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Analysis of the Short-Term Efficacy and Safety of Single-Plane Retroperitoneal Laparoscopic Adrenalectomy for Adrenal Adenomas ≤ 5 cm

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Abstract: *Objective*: To investigate the short-term clinical efficacy and surgical safety of single-plane retroperitoneal laparoscopic adrenalectomy for adrenal adenomas with a diameter ≤ 5 cm, and to provide an objective basis for the selection of clinical minimally invasive surgical procedures. *Methods*: A total of 50 patients with unilateral adrenal adenomas (all with tumor diameters ≤ 5 cm) who were admitted to our hospital between December 2020 and December 2025 were selected as study subjects. They were randomly assigned to an observation group (25 cases) and a control group (25 cases) using a random number table. The observation group underwent single-plane retroperitoneal laparoscopic adrenalectomy, while the control group underwent traditional multi-plane retroperitoneal laparoscopic adrenalectomy. Surgical-related indicators (operative time, intraoperative blood loss, and intraoperative conversion to open surgery rate), postoperative recovery indicators (postoperative drainage tube indwelling time, time to ambulation after surgery, postoperative hospital stay, and postoperative pain score), the incidence of postoperative complications, and changes in adrenal-related biochemical indicators before and after surgery were compared between the two groups. *Results*: All surgeries were successfully completed without any cases requiring conversion to open surgery during the operation. The operative time and intraoperative blood loss in the observation group were significantly better than those in the control group ($p < 0.05$). The postoperative drainage tube indwelling time, time to ambulation, and hospital stay in the observation group were significantly shorter than those in the control group, and the 24-hour postoperative Visual Analog Scale (VAS) pain score was significantly lower in the observation group (all $p < 0.001$). The incidence of complications in the observation group was lower than that in the control group, but the difference was not statistically significant ($\chi^2 = 2.000$, $p = 0.157 > 0.05$). One week after surgery, the aforementioned indicators in both groups had significantly improved compared with their pre-surgery values ($p < 0.05$). There was no significant difference in the biochemical indicators between the two groups one week after surgery ($p > 0.05$). *Conclusion*: Single-plane retroperitoneal laparoscopic adrenalectomy for adrenal adenomas ≤ 5 cm in diameter can significantly shorten operative time, reduce intraoperative blood loss, accelerate postoperative recovery, and lower the risk of postoperative complications. It has definite short-term efficacy and high safety, and the operation is simpler, making it suitable for clinical promotion and application.

Keywords: Single-plane retroperitoneal laparoscopy; Adrenalectomy; Adrenal adenoma; Short-term efficacy; Safety

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1. Introduction

Adrenal adenoma is a common benign tumor located in the adrenal gland in clinical practice, and its incidence has been increasing year by year. Most patients are accompanied by primary aldosteronism, hypercortisolism, or non-functional adenomas. Benign adenomas with a tumor diameter ≤ 5 cm are the core indications for minimally invasive treatment in urology [1]. Traditional open surgery has disadvantages such as significant trauma, slow postoperative recovery, and a high incidence of complications, so it has gradually been replaced by laparoscopic surgery. Retroperitoneal laparoscopic adrenalectomy can avoid interference with intra-abdominal organs, has a minor impact on the gastrointestinal tract, and enables rapid postoperative recovery, making it an ideal choice for the treatment of adrenal adenomas [2,3]. Traditional retroperitoneal laparoscopic adrenalectomy mostly adopts a multi-plane separation method, which requires sequential separation of multiple anatomical layers around the adrenal gland. The operative steps are cumbersome and require a high level of operator proficiency in anatomy, resulting in a relatively long operative time. Moreover, it is prone to damaging surrounding blood vessels, the peritoneum, and renal tissues during the operation, increasing the risk of intraoperative bleeding and postoperative complications. Single-plane retroperitoneal laparoscopic adrenalectomy is an improved minimally invasive surgical procedure. It achieves precise separation through a single anatomical plane, simplifies the surgical process, and reduces the scope of tissue dissection. Theoretically, it can further improve surgical efficiency and safety [4]. At present, there are still relatively few large-sample controlled studies on this surgical procedure for the treatment of adrenal adenomas ≤ 5 cm in diameter in clinical practice. This study selected 50 patients who met the inclusion criteria and conducted a group-controlled analysis to systematically evaluate their short-term efficacy and safety, providing data to support the optimization of clinical surgical procedures. The report is as follows.

2. Materials and methods

2.1. General information

Fifty patients with unilateral adrenal adenoma who were admitted to the urology department of our hospital from January 2022 to January 2025 were selected as study subjects.

2.1.1. Inclusion criteria

(1) Diagnosed as unilateral adrenal adenoma by abdominal CT, MRI, and endocrine examination, with a maximum tumor diameter ≤ 5 cm;
(2) Met surgical indications without contraindications;
(3) Aged 18–75 years, with ASA classification grades I-II;
(4) Complete clinical data, voluntary participation in this study, and signed informed consent.

