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A Comparative Review of the Efficacy of Laparoscopic Partial versus Total Adrenalectomy in the Treatment of Primary Aldosteronism Abstract

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Abstract: Primary aldosteronism (PA) is a leading cause of secondary hypertension, with radical treatment relying primarily on adrenal adenoma resection. Laparoscopic partial adrenalectomy (LPA) and total adrenalectomy (LTA) are the two mainstream surgical approaches in clinical practice. LPA has unique merits in preserving adrenal function, whereas LTA ensures more reliable therapeutic outcomes in specific cases by achieving complete lesion removal. This paper systematically reviews clinical evidence regarding the therapeutic efficacy, safety profiles, and postoperative hormonal function recovery of the two procedures. Integrating advancements in robot-assisted surgical technologies, it further discusses their respective indications and postoperative management strategies, aiming to provide a scientific foundation for individualized clinical decision-making.

Keywords: Laparoscopy; Partial Adrenalectomy; Total Adrenalectomy; Primary Aldosteronism; Efficacy Comparison; Hormonal Function Recovery

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1. Introduction

The comparative efficacy of LPA and LTA in PA treatment has emerged as a key focus in clinical research. PA, predominantly caused by adrenal adenomas, is characterized by hypertension and hypokalemia, severely impairing patients' quality of life. Traditionally, LTA was considered the gold standard. However, with the advancement of laparoscopic techniques, LPA— which preserves partial adrenal tissue— has gradually become a research hotspot.

Studies indicate that LPA can reduce the risk of postoperative hormonal dysfunction, effectively alleviate hypertension and hypokalemia, and decrease the need for long-term hormone replacement therapy[1]. Nevertheless, a consensus on their relative efficacy and safety remains elusive. Some research suggests that LPA has a higher failure rate in blood pressure control and hormonal normalization, with certain patients requiring further interventions postoperatively. LPA is more suitable for patients with small adenomas, while LTA is preferable for large tumors. Clinical selection of surgical approaches should be individualized based on patient-specific conditions, tumor size, and location. Further investigations into the long-term efficacy and safety of both procedures are warranted.

2. Pathogenic mechanism and surgical indications of primary aldosteronism

2.1. Pathogenic mechanism

PA is a major endocrine disorder leading to secondary hypertension, primarily caused by autonomous hypersecretion of aldosterone from adrenal adenomas. Aldosterone binds to mineralocorticoid receptors (MR) in renal tubules, upregulating the expression of epithelial sodium channels (ENaC) and sodium-chloride cotransporters (NCC). This enhances renal sodium reabsorption, triggering water and sodium retention and subsequent hypertension[2]. Concurrently, excessive aldosterone promotes potassium excretion, inducing hypokalemia and exacerbating hypertensive pathophysiology.

Clinically, PA is associated with secondary hyporeninemia due to negative feedback: elevated aldosterone levels suppress renin secretion, reducing plasma renin activity (PRA). Hypokalemia, a hallmark electrolyte disturbance in PA, is strongly linked to increased cardiovascular risk, highlighting the need to monitor aldosterone levels and electrolyte balance in hypertensive patients.

Genetic factors also play a critical role. KCNJ5 gene mutation is the most common pathogenic variant in aldosterone-producing adenomas (APA). It disrupts cellular calcium signaling pathways, driving excessive aldosterone secretion and correlating with tumor growth, clinical manifestations, and treatment responses. This provides a theoretical basis for the precise diagnosis and management of PA.

2.2. Surgical indications

Selecting appropriate indications for LPA and LTA is pivotal for PA treatment. The primary candidates are patients with unilateral adrenal adenomas refractory to medical therapy. When medications fail to control hypertension or electrolyte imbalances, surgical intervention is recommended. Laparoscopic procedures yield favorable outcomes in such cases[3], with LTA resulting in significant hypertension improvement and near-normalization of aldosterone levels in most patients.

