Original Article

Comparison of postoperative biochemical indicators and surgical result between partial adrenalectomy and total adrenalectomy: a systematic review and meta-analysis

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Background: The selection and extent of application for both total adrenalectomy (TA) and partial adrenalectomy (PA) within this surgical approach continue to be matters of debate. This paper compares the postoperative efficacy and functional indicators of PA and TA to provide comprehensive insights for clinicians to consider the best surgical treatment options.

Methods: Systematic review on PubMed, Embase, Cochrane Library, Web of Science, and China National Knowledge Infrastructure (CNKI) was conducted. We compared several key factors between TA and PA, including operating time (OT), blood loss, length of hospital stay, serum aldosterone levels, plasma renin activity, postoperative aldosterone to renin ratio (ARR), systolic and diastolic blood pressure, early postoperative complications, and blood potassium concentration. Data were collected by the Cochran-Mantel-Haenszel method, and Review Manager software (RevMan) version 5.3 was used.

Results: The results showed that compared to TA, PA had a shorter OT [weighted mean difference (WMD) =−12.16; 95% confidence interval (CI): −19.42, −4.89; I^2=96%; P=0.001]. Compared with PA, TA had a better recovery of diastolic blood pressure (WMD =2.12; 95% CI: 0.42, 3.81; I^2=0%; P=0.01). Regarding serum aldosterone, plasma renin activity, postoperative ARR, systolic blood pressure, early postoperative complications, length of hospital stay, and blood potassium, there was no significant difference between PA and TA (P>0.05). In subgroup analysis, results indicated that there was currently no significant difference in most results between PA and TA (P>0.05). For patients aged 50 years or younger, PA had a shorter OT compared to TA (WMD =−19.71; 95% CI: −35.99, −3.42; I^2=95%; P=0.02). For tumor size ≤2.0 cm, the intraoperative blood loss of PA was greater than that of TA (WMD =16.76; 95% CI: 3.62, 29.90; I^2=37%; P=0.01).

Conclusions: The OT was shorter in PA than in TA, and shorter in younger patients. The recovery of diastolic blood pressure after TA was better than that of PA. When the tumor was 2 cm or small, TA had less blood loss than PA. There was no significant difference in functional indexes between PA and TA. PA offers advantages in surgical outcomes compared to TA. However, for tumors ≤2 cm, TA may provide greater benefits to patients. Additionally, TA demonstrates superior recovery of diastolic blood pressure compared to PA according to functional indicators.

Keywords: Partial adrenalectomy (PA); adrenal glands; complications; outcome; total adrenalectomy (TA)

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Introduction

According to GLOBOCAN's 2020 data, adrenal tumors, coupled with kidney neoplasms, ranked 15th among cancers that pose a threat to human life (1). They have an incidence rate of 4% in East Asia and a worldwide rate of about 4.6% (1). According to the Chinese urology and andrology guidelines 2023, the probability of pheochromocytoma in Chinese citizens is 0.002–0.008% (2,3). The probability of hypercortisolism is 0.002–0.005%, and the probability of adrenocortical cancer is 0.001–0.002% (4-6). Currently, laparoscopic surgery is upheld as the gold standard for adrenal tumor treatment. However, the selection and extent of application for both total adrenalectomy (TA) and partial adrenalectomy (PA) within this surgical approach continue to be a matter of debate.

TA, often utilized as a surgical intervention for adrenal disorders, is suitable for a diverse range of conditions, including adrenal adrenocortical cancer, aldosteronism, and pheochromocytoma. Its merits are highlighted by lessened perioperative complications and reduced postoperative fatality rate (7,8). TA holds the advantage of triggering notable alterations in the postoperative biochemical markers for functional tumors (9). However, making a hasty decision to opt for bilateral TA may result in lifelong reliance on steroids and thus diminishing the patient's quality of life after the surgery. Inadequate corticosteroid replacement treatment can also lead to a life-threatening Addisonian crisis (10). Research has further indicated that a decrease in quality of life and an increase in mortality rates in patients may be associated with the lifelong utilization of steroid hormones (11).

PA can avoid lifelong steroid use. In dealing with more prevalent small functional tumors such as sporadic pheochromocytoma, aldosterone, or cortisol-secreting adenomas, the strategy helps to conserve normal adrenal tissue and significantly reduce the likelihood of future adrenal crises. However, PA is comparatively less effective than TA in mitigating long-term complications (12-14). We discovered that most research papers usually limit their focus to the post-surgery index comparison of a single illness, and articles with relevant data from recent years have not been included in previous research papers. However, our study has broadened its scope by including multiple diseases and incorporating the latest research, thus improving the validity and reliability of our findings.

Based on this debate, this article aims to compare the postoperative indicators and functional indicators of PA and TA, compare the safety and effectiveness of these surgical methods, and help clinical doctors make cautious choices when making surgical treatment plans. We present this article in accordance with the PRISMA reporting checklist (available at https://gs.amegroups.com/article/view/10.21037/gs-24-345/rc) (15,16).

Highlight box

Key findings
- Partial adrenalectomy (PA) offers advantages in surgical outcomes compared to total adrenalectomy (TA). However, for tumors ≤2 cm, TA may provide greater benefits to patients. Additionally, TA demonstrates superior recovery of diastolic blood pressure compared to PA when evaluating functional indicators.

What is known and what is new?
- PA offers advantages in surgical outcomes compared to TA.
- For tumors ≤2 cm, TA may provide greater benefits to patients. Additionally, TA demonstrates superior recovery of diastolic blood pressure compared to PA when evaluating functional indicators.

What is the implication, and what should change now?
- This indicates that there is indeed a difference between PA and TA, and clinicians should choose the corresponding operation according to different tumor sizes and postoperative effects.

Methods

This review has obtained proactive registration in the PROSPERO database, identified as CRD42023467287.

Search strategy

Five databases, namely PubMed, Cochrane, Web of Science, China National Knowledge Infrastructure (CNKI), and Embase, were utilized in the search process. The search criteria included articles up to December 2023 with keywords: "Partial adrenalectomy" and "Total adrenalectomy", and inclusion criteria were as follows:

Table 1 Main baseline data: patient characteristics and tumor characteristics for the studies included 9

References	Article type	Age (years old)		Tumor size (cm)		Male/female		Side left/right		NOS (score)	Tumor type
		PA	TA	PA	TA	PA	TA	PA	TA		
Balci *et al.* (17), 2020†	Retrospective	42.1	46.9	0.42	0.38	6/9	8/17	11/4	10/15	6	Mixed
Chen *et al.* (18), 2014	Retrospective	48.50±10.90	48.70±11.30	2.02±0.91	2.10±0.83	7/9	21/26	11/5	25/22	7	Conn's
Liu *et al.* (19), 2020	Retrospective	48.27±11.47	56.42±16.42	1.86±0.65	1.96±0.96	22/43	12/19	38/27	18/13	7	Conn's
Ishidoya *et al.* (20), 2005	Retrospective	49.30±9.38	50.47±9.87	1.54±0.44	1.68±7.93	15/14	31/32	12/17	37/25	6	Conn's
Fu *et al.* (21), 2011	Prospective	43.00±5.80	41.00±7.80	1.90±0.20	1.80±0.40	45/59	48/60	46/58	55/53	8	Conn's
Billmann *et al.* (22), 2021	Retrospective	45.90±14.00	53.10±15.00	1.80±1.60	3.40±2.30	46/35	69/99	45/36	87/81	7	Conn's
Simforoosh *et al.* (23), 2020	Retrospective	39.05±12.26	41.18±13.38	4.32±3.09	5.44±3.08	13/10	52/65	11/12	34/83	7	Mixed
Walz *et al.* (24), 2004‡	Retrospective	44.5±15.3	51.00±13.50	2.80±1.50	2.80±1.60	38/58	86/138	49/51	116/106	7	Mixed
Anceschi *et al.* (25), 2021	Retrospective	55.50±17.78	53.66±13.70	2.41±0.78	4.15±2.70	13/16	23/38	22/7	23/38	6	Conn's

Data are expressed as mean ± standard deviation or number. †, it was the only study that used median data; ‡, it was the only article that included bilateral tumors. Patients with bilateral pheochromocytomas, 1 patient with bilateral Cushing's adenoma. Mixed: included pheochromocytoma, Cushing or Conn's disease. PA, partial adrenalectomy; TA, total adrenalectomy; NOS, Newcastle-Ottawa Quality Assessment Scale.

