day 1 | 0.795 (0.683–0.885) | 0.770 (0.615–1.150) |
| Postoperative month 1 | 0.890 (0.715–1.080) | 0.905 (0.747–1.050) |
| Postoperative month 3 | 0.970 (0.720–1.040) | 0.915 (0.775–1.230) |
| Postoperative month 6 | 0.810 (0.715–0.985) | 0.930 (0.730–1.140) |

No statistically significant difference in eGFR or creatinine was observed between groups at any time point (all p>0.05). IQR: Interquartile range, eGFR: Estimated glomerular filtration rate

In the present study, the decline in eGFR at postoperative month 3 was significantly more pronounced in patients with spontaneous hypokalemia compared with those without spontaneous hypokalemia (p=0.04). These observations are consistent with those of Lu et al. (11), who identified hypokalemia as an independent predictor of postoperative renal function impairment in a large Taiwanese cohort of 328 patients, and with Tomiie et al. (7), who demonstrated that lower preoperative serum potassium concentrations were independently associated with a clinically significant drop in GFR category after adrenalectomy. These findings suggest that spontaneous hypokalemia, as a marker of severe and prolonged aldosterone excess, identifies patients with PA who are at higher risk of postoperative renal function decline and may serve as a preoperative indicator to guide patient counseling and nephrological follow-up.

Among the preoperative variables examined, baseline aldosterone concentration and aldosterone-to-renin ratio were significantly and negatively correlated with eGFR at postoperative month 6 (r: -0.52, p=0.003, and r: -0.39, p=0.02, respectively), indicating that patients with a greater degree of autonomous aldosterone excess had lower absolute renal function at 6 months postoperatively. This finding is consistent with the concept that higher aldosterone levels reflect more severe and potentially longer-standing mineralocorticoid-mediated renal injury, including glomerulosclerosis, tubular atrophy, and interstitial fibrosis, all of which reduce the kidney's functional capacity in the postoperative period (3,12,13). The positive correlation between preoperative eGFR and 6-month eGFR (r: 0.51, p=0.02) was expected and reflected the strong tracking of renal function over time; patients with better baseline renal function tended to maintain higher postoperative eGFR values. Collectively, these findings suggest that preoperative aldosterone levels are key determinants of postoperative renal function and that patients with overt biochemical hyperaldosteronism may warrant closer nephrological surveillance postoperatively.

The negative correlation between age at diagnosis and month 6 eGFR (r: -0.50, p=0.002) likely reflects the progressive age-related decline in the renal functional reserve, which limits the kidney's capacity to maintain adequate filtration following the resolution of aldosterone-driven hyperfiltration. In older patients, the nephron mass available for functional recovery is inherently reduced, and the superimposed structural damage from chronic aldosterone excess and hypertension may compound this age-related vulnerability, resulting in lower absolute eGFR values at 6 months postoperatively compared with younger patients. Multiple cohort studies and meta-analyses have identified older age as a significant predictor of long-term eGFR decline or postoperative CKD after adrenalectomy for PA (5,8,14). The observed positive correlation between baseline systolic blood pressure and eGFR at six months (r: 0.37, p=0.02) may reflect glomerular hyperfiltration. However, this interpretation should be regarded as hypothesis-generating rather than a confirmed causal mechanism, given the retrospective, correlational design of this study. Patients with elevated preoperative systolic blood pressure may exhibit greater pressure-related glomerular hyperfiltration, which could contribute to a higher preoperative eGFR and, consequently, to a higher absolute eGFR at six months postoperatively, even after partial resolution of the hyperfiltration state. Further studies incorporating direct measures of glomerular hemodynamics would be needed to confirm this association.

Regarding clinical and biochemical outcomes, 69% of patients achieved complete biochemical remission at the 3-month follow-up. This result is consistent with remission rates reported in the literature for unilateral adrenalectomy in PA, which typically range from 60% to 99%, depending on how remission is defined and the duration of follow-up (15,16). Complete clinical blood pressure response, defined as normalization of blood pressure without antihypertensive medication, was observed in 36.9% of patients. By comparison, the majority (57.9%) achieved a partial response, characterized by a reduction in antihypertensive medication burden. The two patients who did not achieve a biochemical response also showed no clinical blood pressure response, suggesting persistent autonomous aldosterone secretion as the underlying mechanism of treatment failure in these cases. Across cohorts and meta-analyses, 20-30% of PA patients become normotensive without drugs (6,17,18); about half have improved BP and/or lower medication needs (6,18,19); and roughly 10-20% show little clinical BP benefit, despite very high biochemical cure rates (6,20). Our findings are in line with those reported in large multicenter series. The prevalence of a partial hypertensive response post-adrenalectomy may indicate that the underlying essential hypertension coexists with PA, potentially limiting the degree of blood pressure resolution following surgical cure. Remarkably, serum potassium levels returned to normal in all 20 patients who experienced spontaneous hypokalemia before surgery without requiring supplementation. This outcome confirms the complete reversal of the condition of mineralocorticoid excess and highlights one of the most consistent and reproducible advantages of surgical intervention in PA.