Imaging and endocrinological assessments are essential for surgical planning. CT or MRI identifies the lesion side, while adrenal vein sampling (AVS) precisely locates the source of aldosterone hypersecretion, distinguishing unilateral adenomas from bilateral adrenal lesions to guide surgical selection.

Patient-specific factors, including general health and adrenal function, also influence surgical decisions. Elderly patients or those with comorbidities are better suited for LPA to minimize postoperative complications. LPA effectively preserves adrenal function and reduces long-term hormone replacement needs, an advantage supported by extensive clinical evidence.

2.3. Clinical considerations for surgical selection

Choosing between LPA and LTA requires comprehensive evaluation of patient conditions and postoperative hormonal recovery potential. LTA is indicated for large adenomas or tumors invading adjacent tissues, as it achieves complete lesion resection and effectively corrects hypertension and electrolyte disorders. A retrospective study of 96 APA patients demonstrated that all LTA recipients experienced improved hypertension and normalized hormonal levels.

LPA is suitable for localized tumors where normal adrenal tissue can be preserved, with its core advantage lying in reducing hormone replacement requirements. A systematic review noted that LPA is associated with shorter hospital stays and lower complication rates[4], but carries a relatively higher treatment failure rate (7.7% of patients show no improvement in hypertension or electrolyte levels postoperatively).

A comprehensive assessment of surgical risks and hormonal recovery is essential. A study of 234 patients found that the incidence of postoperative hypocortisolism was significantly lower in the LPA group than in the LTA group[5]. Clinicians should formulate individualized plans based on tumor size, patient health status, and expected postoperative recovery.

3. Clinical efficacy and safety of laparoscopic total adrenalectomy

3.1. Surgical techniques and procedures

LTA can be performed via transabdominal or retroperitoneal laparoscopic approaches, with the core objective of complete resection of diseased adrenal tissue. Laparoscopic adrenalectomy offers minimal trauma, rapid recovery, and low complication rates, making it the standard technique for adrenal tumor treatment.

Operative time, blood loss, and hospital stay are key safety metrics. Studies show that laparoscopic LTA has an average operative time of 69.8 minutes— significantly shorter than the 108.6 minutes of open surgery— with substantially less intraoperative bleeding.

Robot-assisted surgical technologies have further enhanced surgical precision, providing three-dimensional stereoscopic vision and flexible manipulation to address complex surgical scenarios. A systematic evaluation confirmed that robot-assisted surgery outperforms conventional laparoscopy in reducing blood loss and shortening hospital stays[6], while improving patient satisfaction and lowering complication risks.

3.2. Efficacy evaluation

Postoperative reductions in aldosterone levels and improved blood pressure control are core efficacy indicators for LTA. Research confirms that LTA achieves significant blood pressure improvement, with both aldosterone and potassium levels returning to normal ranges in all patients, demonstrating high therapeutic efficacy. In contrast, approximately 7.7% of LPA patients show no improvement in hypertension or hypokalemia, particularly those with multiple adenomas.

Postoperative potassium normalization and symptom relief are also critical efficacy measures. LTA recipients experience rapid potassium recovery and marked alleviation of symptoms such as headache and fatigue, significantly enhancing quality of life[7]. Conversely, residual adenomas after LPA may lead to persistent hypertension or hypokalemia, requiring continued antihypertensive medication.

Long-term follow-up indicates that LTA has a near-zero recurrence rate, with patients maintaining stable blood pressure and biochemical indicators over time[8]. LPA, however, carries a higher recurrence risk, especially in patients with multiple adenomas[9]. Clinical surgical selection should be based on individual patient conditions and adenoma characteristics.

3.3. Postoperative complications and hormonal impact

Postoperative adrenal insufficiency is a major complication of LTA, potentially requiring lifelong hormone replacement therapy and even triggering acute adrenal crisis in severe cases. Close monitoring of hormonal levels before and after surgery is essential to adjust treatment plans promptly.