(I) the study focused on the comparison of PA and TA in the literature. (II) Non-univariate comparison. (III) Comparative safety and efficacy articles. (IV) Randomized controlled trials ought to be incorporated, as well as both prospective controlled trials and retrospective studies. (V) Full papers containing at least one outcome parameter, such as operating time (OT), blood loss, hospital stay, serum aldosterone, plasma renin activity, postoperative aldosterone to renin ratio (ARR), blood potassium. (VI) Adrenal tumor types are not restricted, etc. Exclusion criteria were as follows: (I) studies that are not relevant to the topic or lack complete data. (II) Letters, case reviews, and conference abstracts. (III) Animal experiments, and animal case studies. (IV) Non-comparative safety and efficacy articles. (V) Univariate comparison.

Data extraction

Baseline data were collected based on the original data provided by the included literature, focusing on common baseline characteristics found in most included studies, and categorized the data by article type, tumor size, tumor location, gender, age, Newcastle-Ottawa Quality Assessment Scale (NOS) score, and tumor type (*Table 1*). The indicators for comparison included OT, blood loss, length of hospital stay, serum aldosterone and plasma renin activity levels, postoperative ARR, systolic and diastolic blood pressure, early postoperative complications, and blood potassium concentration. In processing the data, we also obtained some data with no original data but a clear classification of clinical remission and non-remission. In order to avoid bias, we did not use those data as the content of data analysis but chose to use other data with raw data for data analysis. As for the data of some early complications, we compared the Clavien-Dindo classification of early complications and found that most of their articles did not provide detailed descriptions of complication data, only verbal descriptions of no complications or only grade 1 complications. We selected articles with original data and selected grade 1 complications with more data as the data for comprehensive analysis.

Statistical analysis

The article's original data definition served as a foundational reference for data recording. In terms of data gathering, this document utilized the Cochran-Mantel-Haenszel approach using the RevMan software, version 5.3. Data that were not immediately usable, such as median values, range metrics, and interquartile spreads, were transformed into a usable format through specific statistical methodologies (26,27). Continuous variables were computed using the weighted mean difference (WMD), while binary variables were assessed using odds ratios (ORs) with the same level of confidence. Both were calculated with 95% confidence intervals (CIs). The variance across the different studies was examined utilizing chi-square analysis along with the I-squared test for a comprehensive evaluation of heterogeneity. The random effects model is used to process all data models. The criterion for high heterogeneity is I^2>50%. Finally, a value of P<0.05 is considered statistically significant.

Subgroup analysis

When processing data on OT and blood loss, we found significant heterogeneity in the data. In order to obtain accurate data results for analysis, we combined the data with subgroup classification: year, age, sample size, tumor size. Based on its data characteristics, we selected 2012, 50 years old, 100 sample size, and 2 cm as the cut-off point for data analysis. To enhance the rigor of the article, we categorized the tumor types into Conn's and mixed based on the inclusion criteria, allowing us to conduct a more detailed subgroup analysis. We also categorized the data into transperitoneal and retroperitoneal types, identifying three studies transperitoneally, three retroperitoneally, and the remainder as mixed. However, significant discrepancies in the original data led us to abandon this grouping approach.

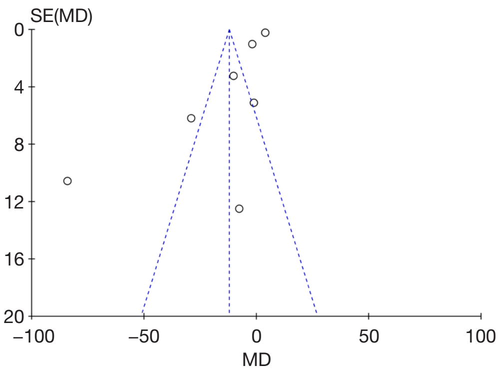


Figure 1 Funnel plot. SE, standard error; MD, mean difference.

Bias assessment

In this paper, the data processing function of RevMan 5.3 was used to draw a funnel plot and evaluate the bias of data with high heterogeneity (*Figure 1*). The random effects model was used to process the data. Concurrently, ROBINS-I was used to assess for bias risk in non-randomized clinical trials (RCTs), including bias: (I) pre-intervention: (i) confounding, (ii) selection of participants; (II) intervening: (i) classification of exposures; (III) post-intervention: (i) departures from intended exposures, (ii) missing data, (iii) measurement of outcomes, (iv) selection of the reported result (*Table 2*) (28). The NOS was employed to examine the quality of non-randomized studies. Evaluations were conducted on three dimensions: selection, comparability, and exposure/outcome. Studies scoring at least 7 were categorized as high quality (*Table 2*).

Results

We searched for a total of 1,751 screening records. Firstly, 319 duplicate articles were excluded, and then

Table 2 Bias domain

Bias domain	Ishidoya *et al.* (20), 2005	Chen *et al.* (18), 2014	Liu *et al.* (19), 2020	Billmann *et al.* (22), 2021	Balci *et al.* (17), 2020	Fu *et al.* (21), 2011	Simforoosh *et al.* (23), 2020	Walz *et al.* (24), 2004	Anceschi *et al.* (25), 2021
Bias due to confounding	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
Bias in selection of participants into the study	Low	Low	Low	Low	Low	Low	Low	Low	Low
Bias in classification of interventions	Moderate	Low	Low	Moderate	Low	Low	Low	Low	Moderate
Bias in classification of interventions	Low	Low	Moderate	Moderate	Moderate	Low	Low	Low	Low
Bias in classification of interventions	Low	Low	Low	Low	High	Low	Low	Low	Moderate
Bias in classification of interventions	Low	Moderate	Moderate	Moderate	Moderate	Low	Low	Low	Low
Bias in selection of the reported result	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
Overall bias	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate

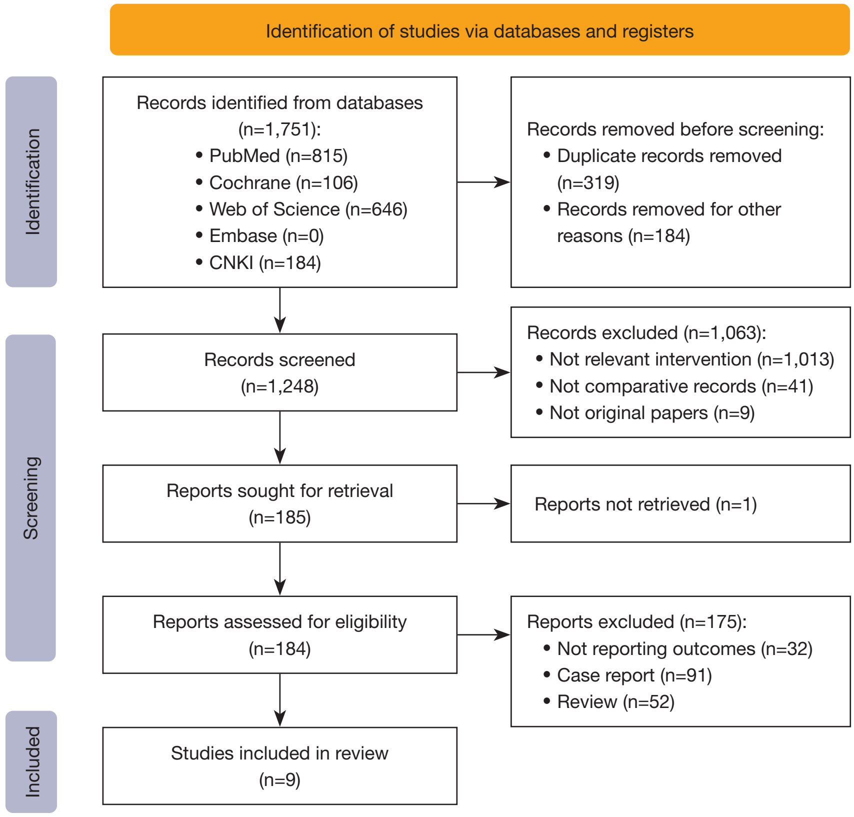


Figure 2 Screening process. CNKI, China National Knowledge Infrastructure.

we screened out articles without relevant intervention, as well as reviews and individual case reports, Further screening was conducted to identify articles without original literature, perioperative and postoperative data, and relevant comparisons. Finally, 10 articles were preliminarily screened. After studying 10 data articles, we manually screened out 1 article without high-quality data and finally included 9 articles. Among them, we included a total of 8 retrospective studies and 1 prospective study included six Conn's articles and three mixed articles. The mixed articles including pheochromocytoma and Cushing or Conn's disease (*Figure 2*). Through the above screening process, we eliminated 1,063 irrelevant articles, 1 article without original literature, and eliminated 91 case reports, 52 reviews, and 32 articles without results, a total of 9 articles were ultimately included in our study. The specific process is shown in *Figure 3*. The data and characteristics included in the study are shown in *Table 1*.