### Study Limitations

Several limitations of the present study warrant acknowledgment. First, the retrospective single-center design limits the generalizability of the findings to other institutional settings and patient populations. Second, the relatively small sample size restricts the statistical power of correlation analyses and precludes robust multivariable regression modeling for identifying independent predictors of postoperative renal function. This limitation was particularly evident in the subgroup comparison between patients with and without complete biochemical remission, in which no significant difference in postoperative eGFR or change in creatinine was detected. However, the limited number of patients available for this comparison substantially restricted the statistical power to detect a clinically meaningful difference between groups; therefore, this negative finding should be interpreted with caution. Furthermore, eGFR data at postoperative month 3 were available for only 29 of 38 patients (76.3%), as the remaining 9 patients did not attend their scheduled follow-up visit. However, no systematic clinical difference was apparent between those with available data and those without; the possibility of informative loss to follow-up cannot be entirely excluded. Third, AVS was performed in 27 patients; however, successful bilateral cannulation was achieved in only 13 patients, and the lateralization index was therefore not included as a primary study variable. Fourth, the absence of long-term follow-up beyond 6 months precludes conclusions regarding the durability of renal function recovery and the potential long-term renoprotective benefit of adrenalectomy. Fifth, preoperative serum potassium data were recorded after potassium supplementation in most patients, precluding a reliable assessment of the true nadir potassium concentration. This variable is a stronger predictor of postoperative eGFR decline than the immediate preoperative value.

## Conclusion

Unilateral adrenalectomy for PA was associated with a transient decline in eGFR at postoperative month 3; values approached baseline by month 6, and there was no evidence of persistent deterioration. This decline was more significant in patients with spontaneous hypokalemia, and the postoperative eGFR was associated with initial aldosterone levels, pre-surgery kidney function, and patient age. Complete biochemical remission was achieved in 69.0% of patients, and potassium levels normalized in all hypokalemic patients following surgery. These findings support the renal safety of adrenalectomy in appropriately selected patients with PA and highlight spontaneous hypokalemia as a clinically useful preoperative indicator of postoperative renal vulnerability. Early diagnosis and treatment are essential to optimizing long-term renal and cardiovascular outcomes.

### Ethics

**Ethics Committee Approval:** The study was conducted in accordance with the ethical standards of the 1975 Declaration of Helsinki and was approved by the Local Ethics Committee of University of Health Sciences Türkiye, Başakşehir Çam and Sakura City Hospital (decision number: 48, date: 21.01.2026).

**Informed Consent:** The ethics committee waived the requirement for informed consent due to the retrospective nature of the study and the use of anonymized data.

### Footnotes

**Authorship Contributions:** Surgical and Medical Practices - A.P., A.Ç.; Concept - Ş.B., M.N., E.H.; Design - Ş.B., M.N., E.H.; Data Collection

or Processing - Ş.B., A.P., A.Ç.; Analysis or Interpretation - Ş.B., M.N.; Literature Search - Ş.B., A.P., A.Ç.; Writing - Ş.B., A.P., E.H.