Surgical complications, including bleeding, infection, and adjacent organ injury, cannot be overlooked. A retrospective analysis reported that 11.8% of patients experienced complications such as splenic hemorrhage and renal artery injury, which are closely related to surgical techniques, patient comorbidities, and operative details.

Postoperative hormonal monitoring and management are critical for patient prognosis. Regular measurement of serum aldosterone and other hormone levels enables early detection of adrenal insufficiency, with timely initiation of hormone replacement therapy to reduce complication risks and ensure safe recovery.

4. Efficacy and advantages of laparoscopic partial adrenalectomy

4.1. Surgical indications and technical key points

The primary indication for LPA is unilateral small tumors, especially benign adenomas with a diameter less than 5 cm. Preoperative CT or MRI is required to determine tumor size and location and assess surgical feasibility.

LPA is technically demanding, requiring surgeons to possess precise positioning and resection skills. Intraoperative pneumoperitoneum and high-definition endoscopes enhance visual clarity, facilitating accurate lesion identification and

resection[10]. Robot-assisted surgery further improves safety and precision, significantly reducing blood loss and shortening hospital stays in complex cases such as large tumors or obese patients. Additionally, robotic systems reduce instrument exchange frequency, optimize surgical field control, and enhance overall surgical quality.

4.2. Clinical efficacy and hormonal function protection

The core advantage of LPA is preserving functional adrenal tissue and reducing the incidence of postoperative hormonal deficiency. Studies show that LTA carries a higher risk of hormonal insufficiency, with some patients requiring long-term hormone replacement. In contrast, LPA recipients exhibit satisfactory aldosterone recovery and effective blood pressure control, with particularly notable efficacy in elderly patients and those with multiple adenomas.

A key distinction between the two procedures lies in postoperative hormone replacement requirements. LPA significantly reduces reliance on exogenous hormones, alleviating patients' economic burden and treatment dependence[11]. This benefit is directly attributed to the preservation of normal adrenal tissue, which also contributes to improved overall health and quality of life.

4.3. Postoperative recovery and complications

LPA is characterized by minimal surgical trauma and rapid recovery. Studies indicate that the average hospital stay for laparoscopic adrenalectomy (including LPA) is 39.3 hours, shorter than the 46.3 hours of open surgery. Fast recovery is attributed to minimal trauma, reduced bleeding, and low complication rates, enabling patients to resume daily activities and physiological functions more quickly.

Laparoscopic procedures have a significantly lower complication rate than open surgery, with most complications classified as mild Clavien-Dindo grade II. Three-dimensional laparoscopic systems further reduce blood loss and complications compared to traditional two-dimensional systems, improving patient satisfaction and long-term prognosis.

Notably, LPA patients require regular hormonal monitoring to assess residual adrenal function and recurrence risk. Hormonal fluctuations or recurrence may occur, particularly in the early postoperative period. Individualized follow-up plans are therefore necessary to facilitate timely intervention for recurrent hypertension or hormonal abnormalities.

5. Postoperative hormonal function recovery and replacement therapy

5.1. Variation pattern of postoperative hormonal levels

Adrenal cortical hormone levels generally decline in the early postoperative period, with the initial plasma cortisol measurement significantly lower than preoperative levels due to surgical stress and temporary adrenal dysfunction. After unilateral adrenalectomy, cortisol levels drop to their lowest point on postoperative day 1, but most patients' hormonal levels return to normal within 2–3 days via the compensatory function of residual adrenal tissue.

Monitoring adrenocorticotropic hormone (ACTH) levels is crucial for evaluating adrenal function recovery. Persistent hypohormonal levels may indicate adrenal insufficiency; if hormonal levels remain below the normal range 3 days postoperatively, hormone replacement therapy should be initiated promptly to prevent complications.