Surgical results

In the surgical results, we compared the OT, blood loss, and hospital stay between PA and TA. In data analysis, we found significant heterogeneity in the results of OT and blood loss, to reduce its heterogeneity and bias, we divided the two sets of data into four subgroups for analysis. The results were as follows:

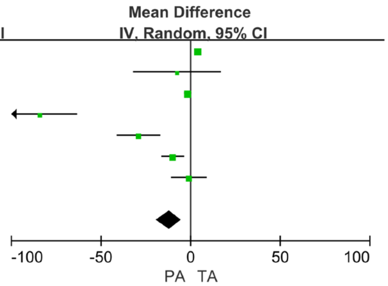
Operation time

In *Figure 3A*, the comparison of OT: PA had a shorter OT compared to TA (WMD =−12.16; 95% CI: −19.42, −4.89; I^2=96%; P=0.001, *Figure 3A*). Subgroups were included sample size, age, study year, and tumor size were included. The use of the appeal statistics method for subgroup analysis showed differences in the results compared to the ungrouped data. In the data results of OT, the OT of PA in subgroup ≤50 years old was shorter than that of TA (WMD =−19.71;

A

Study or Subgroup	PA Mean	PA SD	PA Total	TA Mean	TA SD	TA Total	Weight	Mean Difference IV, Random, 95% CI
Billmann F 2021	48	1.66	78	44.04	1.7	156	20.5%	3.96 [3.51, 4.41]
Chen SF 2014	95.9	46.1	16	103.5	33.1	47	6.2%	-7.60 [-32.09, 16.89]
Fu B 2011	41.6	9	104	43.3	6	108	20.2%	-1.70 [-3.77, 0.37]
Ishidoya S 2005	115	46.4	29	199	48.7	63	7.7%	-84.00 [-104.73, -63.27]
Liu JH 2020	76.2	25.9	65	105.3	29.6	31	13.0%	-29.10 [-41.27, -16.93]
Simforoosh N 2020	102	15	23	112	10	117	17.7%	-10.00 [-16.39, -3.61]
Walz MK 2004	79	42	100	80	44	225	14.7%	-1.00 [-11.04, 9.04]
Total (95% CI)			**415**			**747**	**100.0%**	**-12.16 [-19.42, -4.89]**

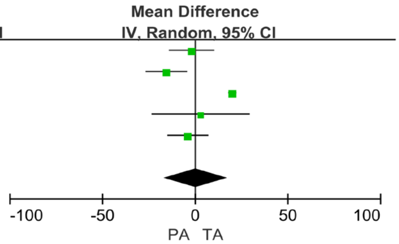
Heterogeneity: Tau² = 66.94; Chi² = 142.88, df = 6 (P < 0.00001); I² = 96%
Test for overall effect: Z = 3.28 (P = 0.001)



B

Study or Subgroup	PA Mean	PA SD	PA Total	TA Mean	TA SD	TA Total	Weight	Mean Difference IV, Random, 95% CI
Billmann F 2021	32	40	78	34	54	156	20.5%	-2.00 [-14.27, 10.27]
Chen SF 2014	21.9	7.5	16	37.5	37	47	20.9%	-15.60 [-26.80, -4.40]
Fu B 2011	35.3	10	104	15.3	6	108	22.8%	20.00 [17.77, 22.23]
Liu JH 2020	69.5	51.9	65	66.6	66.2	31	14.9%	2.90 [-23.60, 29.40]
Walz MK 2004	29	31	100	33	71	225	20.9%	-4.00 [-15.09, 7.09]
Total (95% CI)			**363**			**567**	**100.0%**	**0.48 [-16.92, 17.88]**

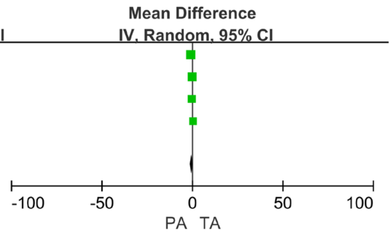
Heterogeneity: Tau² = 344.85; Chi² = 63.57, df = 4 (P < 0.00001); I² = 94%
Test for overall effect: Z = 0.05 (P = 0.96)



C

Study or Subgroup	PA Mean	PA SD	PA Total	TA Mean	TA SD	TA Total	Weight	Mean Difference IV, Random, 95% CI
Anceschi U 2021	3.06	0.37	29	4	0.43	61	28.7%	-0.94 [-1.11, -0.77]
Billmann F 2021	2.72	1.04	78	2.89	1.51	156	26.8%	-0.17 [-0.50, 0.16]
Chen SF 2014	3.56	0.89	16	3.96	1.17	47	23.0%	-0.40 [-0.95, 0.15]
Fu B 2011	4.2	1.8	65	3.9	1.3	31	21.5%	0.30 [-0.33, 0.93]
Total (95% CI)			**188**			**295**	**100.0%**	**-0.34 [-0.91, 0.22]**

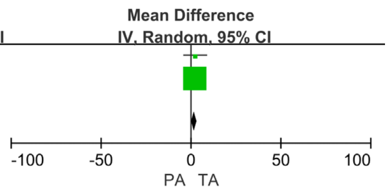
Heterogeneity: Tau² = 0.28; Chi² = 28.01, df = 3 (P < 0.00001); I² = 89%
Test for overall effect: Z = 1.19 (P = 0.23)



D

Study or Subgroup	PA Mean	PA SD	PA Total	TA Mean	TA SD	TA Total	Weight	Mean Difference IV, Random, 95% CI
Chen SF 2014	88.27	11.28	16	85.92	12.92	47	6.5%	2.35 [-4.30, 9.00]
Fu B 2011	83.4	6	104	81.3	7	108	93.5%	2.10 [0.35, 3.85]
Total (95% CI)			**120**			**155**	**100.0%**	**2.12 [0.42, 3.81]**

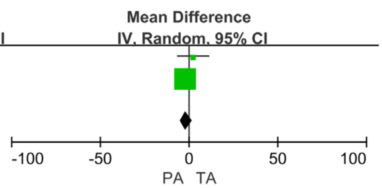
Heterogeneity: Tau² = 0.00; Chi² = 0.01, df = 1 (P = 0.94); I² = 0%
Test for overall effect: Z = 2.45 (P = 0.01)



E

Study or Subgroup	PA Mean	PA SD	PA Total	TA Mean	TA SD	TA Total	Weight	Mean Difference IV, Random, 95% CI
Chen SF 2014	141.18	17.39	16	138.88	11.28	47	12.2%	2.30 [-6.81, 11.41]
Fu B 2011	107.2	14	104	109.4	11	108	87.8%	-2.20 [-5.60, 1.20]
Total (95% CI)			**120**			**155**	**100.0%**	**-1.65 [-4.83, 1.53]**

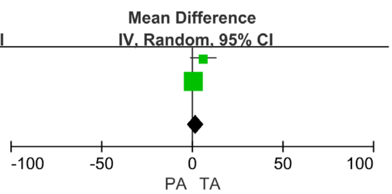
Heterogeneity: Tau² = 0.00; Chi² = 0.82, df = 1 (P = 0.36); I² = 0%
Test for overall effect: Z = 1.02 (P = 0.31)