**Conflict of Interest:** No conflict of interest was declared by the authors.

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## References

1. Vaidya A, Mulatero P, Baudrand R, Adler GK. The expanding spectrum of primary aldosteronism: implications for diagnosis, pathogenesis, and treatment. Endocr Rev. 2018; 39: 1057-88.
2. Rossi GP, Bernini G, Desideri G, Fabris B, Ferri C, Giacchetti G, et al. Renal damage in primary aldosteronism: results of the PAPY Study. Hypertension. 2006; 48: 232-8.
3. Monticone S, Sconfienza E, D'Ascenzo F, Buffolo F, Satoh F, Sechi LA, et al. Renal damage in primary aldosteronism: a systematic review and meta-analysis. J Hypertens. 2020; 38: 3-12.
4. Adler GK, Stowasser M, Correa RR, Khan N, Kline G, McGowan MJ, et al. Primary aldosteronism: an Endocrine Society Clinical Practice Guideline. J Clin Endocrinol Metab. 2025; 110: 2453-95. Erratum in: J Clin Endocrinol Metab.; 110: e3933-4.
5. Yang YS, Lee SH, Kim JH, Yoo JH, Lee JH, Lee SY, et al. Contralateral suppression at adrenal venous sampling is associated with renal impairment following adrenalectomy for unilateral primary aldosteronism. Endocrinol Metab (Seoul). 2021; 36: 875-84.
6. Williams TA, Lenders JWM, Mulatero P, Burrello J, Rottenkolber M, Adolf C, et al. Outcomes after adrenalectomy for unilateral primary aldosteronism: an international consensus on outcome measures and analysis of remission rates in an international cohort. Lancet Diabetes Endocrinol. 2017; 5: 689-99.
7. Tomiie Y, Hibi Y, Nobe R, Yokoi K, Koshima Y, Ogawa K, et al. Changes in kidney function after adrenalectomy in patients with primary aldosteronism. Fujita Med J. 2025; 11: 28-35.
8. Chen JY, Huang KH, Lin YH, Chueh JS, Wang HY, Wu VC. Association of dip in eGFR with clinical outcomes in unilateral primary aldosteronism patients after adrenalectomy. J Clin Endocrinol Metab. 2024; 109: e965-74.
9. Iwakura Y, Morimoto R, Kudo M, Ono Y, Takase K, Seiji K, et al. Predictors of decreasing glomerular filtration rate and prevalence of chronic kidney disease after treatment of primary aldosteronism: renal outcome of 213 cases. J Clin Endocrinol Metab. 2014; 99: 1593-8.
10. Yoon JH, Chung HS, Hong AR, Kim HK, Kang HC, Kim MS, et al. Is acute kidney injury after laparoscopic adrenalectomy related to the progression of chronic kidney disease in patients with primary aldosteronism? Investig Clin Urol. 2021; 62: 560-8.
11. Lu YC, Liu KL, Wu VC, Wang SM, Lin YH, Chueh SJ, et al. Factors associated with renal function change after unilateral adrenalectomy in patients with primary aldosteronism. Int J Urol. 2022; 29: 831-7.
12. Martín-Fernández B, Rubio-Navarro A, Cortegano I, Ballesteros S, Alía M, Cannata-Ortiz P, et al. Aldosterone induces renal fibrosis and inflammatory M1-macrophage subtype via mineralocorticoid receptor in rats. PLoS One. 2016; 11: e0145946.
13. Polenus P, Đuran A, Karanović Štambuk S. Aldosterone in chronic kidney disease. Biomedicines. 2025; 13: 2081.
14. Kim DH, Kwon HJ, Ji SA, Jang HR, Jung SH, Kim JH, et al. Risk factors for renal impairment revealed after unilateral adrenalectomy in patients with primary aldosteronism. Medicine (Baltimore). 2016; 95: e3930.
15. Artiles Medina A, Gómez Dos Santos V, Mínguez Ojeda C, Sanjuanbenito A, Gómez-Ramírez J, Mercader E, et al. The role of adrenal-sparing surgery in the management of aldosterone-producing adenoma: a systematic review and meta-analysis. Eur J Endocrinol. 2025; 193: S36-52.
16. Murasawa S, Kageyama K, Usutani M, Asari Y, Kinoshita N, Nakada Y, et al. Biochemical evaluation by confirmatory tests after unilateral adrenalectomy for primary aldosteronism. J Renin Angiotensin Aldosterone Syst. 2023; 2023: 5732812.
17. Marzano L, Ronco C. Clinical and biochemical outcomes after adrenalectomy for primary aldosteronism in tertiary and quaternary referral centers: data from SOPRANO study. Hypertens Res. 2024; 47: 721-34.
18. Morisaki M, Kurihara I, Itoh H, Naruse M, Takeda Y, Katabami T, et al. Predictors of clinical success after surgery for primary aldosteronism in the Japanese Nationwide Cohort. J Endocr Soc. 2019; 3: 2012-22.
19. Vorselaars WMCM, Nell S, Postma EL, Zarnegar R, Drake FT, Duh QY, et al. Clinical outcomes after unilateral adrenalectomy for primary aldosteronism. JAMA Surg. 2019; 154: e185842.
20. Zekarias K, Kohlenberg J, Ikramuddin S. Primary aldosteronism surgery outcomes under current blood pressure guidelines. Endocr Pract. 2026; 32: 31-7.