5.2. Indications and management of hormone replacement therapy

Hormone replacement therapy (HRT) is primarily indicated for patients with postoperative adrenal insufficiency, especially those undergoing LTA or LPA with significant hormonal decline. Cortisol and aldosterone are essential for maintaining blood pressure and electrolyte balance; their deficiency severely impacts patient health, necessitating close postoperative hormonal monitoring and targeted replacement therapy.

Preoperative hormonal levels and resection extent directly influence HRT requirements. Patients with preoperative adrenal insufficiency are more likely to need long-term HRT postoperatively. LPA reduces HRT dependence compared to

LTA due to preserved adrenal tissue.

Standardized postoperative monitoring and individualized treatment are key to improving quality of life. Clinicians should adjust HRT dosages based on patient gender, age, comorbidities, and recovery status, collaborating with multidisciplinary teams (endocrinology, surgery, etc.) to ensure efficacy and minimize treatment risks.

5.3. Monitoring value of related biological indicators

ACTH and morning cortisol levels are core indicators for evaluating adrenal function, reflecting pathological states and aiding in the diagnosis of endogenous aldosterone hypersecretion[12]. Morning cortisol levels directly indicate adrenal activity, providing a critical basis for clinical diagnosis and treatment.

Changes in blood eosinophil counts can assist in assessing hormonal status. Elevated eosinophil counts are associated with endocrine disorders, and their fluctuations in PA patients correlate with hormonal changes, serving as a supplementary monitoring tool.

Comprehensive evaluation combining biological indicators and clinical symptoms is essential. Some patients may present with symptoms despite normal hormonal levels, requiring further imaging or biomarker testing to optimize treatment plans and enhance precision.

6. Latest technological advances and future research directions

6.1. Application of robot-assisted surgical technology

Robot-assisted surgery is increasingly utilized in adrenal procedures, with platforms like the Senhance system significantly improving surgical accuracy and safety. A case series of 12 robot-assisted surgeries reported an average operative time of 165.1 minutes and estimated blood loss of only 47 ml, with all adenoma patients achieving biochemical remission, confirming the technology's feasibility in benign adrenal surgeries.

Robotic surgery demonstrates distinct advantages in LPA, enabling maximal preservation of healthy tissue and reducing postoperative complications. Studies show that robotic procedures shorten hospital stays and lower complication rates[13], with successful application in complex cases such as pediatric adrenal tumors.

With accumulating clinical data and technological advancements, robot-assisted surgery is expected to play an increasingly important role in adrenal disease treatment, offering patients superior therapeutic options.

6.2. Research on postoperative biochemical indicators and prognosis

Preoperative ACTH levels are closely correlated with postoperative hormonal recovery; higher preoperative levels often predict faster adrenal function normalization. Postoperative ACTH monitoring helps assess hormonal status and guide treatment adjustments.

Biomarker monitoring is valuable for evaluating postoperative recovery. Early detection of aldosterone, renin, and electrolyte levels can predict long-term outcomes and identify potential complications or hormonal dysfunction. A rapid postoperative decline in aldosterone levels typically indicates good recovery, while persistent elevation may signal incomplete adrenal function restoration.

Current research is largely limited to single-center, small-sample retrospective analyses, suffering from selection bias and limited generalizability. Large-scale, multicenter prospective studies are urgently needed to clarify the relationship between postoperative biochemical indicators and prognosis, providing a stronger evidence base for clinical practice.

6.3. Formulation of individualized surgical plans

The formulation of individualized surgical plans should be based on imaging evaluation and endocrinological testing results. CT and MRI examinations can clarify the tumor size, location, and its relationship with surrounding tissues, as well as determine the benign or malignant nature of the tumor and the presence of metastasis. [14]. Endocrinological tests assess

adrenal dysfunction severity, guiding decisions on preserving healthy tissue to minimize postoperative complications.

Advances in molecular diagnostic technology provide new insights for personalized planning. Molecular pathological analysis reveals tumor biological characteristics and malignancy potential, facilitating the selection of LPA or LTA to balance precise resection and functional preservation.