F

Study or Subgroup	PA Mean	PA SD	PA Total	TA Mean	TA SD	TA Total	Weight	Mean Difference IV, Random, 95% CI
Chen SF 2014	34.6	12.6	16	28.6	13.8	47	27.3%	6.00 [-1.33, 13.33]
Fu B 2011	8.6	2.9	104	8.1	4.2	108	72.7%	0.50 [-0.47, 1.47]
Total (95% CI)			**120**			**155**	**100.0%**	**2.00 [-2.80, 6.80]**

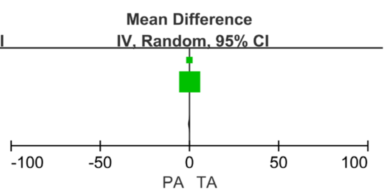
Heterogeneity: Tau² = 8.02; Chi² = 2.13, df = 1 (P = 0.14); I² = 53%
Test for overall effect: Z = 0.82 (P = 0.41)



G

Study or Subgroup	PA Mean	PA SD	PA Total	TA Mean	TA SD	TA Total	Weight	Mean Difference IV, Random, 95% CI
Chen SF 2014	4.29	0.57	16	4.36	0.35	47	15.9%	-0.07 [-0.37, 0.23]
Fu B 2011	4.5	0.3	104	4.4	0.5	108	84.1%	0.10 [-0.01, 0.21]
Total (95% CI)			**120**			**155**	**100.0%**	**0.07 [-0.05, 0.19]**

Heterogeneity: Tau² = 0.00; Chi² = 1.11, df = 1 (P = 0.29); I² = 10%
Test for overall effect: Z = 1.18 (P = 0.24)



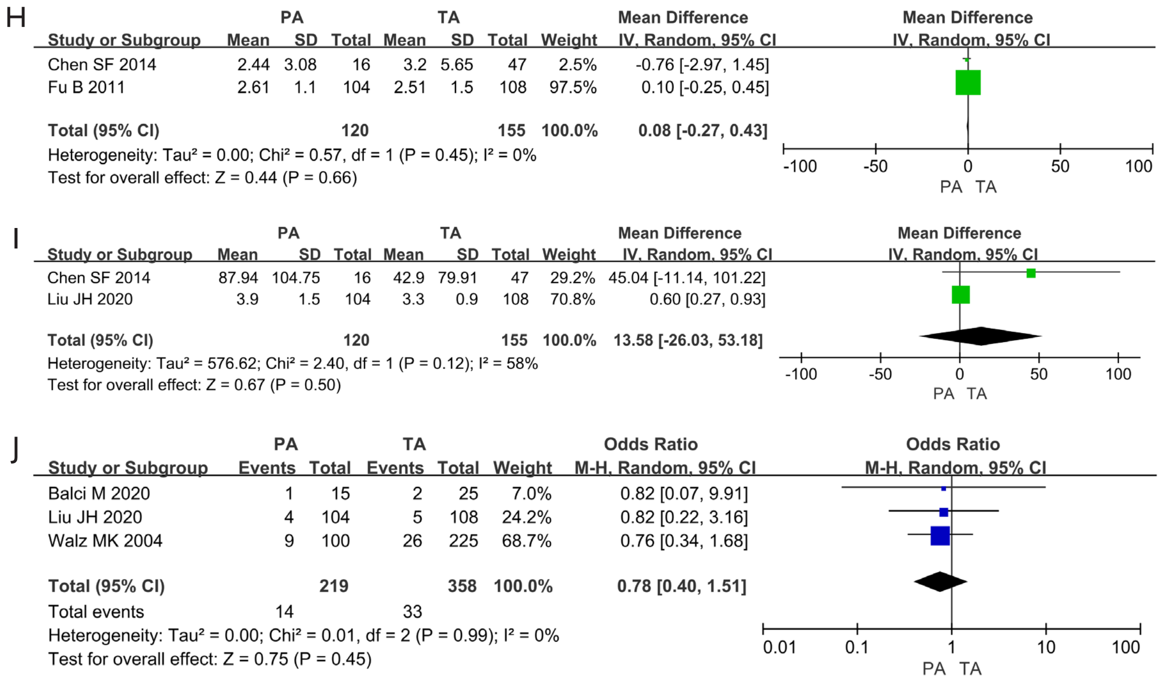


Figure 3 Surgical results and functional indicators. (A) PA *vs.* TA: operation time. (B) PA *vs.* TA: blood loss. (C) PA *vs.* TA: hospital stay. (D) PA *vs.* TA: diastolic blood pressure. (E) PA *vs.* TA: systolic blood pressure. (F) PA *vs.* TA: serum aldosterone. (G) PA *vs.* TA: potassium. (H) PA *vs.* TA: plasma renin activity. (I) PA *vs.* TA: ARR. (J) PA *vs.* TA: early complication. PA, partial adrenalectomy; TA, total adrenalectomy; SD, standard deviation; IV, inverse variance; CI, confidence interval; M-H, Mantel-Haenszel; ARR, aldosterone to renin ratio.

95% CI: −35.99, −3.42; I^2=95%; P=0.02, *Figure 4A*), which was consistent with the conclusion of ungrouped data. However, there was no statistically significant difference between subgroups >50 years old. Furthermore, the results of the subgroup analysis did not show statistical significance based on year and tumor size (P>0.05).

Blood loss

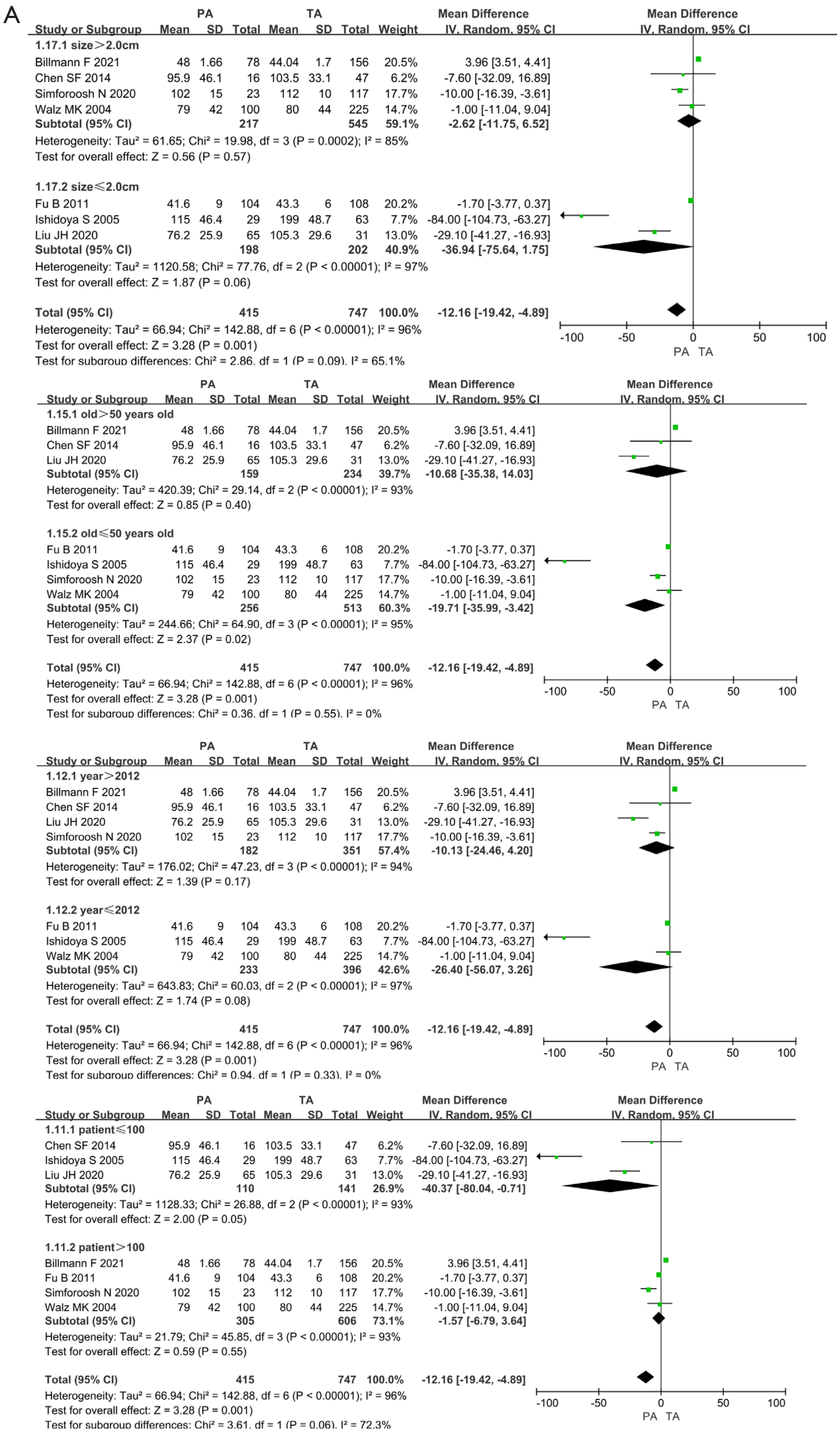
In *Figure 3B*, data about blood loss were extracted from five studies (18,19,21,22,24). Our final meta-analysis indicated that there was no significant difference in blood loss between PA and TA (WMD =0.48; 95% CI: −16.92, 17.88; I^2=94%; P=0.96, *Figure 3B*). Similarly, we used the appellate subgroup analysis and concluded. The analysis results show that age and sample size data were not statistically significant, which was the same as that of ungrouped data. In the subgroup of tumor size, there was no statistically significant difference in the results of data with tumor size >2.0 cm, which was the same as the ungrouped data. However, for tumor size ≤2.0 cm, the intraoperative blood loss associated with PA surpasses that of TA (WMD =16.76; 95% CI: 3.62, 29.90; I^2=37%; P=0.01, *Figure 4B*).