Multidisciplinary collaboration is key to advancing individualized and precision medicine for adrenal diseases. Close cooperation among endocrinologists, surgeons, pathologists, and radiologists enables comprehensive patient evaluation, particularly for complex cases such as familial pheochromocytoma or unclear unilateral/bilateral PA, significantly improving surgical success rates and patient prognosis.

7. Efficacy comparison and decision-making suggestions in clinical practice

7.1. Efficacy comparison between LPA and LTA

Both procedures effectively control aldosterone levels and hypertension. A study of 87 patients undergoing unilateral adrenalectomy found that 77% achieved complete biochemical success, with 65% reducing antihypertensive medication dosage[15], confirming the efficacy of surgical intervention.

LPA has a distinct advantage in preserving adrenal function. By retaining normal adrenal tissue, it maintains long-term hormonal stability and reduces hormone replacement needs, making it particularly suitable for patients with high hormone dependence. LPA also offers shorter hospital stays and faster recovery.

LTA is preferable for complex cases, such as multiple lesions or large tumors, as complete resection reduces recurrence risk. Studies show that LTA achieves more stable biochemical improvement and has a significantly lower long-term recurrence rate than LPA. Clinical surgical selection should be based on tumor characteristics, patient health status, and postoperative expectations.

7.2. Safety and complication rate analysis

LPA has lower postoperative complication rates and reduced risk of hormonal dysfunction due to minimal trauma, but it demands high technical proficiency and surgical experience.

LTA carries a relatively higher complication risk, including postoperative hormonal dysfunction, bleeding, and infection. Rigorous preoperative evaluation of patient medical history and health status is essential, with full disclosure of potential complications and management strategies to patients. Enhanced postoperative monitoring and management are also required.

Notable differences exist in the risk of postoperative hormonal dysfunction between the two procedures. LTA often causes a sharp decline in hormonal levels, potentially leading to metabolic disorders such as hypoglycemia and hypotension. In contrast, LPA results in milder hormonal fluctuations due to preserved adrenal function, benefiting long-term patient health. Clinicians should weigh the pros and cons, prioritizing LPA when adrenal function preservation is possible.

7.3. Individualized considerations in clinical decision-making

Tumor size, location, and adrenal function status are core determinants of surgical selection. For small, functionally intact tumors, LPA is preferred to preserve adrenal physiology. For large or dysfunctional tumors, LTA is more appropriate to ensure complete lesion removal and reduce recurrence risk.

Postoperative hormonal monitoring and replacement therapy should be individualized. LPA patients require regular aldosterone and hormone level monitoring to assess adrenal function recovery. LTA patients need long-term HRT plans, with dosage adjustments based on clinical response and potential adjunctive therapy with aldosterone antagonists to control blood pressure.

Patient preferences and postoperative quality of life should be incorporated into decision-making. Preoperative

communication to understand patient expectations and quality of life needs helps formulate patient-centered treatment plans. Postoperative quality of life assessments— including psychological state, physical recovery, and daily activity ability— are important metrics for evaluating surgical outcomes, ensuring that treatment maximizes both efficacy and quality of life.

8. Conclusion

LPA and LTA each have unique advantages and limitations in PA treatment. LPA effectively preserves adrenal function and reduces hormone replacement requirements, making it suitable for patients with localized tumors. LTA offers thorough lesion removal, lower recurrence rates, and more stable efficacy in complex cases. Postoperative monitoring of hormonal levels and ACTH is critical for evaluating recovery and guiding treatment adjustments.

Advancements in robot-assisted surgery have significantly improved surgical precision and safety, providing new solutions for complex cases. Individualized treatment is the core direction of future PA surgery, requiring the integration of imaging, endocrinological tests, and molecular diagnostics, combined with multidisciplinary collaboration to develop optimal patient-specific plans.

Current evidence on the long-term efficacy of LPA and LTA remains limited by the lack of large-scale prospective studies. Future research should focus on multicenter trials to validate existing findings, optimize surgical techniques and postoperative management, and advance PA treatment toward precision and individualization.

Disclosure statement

The author declares no conflict of interest.

References

[1] Hu X, Arthur Vithran DT, Yang Z, et al., 2025, Ectopic Adrenocortical Adenoma Causing Malignant Hypertension and Hypokalemia. Am J Case Rep, 26: e948022.

[2] Zennaro MC, Boulkroun S, Fernandes-Rosa FL, 2020, Pathogenesis and Treatment of Primary Aldosteronism. Nat Rev Endocrinol, 16(10): 578-589.

[3] Liu JH, Wei XD, Fu CC, et al., 2020, Long-Term Results of Laparoscopic Partial Versus Total Adrenalectomy for Aldosterone Producing Adenoma. Urol J, 17(4): 4981.

[4] Li KP, Duan X, Yang XS, et al., 2021, Partial Versus Total Adrenalectomy for the Treatment of Unilateral Aldosterone-Producing Adenoma: A Systematic Review and Meta-Analysis. Updates Surg, 73(6): 2301-2313.

[5] Billmann F, Billeter A, Thomusch O, et al., 2021, Minimally Invasive Partial Versus Total Adrenalectomy for Unilateral Primary Hyperaldosteronism: A Retrospective, Multicenter Matched-Pair Analysis Using the New International Consensus on Outcome Measures. Surgery, 169(6): 1361-1370.

[6] Gan L, Peng L, Li J, et al., 2022, Comparison of the Effectiveness and Safety of Robotic-Assisted and Laparoscopic in Adrenalectomy: A Systematic Review and Meta-Analysis. Int J Surg, 105: 106853.

[7] Knežević N, Penezić L, Kuliš T, et al., 2022, Senhance Robot-Assisted Adrenalectomy: A Case Series. Croat Med J, 63(2): 197-201.

[8] Ren R, Han H, Ma J, et al., 2024, Glucocorticoid Replacement Therapy After Retroperitoneal Laparoscopic Unilateral Adrenal Adenoma Resection in Patients with Non-Cortisol Secreting Tumors: A Retrospective Cohort Study. Gland Surg, 13(11): 2189-2197.

[9] Artiles Medina A, Gómez Dos Santos V, Mínguez Ojeda C, et al., 2025, The Role of Adrenal-Sparing Surgery in the

Management of Aldosterone-Producing Adenoma: A Systematic Review and Meta-Analysis. Eur J Endocrinol, 193(3): S36-S52.

[10] Coco D, Leanza S, 2025, Robotic Adrenalectomy: A Comprehensive Review of Perioperative Outcomes, Comparative Efficacy, and Technological Advancements. J Robot Surg, 19(1): 659.

[11] Guo RQ, Li YM, Li XG, 2021, Comparison of the Radiofrequency Ablation Versus Laparoscopic Adrenalectomy for Aldosterone-Producing Adenoma: A Meta-Analysis of Perioperative Outcomes and Safety. Updates Surg, 73(4): 1477-1485.

[12] Brown JM, Honzel B, Tsai LC, et al., 2025, Characterizing the Origins of Primary Aldosteronism. Hypertension, 82(2): 306-318.

[13] Xue Y, Li X, Tang Y, et al., 2024, Patient Satisfaction Analysis of Robot-Assisted Minimally Invasive Adrenalectomy: A Single-Center Retrospective Study. J Robot Surg, 18(1): 39.

[14] Carling T, LaRue M, 2025, Improved and Individualized Approach to Adrenal Surgery. Endocr Relat Cancer, 32(7).

[15] Hartmann I, Hruska F, Vaclavik J, et al., 2022, Hypertension Outcomes of Adrenalectomy for Unilateral Primary Aldosteronism. Endocrine, 76(1): 142-150.