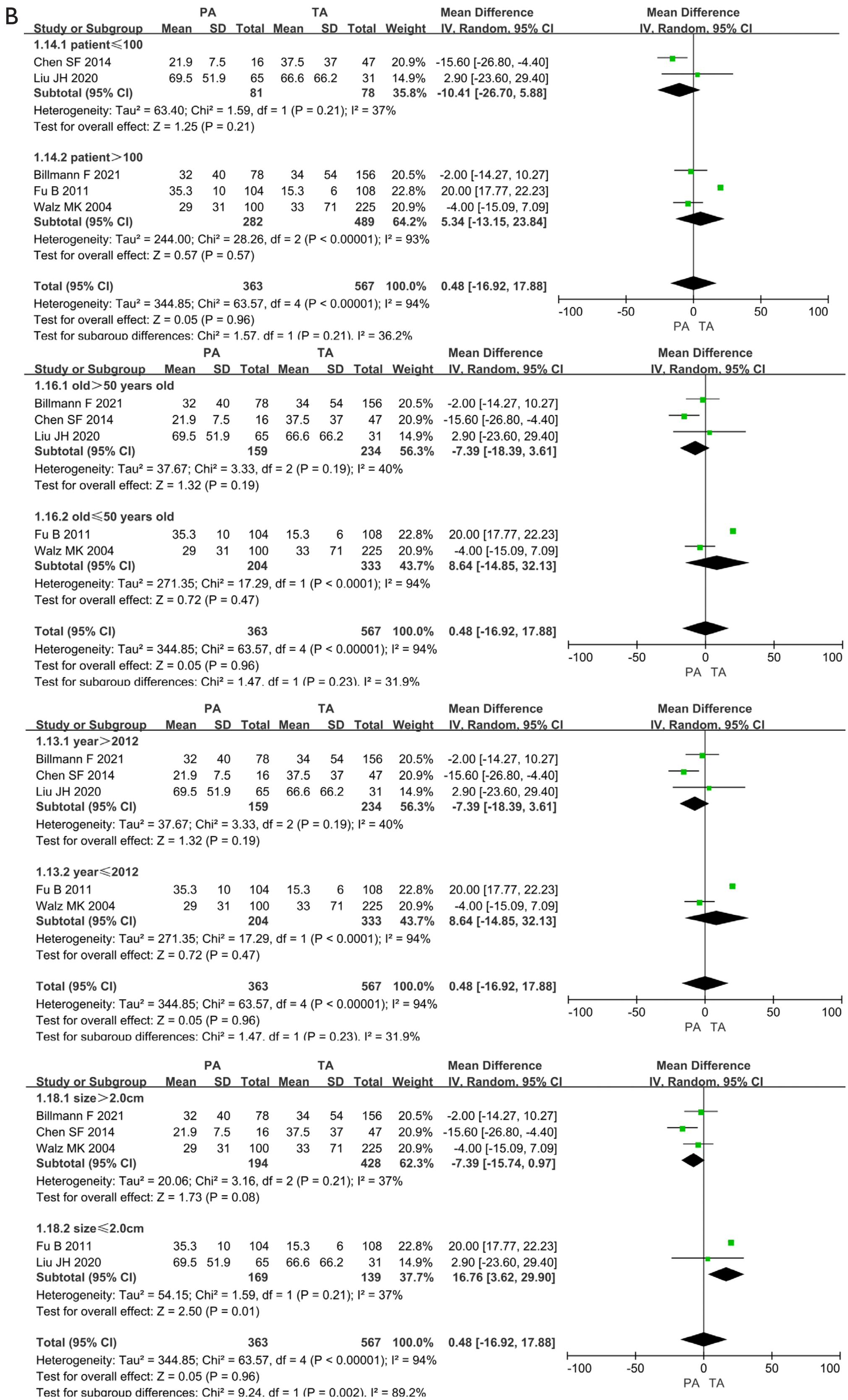
Hospitalization time

Referring to *Figure 3C*, after the collective analysis of four studies (18,21,22,25), a high degree of heterogeneity among the studies was noted, warranting the use of a random effect model. Consequently, there was no discernable difference in the duration of hospital stays between partial resection and full resection (WMD =−0.34; 95% CI: −0.91, 0.22; I^2=89%; P=0.23, *Figure 3C*).

Functional indicators

In assessing the follow-up prognosis between PA and TA, we evaluated functional indicators including systolic and diastolic blood pressure, serum aldosterone levels, post-surgery potassium concentration, plasma renin activity, along with ARR. The displayed results were as follows:


A
PA TA Mean Difference Mean Difference
Study or Subgroup Mean SD Total Mean SD Total Weight IV, Random, 95% CI IV, Random, 95% CI
1.17.1 size＞2.0cm
Billmann F 2021 48 1.66 78 44.04 1.7 156 20.5% 3.96 [3.51, 4.41]
Chen SF 2014 95.9 46.1 16 103.5 33.1 47 6.2% -7.60 [-32.09, 16.89]
Simforoosh N 2020 102 15 23 112 10 117 17.7% -10.00 [-16.39, -3.61]
Walz MK 2004 79 42 100 80 44 225 14.7% -1.00 [-11.04, 9.04]
Subtotal (95% CI) 217 545 59.1% -2.62 [-11.75, 6.52]
Heterogeneity: Tau² = 61.65; Chi² = 19.98, df = 3 (P = 0.0002); I² = 85%
Test for overall effect: Z = 0.56 (P = 0.57)
1.17.2 size≤2.0cm
Fu B 2011 41.6 9 104 43.3 6 108 20.2% -1.70 [-3.77, 0.37]
Ishidoya S 2005 115 46.4 29 199 48.7 63 7.7% -84.00 [-104.73, -63.27]
Liu JH 2020 76.2 25.9 65 105.3 29.6 31 13.0% -29.10 [-41.27, -16.93]
Subtotal (95% CI) 198 202 40.9% -36.94 [-75.64, 1.75]
Heterogeneity: Tau² = 1120.58; Chi² = 77.76, df = 2 (P < 0.00001); I² = 97%
Test for overall effect: Z = 1.87 (P = 0.06)
Total (95% CI) 415 747 100.0% -12.16 [-19.42, -4.89]
Heterogeneity: Tau² = 66.94; Chi² = 142.88, df = 6 (P < 0.00001); I² = 96%
Test for overall effect: Z = 3.28 (P = 0.001)
Test for subgroup differences: Chi² = 2.86, df = 1 (P = 0.09), I² = 65.1%
-100 -50 0 50 100
PA TA
PA TA Mean Difference Mean Difference
Study or Subgroup Mean SD Total Mean SD Total Weight IV, Random, 95% CI IV, Random, 95% CI
1.15.1 old＞50 years old
Billmann F 2021 48 1.66 78 44.04 1.7 156 20.5% 3.96 [3.51, 4.41]
Chen SF 2014 95.9 46.1 16 103.5 33.1 47 6.2% -7.60 [-32.09, 16.89]
Liu JH 2020 76.2 25.9 65 105.3 29.6 31 13.0% -29.10 [-41.27, -16.93]
Subtotal (95% CI) 159 234 39.7% -10.68 [-35.38, 14.03]
Heterogeneity: Tau² = 420.39; Chi² = 29.14, df = 2 (P < 0.00001); I² = 93%
Test for overall effect: Z = 0.85 (P = 0.40)
1.15.2 old≤50 years old
Fu B 2011 41.6 9 104 43.3 6 108 20.2% -1.70 [-3.77, 0.37]
Ishidoya S 2005 115 46.4 29 199 48.7 63 7.7% -84.00 [-104.73, -63.27]
Simforoosh N 2020 102 15 23 112 10 117 17.7% -10.00 [-16.39, -3.61]
Walz MK 2004 79 42 100 80 44 225 14.7% -1.00 [-11.04, 9.04]
Subtotal (95% CI) 256 513 60.3% -19.71 [-35.99, -3.42]
Heterogeneity: Tau² = 244.66; Chi² = 64.90, df = 3 (P < 0.00001); I² = 95%
Test for overall effect: Z = 2.37 (P = 0.02)
Total (95% CI) 415 747 100.0% -12.16 [-19.42, -4.89]
Heterogeneity: Tau² = 66.94; Chi² = 142.88, df = 6 (P < 0.00001); I² = 96%
Test for overall effect: Z = 3.28 (P = 0.001)
Test for subgroup differences: Chi² = 0.36, df = 1 (P = 0.55), I² = 0%
-100 -50 0 50 100
PA TA
PA TA Mean Difference Mean Difference
Study or Subgroup Mean SD Total Mean SD Total Weight IV, Random, 95% CI IV, Random, 95% CI
1.12.1 year＞2012
Billmann F 2021 48 1.66 78 44.04 1.7 156 20.5% 3.96 [3.51, 4.41]
Chen SF 2014 95.9 46.1 16 103.5 33.1 47 6.2% -7.60 [-32.09, 16.89]
Liu JH 2020 76.2 25.9 65 105.3 29.6 31 13.0% -29.10 [-41.27, -16.93]
Simforoosh N 2020 102 15 23 112 10 117 17.7% -10.00 [-16.39, -3.61]
Subtotal (95% CI) 182 351 57.4% -10.13 [-24.46, 4.20]
Heterogeneity: Tau² = 176.02; Chi² = 47.23, df = 3 (P < 0.00001); I² = 94%
Test for overall effect: Z = 1.39 (P = 0.17)
1.12.2 year≤2012
Fu B 2011 41.6 9 104 43.3 6 108 20.2% -1.70 [-3.77, 0.37]
Ishidoya S 2005 115 46.4 29 199 48.7 63 7.7% -84.00 [-104.73, -63.27]
Walz MK 2004 79 42 100 80 44 225 14.7% -1.00 [-11.04, 9.04]
Subtotal (95% CI) 233 396 42.6% -26.40 [-56.07, 3.26]
Heterogeneity: Tau² = 643.83; Chi² = 60.03, df = 2 (P < 0.00001); I² = 97%
Test for overall effect: Z = 1.74 (P = 0.08)
Total (95% CI) 415 747 100.0% -12.16 [-19.42, -4.89]
Heterogeneity: Tau² = 66.94; Chi² = 142.88, df = 6 (P < 0.00001); I² = 96%
Test for overall effect: Z = 3.28 (P = 0.001)
Test for subgroup differences: Chi² = 0.94, df = 1 (P = 0.33), I² = 0%
-100 -50 0 50 100
PA TA
PA TA Mean Difference Mean Difference
Study or Subgroup Mean SD Total Mean SD Total Weight IV, Random, 95% CI IV, Random, 95% CI
1.11.1 patient≤100
Chen SF 2014 95.9 46.1 16 103.5 33.1 47 6.2% -7.60 [-32.09, 16.89]
Ishidoya S 2005 115 46.4 29 199 48.7 63 7.7% -84.00 [-104.73, -63.27]
Liu JH 2020 76.2 25.9 65 105.3 29.6 31 13.0% -29.10 [-41.27, -16.93]
Subtotal (95% CI) 110 141 26.9% -40.37 [-80.04, -0.71]
Heterogeneity: Tau² = 1128.33; Chi² = 26.88, df = 2 (P < 0.00001); I² = 93%
Test for overall effect: Z = 2.00 (P = 0.05)
1.11.2 patient＞100
Billmann F 2021 48 1.66 78 44.04 1.7 156 20.5% 3.96 [3.51, 4.41]
Fu B 2011 41.6 9 104 43.3 6 108 20.2% -1.70 [-3.77, 0.37]
Simforoosh N 2020 102 15 23 112 10 117 17.7% -10.00 [-16.39, -3.61]
Walz MK 2004 79 42 100 80 44 225 14.7% -1.00 [-11.04, 9.04]
Subtotal (95% CI) 305 606 73.1% -1.57 [-6.79, 3.64]
Heterogeneity: Tau² = 21.79; Chi² = 45.85, df = 3 (P < 0.00001); I² = 93%
Test for overall effect: Z = 0.59 (P = 0.55)
Total (95% CI) 415 747 100.0% -12.16 [-19.42, -4.89]
Heterogeneity: Tau² = 66.94; Chi² = 142.88, df = 6 (P < 0.00001); I² = 96%
Test for overall effect: Z = 3.28 (P = 0.001)
Test for subgroup differences: Chi² = 3.61, df = 1 (P = 0.06), I² = 72.3%
-100 -50 0 50 100
PA TA


B
PA TA Mean Difference Mean Difference
Study or Subgroup Mean SD Total Mean SD Total Weight IV, Random, 95% CI IV, Random, 95% CI
1.14.1 patient≤100
Chen SF 2014 21.9 7.5 16 37.5 37 47 20.9% -15.60 [-26.80, -4.40]
Liu JH 2020 69.5 51.9 65 66.6 66.2 31 14.9% 2.90 [-23.60, 29.40]
Subtotal (95% CI) 81 78 35.8% -10.41 [-26.70, 5.88]
Heterogeneity: Tau² = 63.40; Chi² = 1.59, df = 1 (P = 0.21); I² = 37%
Test for overall effect: Z = 1.25 (P = 0.21)
1.14.2 patient>100
Billmann F 2021 32 40 78 34 54 156 20.5% -2.00 [-14.27, 10.27]
Fu B 2011 35.3 10 104 15.3 6 108 22.8% 20.00 [17.77, 22.23]
Walz MK 2004 29 31 100 33 71 225 20.9% -4.00 [-15.09, 7.09]
Subtotal (95% CI) 282 489 64.2% 5.34 [-13.15, 23.84]
Heterogeneity: Tau² = 244.00; Chi² = 28.26, df = 2 (P < 0.00001); I² = 93%
Test for overall effect: Z = 0.57 (P = 0.57)
Total (95% CI) 363 567 100.0% 0.48 [-16.92, 17.88]
Heterogeneity: Tau² = 344.85; Chi² = 63.57, df = 4 (P < 0.00001); I² = 94%
Test for overall effect: Z = 0.05 (P = 0.96)
Test for subgroup differences: Chi² = 1.57, df = 1 (P = 0.21), I² = 36.2%
-100 -50 0 50 100
PA TA
PA TA Mean Difference Mean Difference
Study or Subgroup Mean SD Total Mean SD Total Weight IV, Random, 95% CI IV, Random, 95% CI
1.16.1 old>50 years old
Billmann F 2021 32 40 78 34 54 156 20.5% -2.00 [-14.27, 10.27]
Chen SF 2014 21.9 7.5 16 37.5 37 47 20.9% -15.60 [-26.80, -4.40]
Liu JH 2020 69.5 51.9 65 66.6 66.2 31 14.9% 2.90 [-23.60, 29.40]
Subtotal (95% CI) 159 234 56.3% -7.39 [-18.39, 3.61]
Heterogeneity: Tau² = 37.67; Chi² = 3.33, df = 2 (P = 0.19); I² = 40%
Test for overall effect: Z = 1.32 (P = 0.19)
1.16.2 old≤50 years old
Fu B 2011 35.3 10 104 15.3 6 108 22.8% 20.00 [17.77, 22.23]
Walz MK 2004 29 31 100 33 71 225 20.9% -4.00 [-15.09, 7.09]
Subtotal (95% CI) 204 333 43.7% 8.64 [-14.85, 32.13]
Heterogeneity: Tau² = 271.35; Chi² = 17.29, df = 1 (P < 0.0001); I² = 94%
Test for overall effect: Z = 0.72 (P = 0.47)
Total (95% CI) 363 567 100.0% 0.48 [-16.92, 17.88]
Heterogeneity: Tau² = 344.85; Chi² = 63.57, df = 4 (P < 0.00001); I² = 94%
Test for overall effect: Z = 0.05 (P = 0.96)
Test for subgroup differences: Chi² = 1.47, df = 1 (P = 0.23), I² = 31.9%
-100 -50 0 50 100
PA TA
PA TA Mean Difference Mean Difference
Study or Subgroup Mean SD Total Mean SD Total Weight IV, Random, 95% CI IV, Random, 95% CI
1.13.1 year>2012
Billmann F 2021 32 40 78 34 54 156 20.5% -2.00 [-14.27, 10.27]
Chen SF 2014 21.9 7.5 16 37.5 37 47 20.9% -15.60 [-26.80, -4.40]
Liu JH 2020 69.5 51.9 65 66.6 66.2 31 14.9% 2.90 [-23.60, 29.40]
Subtotal (95% CI) 159 234 56.3% -7.39 [-18.39, 3.61]
Heterogeneity: Tau² = 37.67; Chi² = 3.33, df = 2 (P = 0.19); I² = 40%
Test for overall effect: Z = 1.32 (P = 0.19)
1.13.2 year≤2012
Fu B 2011 35.3 10 104 15.3 6 108 22.8% 20.00 [17.77, 22.23]
Walz MK 2004 29 31 100 33 71 225 20.9% -4.00 [-15.09, 7.09]
Subtotal (95% CI) 204 333 43.7% 8.64 [-14.85, 32.13]
Heterogeneity: Tau² = 271.35; Chi² = 17.29, df = 1 (P < 0.0001); I² = 94%
Test for overall effect: Z = 0.72 (P = 0.47)
Total (95% CI) 363 567 100.0% 0.48 [-16.92, 17.88]
Heterogeneity: Tau² = 344.85; Chi² = 63.57, df = 4 (P < 0.00001); I² = 94%
Test for overall effect: Z = 0.05 (P = 0.96)
Test for subgroup differences: Chi² = 1.47, df = 1 (P = 0.23), I² = 31.9%
-100 -50 0 50 100
PA TA
PA TA Mean Difference Mean Difference
Study or Subgroup Mean SD Total Mean SD Total Weight IV, Random, 95% CI IV, Random, 95% CI
1.18.1 size>2.0cm
Billmann F 2021 32 40 78 34 54 156 20.5% -2.00 [-14.27, 10.27]
Chen SF 2014 21.9 7.5 16 37.5 37 47 20.9% -15.60 [-26.80, -4.40]
Walz MK 2004 29 31 100 33 71 225 20.9% -4.00 [-15.09, 7.09]
Subtotal (95% CI) 194 428 62.3% -7.39 [-15.74, 0.97]
Heterogeneity: Tau² = 20.06; Chi² = 3.16, df = 2 (P = 0.21); I² = 37%
Test for overall effect: Z = 1.73 (P = 0.08)
1.18.2 size≤2.0cm
Fu B 2011 35.3 10 104 15.3 6 108 22.8% 20.00 [17.77, 22.23]
Liu JH 2020 69.5 51.9 65 66.6 66.2 31 14.9% 2.90 [-23.60, 29.40]
Subtotal (95% CI) 169 139 37.7% 16.76 [3.62, 29.90]
Heterogeneity: Tau² = 54.15; Chi² = 1.59, df = 1 (P = 0.21); I² = 37%
Test for overall effect: Z = 2.50 (P = 0.01)
Total (95% CI) 363 567 100.0% 0.48 [-16.92, 17.88]
Heterogeneity: Tau² = 344.85; Chi² = 63.57, df = 4 (P < 0.00001); I² = 94%
Test for overall effect: Z = 0.05 (P = 0.96)
Test for subgroup differences: Chi² = 9.24, df = 1 (P = 0.002), I² = 89.2%
-100 -50 0 50 100
PA TA

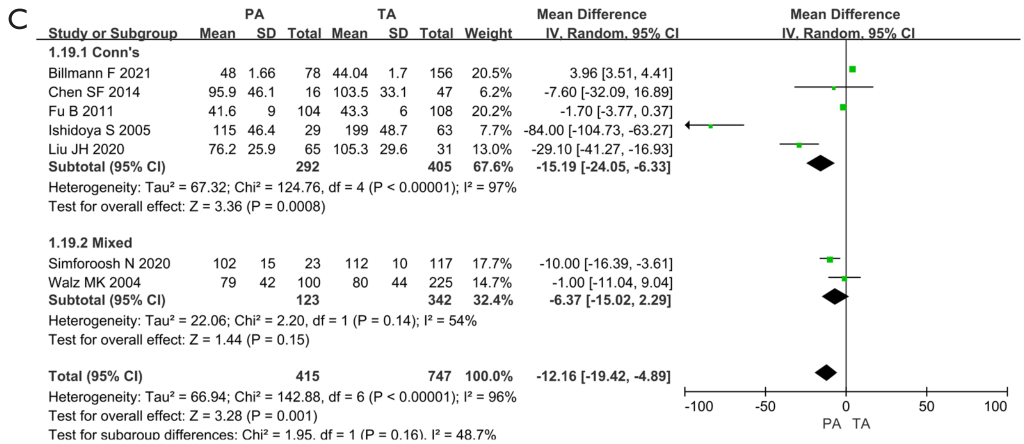


Figure 4 Subgroup result. (A) PA *vs.* TA: operation time. (B) PA *vs.* TA: blood loss. (C) PA *vs.* TA: Conn's *vs.* mixed. Mixed: included pheochromocytoma, Cushing or Conn's disease. PA, partial adrenalectomy; TA, total adrenalectomy; SD, standard deviation; IV, inverse variance; CI, confidence interval.

Postoperative diastolic blood pressure and systolic blood pressure

In *Figure 3D*, to further reduce heterogeneity, we used a random effect model, compared with PA, TA had better diastolic blood pressure recovery (WMD =2.12; 95% CI: 0.42, 3.81; I^2=0%; P=0.01, *Figure 3D*), When comparing the postoperative follow-up indicators of systolic blood pressure between PA and TA, it was also found that there was no significant difference between them (WMD =–1.65; 95% CI: –4.83, 1.53; I^2=0%; P=0.31, *Figure 3E*).

Serum aldosterone

Upon comparing the postoperative follow-up indicators of serum aldosterone between PA and TA, the random-effect model was used, there is no significant disparity was identified (WMD =2.00; 95% CI: –2.80, 6.80; I^2=53%; P=0.41, *Figure 3F*).

Postoperative potassium concentration

When assessing postoperative potassium concentrations, a random-effects model was implemented to diminish heterogeneity. Notably, there also did not appear to be a statistically significant difference between PA and TA (WMD =0.07; 95% CI: –0.05, 0.19; I^2=10%; P=0.24, *Figure 3G*).

Plasma renin activity

In our comparison of plasma renin activity following PA and TA surgery, we deployed a random-effects model and concluded that no statistically significant difference existed (WMD =0.08; 95% CI: –0.27, 0.43; I^2=0%; P=0.66, *Figure 3H*).

ARR

We used the ratio of aldosterone to renin to compare postoperative functional measures to more accurately reflect changes in postoperative functional measures. When we compared the ARR, there was also no significant difference between PA and TA. The random-effects model was used (WMD =13.58; 95% CI: –26.03, 53.18; I^2=58%; P=0.50, *Figure 3I*).

Early postoperative complications

In this paper, the classification and grading data of early complications were compared and classified according to Clavien-Dindo's complications. Combined with the data of early complications, there was no statistical significance between PA and TA in early complications (OR =0.78; 95% CI: 0.40, 1.51; I^2=0%; P=0.45, *Figure 3J*).

Tumor types

In our baseline data analysis, we identified six articles focused on Conn's, while the remaining articles included mixed cases of pheochromocytoma and conditions such as Cushing's or Conn's disease. To address this, we conducted an additional subgroup analysis, focusing on OT due to the availability of more data. A total of seven articles were included in this analysis. It was concluded that the OT of PA in the Conn's tumor group was short with TA (WMD

=−15.19; 95% CI: −24.05, −6.33; I^2=97%; P=0.0008, *Figure 4C*). In the mixed tumor group, the results were not statistically significant (WMD =−6.37; 95% CI: −15.02, 2.29; I^2=54%; P=0.15, *Figure 4C*).

Bias situation

Figure 1 shows that the funnel plot has significant bias and the graph is not symmetrical. We have created a deviation evaluation form to evaluate the reasons for this deviation (*Table 2*). We think that the possibility of data dispersion was due to significant differences in the years of the article.

Discussion

In this section, we examine the comparative results of PA and TA based on nine studies. Several key findings from this analysis merit further discussion.

We began by evaluating surgical outcomes, including OT, blood loss, and length of hospital stay. Our analysis revealed that PA typically had a shorter OT compared to TA, aligning with findings from most of the cited studies. Given the significant variability in the data, we performed a subgroup analysis to address this heterogeneity. We examined OT across different factors, including age, tumor size, year of publication, and total number of patients. The results showed no significant differences in operation time between PA and TA when being analyzed by tumor size, publication year, and total patient count. However, among patients ≤50 years old, PA had a shorter operation time than TA, with a high heterogeneity of 96%. To investigate the sources of this heterogeneity, we identified the study by Ishidoya *et al.*, which focused on a cohort with an average age under 50 years. This study included patient data collected between 1995 and 2004 (20). We observed a significant difference in operation time between the two groups in the study of Ishidoya *et al.*, with PA demonstrating a shorter operation time than TA. However, after excluding this article from our analysis, the heterogeneity was reduced to 66%, and the results were no longer statistically significant. This outcome may be attributed to factors such as the early publication date, the inclusion of data from varied tumor sites, differences in surgical techniques, and the varying proficiency of the operators involved. Next, we examined blood loss and length of stay. Our findings indicated minimal differences in blood loss between the two groups, consistent with the majority of the cited studies. However, to ensure the rigor of our analysis, we conducted a subgroup analysis for blood loss. This analysis revealed that for tumors smaller than 2.0 cm, blood loss was lower in the TA group compared to the PA group.

Finally, we compared the data of other articles with differences, for example, in study of Li *et al.*, they came to a different conclusion from ours: compared to TA, PA had fewer hospital stays, blood loss, and complications when dealing with unilateral aldosterone tumors (29). The reason for this difference may be that we have included more types of tumors, and there are also differences in the inclusion of surgical approaches, the difference between the peritoneal and retroperitoneal approaches may lead to heterogeneity in surgical results and affect data results. Furthermore, the site of adrenal tumor development could introduce additional heterogeneity and influence the outcome of the data. For example, Ishidoya *et al.* reported that if the tumor in PA is small enough and located on the periphery, especially at the top of the adrenal gland, the OT is shorter (20). Data from Fu *et al.* suggest that PA for tumors of the inferior adrenal pole or lower extremity requires more surgical and hemostatic time than for tumors of the upper extremity or outer surface (21).

Regarding the issue of most of the functional indicators appearing in our data being meaningless, when referring to the data from the Li *et al.* article, the biochemical data in the article also showed meaningless results. The write-up also highlighted that postoperative shifts in biochemical markers between PA and TA were not significantly different. Therefore, it cannot be concluded that PA had a higher recurrence rate compared to TA, our results also confirm this (29).

The dimensions of the tumor along with its functionality largely dictate the treatment strategy chosen. It has been reported that adrenal adenoma size is quantitatively positively correlated with cortisol autonomy and metabolic parameters (30). For tumors with biochemical function, incidental tumors with biochemical function are indications for laparoscopic surgery (31). However, most articles do not make a distinction between PA and TA, and the scope of application of PA and TA remains controversial. As to the question of choosing PA *vs.* TA, Kaye *et al.*, also noted in a 2010 article that the idea of preserving adrenal glands for patients with isolated adrenal or bilateral disease is supported by benefits that differ from chronic steroid replacement therapy. Addison's crisis has been reported in up to 35% of patients after bilateral adrenalectomy, with a mortality rate of 3% (32-36). However, in the past 10 years, the PA has been more and more respected. In article of

Zawadzka *et al.*, it was pointed out that the main advantage of PA over complete adrenalectomy is that it reduces the incidence of steroid dependence and thus reduces the risk of adrenal crisis (37). Fu *et al.* also pointed out that adenomas produced by aldosterone were an ideal choice for PA (21). Liu *et al.* also noted that PA can help preserve more adrenal function in younger patients. How much of the adrenal cortex can be retained to achieve this goal, other articles have suggested that a third of the gland can be retained to achieve this goal (19,24,38). However, our data results did not provide much functional indicators data to prove the difference between the two. Some articles have also pointed out that TA is superior to PA in certain conditions, such as Simforoosh *et al.*, who recommended that patients with unilateral aldosterone adenoma and primary aldosteronism should undergo TA instead of PA (23). But Kaye also pointed out that PA had not been fully utilized and advocated the use of PA to remove small, functional tumors, Chen *et al.* also held the same view on PA as Kaye expressing optimism about its prospects (18,36). Balci *et al.* also indicated that PA was safe and feasible in short term research (17).

The limitations of this article are as follows: firstly, this article is a retrospective study, and there are notable differences in the years of the included studies. These temporal variations may have introduced inconsistencies in surgical techniques and the skill levels of the surgeons, potentially impacting the results. Some studies did not conduct RCTs, but instead selected appropriate treatment methods based on the patient's condition, Secondly, there are significant differences in sample size in the literature we included, and there are also slight differences in data in follow-up time. In addition, different literature has different imaging criteria for inclusion and exclusion of patients.

Conclusions

Our findings indicate that PA has a shorter OT than TA, while TA shows more effectiveness in diastolic blood pressure recovery. No significant differences were observed between the PA and TA ungrouped data in terms of blood loss, duration of hospital stay, levels of serum aldosterone and potassium, systolic blood pressure, plasma renin activity, early complications, and postoperative ARR. In the subgroup analysis, when the patient was 50 years old or younger, the OT of PA was less than that of TA, and the tumor size was 2.0 cm or smaller, PA resulting in more surgical bleeding than TA. PA offers advantages in surgical outcomes compared to TA. However, for tumors ≤2 cm, TA may yield greater benefits for patients. Moreover, TA shows better recovery of diastolic blood pressure than PA when assessing functional indicators.

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Footnote

Reporting Checklist: The authors have completed the PRISMA reporting checklist. Available at https://gs.amegroups.com/article/view/10.21037/gs-24-345/rc

Peer Review File: Available at https://gs.amegroups.com/article/view/10.21037/gs-24-345/prf

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://gs.amegroups.com/article/view/10.21037/gs-24-345/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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