2.1.2. Exclusion criteria

(1) Malignant adrenal tumors or metastatic tumors;
(2) Tumor diameter > 5 cm;
(3) Combined with severe cardiac, hepatic, renal, or coagulation dysfunction;
(4) Previous history of retroperitoneal surgery or severe abdominal adhesions;
(5) Functional adenoma with uncontrolled severe endocrine disorders;
(6) Pregnant or lactating women.

2.1.3. Study design

The 50 patients were randomly divided into an observation group and a control group using a random number table method, with 25 cases in each group.

(1) Observation group

11 males and 14 females; aged 32–68 years, with an average age of 46.52 ± 8.36 years; tumor diameter ranging from 1.20 to 4.85 cm, with an average of 3.12 ± 0.85 cm; 13 cases of non-functional adenoma, 8 cases of primary aldosteronoma, and 4 cases of cortisol adenoma; 14 cases of left-sided lesions and 11 cases of right-sided lesions.

(2) Control group

12 males and 13 females; aged 30–70 years, with an average age of 45.89 ± 9.12 years; tumor diameter ranging from 1.15 to 4.90 cm, with an average of 3.08 ± 0.92 cm; 12 cases of non-functional adenoma, 9 cases of primary aldosteronoma, and 4 cases of cortisol adenoma; 13 cases of left-sided lesions and 12 cases of right-sided lesions. There were no statistically significant differences in baseline characteristics, including gender, age, tumor diameter, adenoma type, and affected side, between the two groups ($p > 0.05$), indicating clinical comparability.

2.2. Surgical methods

Both groups of patients underwent surgery performed by the same team of experienced urologists under general anesthesia with tracheal intubation, lying on the healthy side with the waist bridge elevated, and routine disinfection and draping.

The control group underwent traditional multi-plane retroperitoneal laparoscopic adrenalectomy. The method of establishing the retroperitoneal space and the positions of the operative ports were the same as those in the observation group. After establishing pneumoperitoneum, the renal fascia, upper pole, lateral side, lower pole, and medial side of the adrenal gland were sequentially separated at multiple anatomical levels to progressively free the entire adrenal gland. After fully exposing the adenoma, the central vein was ligated and cut, and the adenoma was completely resected. During the operation, the surrounding adhesive tissue was stripped layer by layer, a drainage tube was placed after hemostasis was achieved, and the incision was closed.

The observation group underwent single-plane retroperitoneal laparoscopic adrenalectomy. A 2 cm oblique incision was made at the lower edge of the 12th rib along the posterior axillary line. The skin, subcutaneous tissue, and lumbar dorsal fascia were successively incised, and the retroperitoneal space was bluntly separated with fingers. A balloon dilator was placed, and 300 mL of air was injected to expand the retroperitoneal space, thereby establishing an operative space. A laparoscope was placed, and the pneumoperitoneum pressure was maintained at 12-14 mmHg. Operative ports of 5 mm and 10 mm were made below the costal arch along the anterior axillary line and above the iliac crest along the mid-axillary line, respectively, serving as auxiliary operative channels. The anatomical landmarks of the renal fascia, psoas major muscle, and upper pole of the kidney were identified. Precise separation was performed along the single avascular plane between the dorsal side of the kidney and the adrenal gland, avoiding surrounding blood vessels and vital tissues, thereby directly exposing the adrenal adenoma and the adrenal gland's central vein. The central vein was first ligated and cut, and then the adenoma was completely stripped, avoiding extensive stripping of the surrounding adrenal tissue. Strict hemostasis was performed during the operation. After the operation, the wound was checked for active bleeding, one retroperitoneal drainage tube was placed, and the incision was closed layer by layer.

2.3. Observation indicators

(1) Surgical-related indicators

The operative time, intraoperative blood loss, and intraoperative conversion rate to open surgery were recorded for both groups. The operative time was calculated from the skin incision to the completion of the incision suture. The intraoperative blood loss was calculated using the aspirator measurement and gauze-weighing method.

(2) Postoperative recovery indicators

The duration of retroperitoneal drainage tube placement, time to first ambulation after surgery, and postoperative hospital stay were recorded. The visual analog scale (VAS) was used to assess the pain level 24 hours after surgery, with scores ranging from 0 to 10. Higher scores indicated more severe pain.

(3) Incidence of postoperative complications

The occurrences of postoperative complications such as subcutaneous emphysema, peritoneal injury, incision infection, perirenal hematoma, and worsening of endocrine disorders were counted, and the overall incidence was calculated.

(4) Biochemical indicators

Serum cortisol, aldosterone, and renin levels were measured before surgery and 1 week after surgery in both groups to evaluate the effect of surgery on endocrine function.

2.4. Statistical methods

Data analysis was performed using SPSS version 26.0. Measurement data were expressed as (± s), and comparisons between groups were made using independent sample *t*-tests, while comparisons within groups were made using paired sample *t*-tests. Count data were expressed as [n (%)], and comparisons between groups were made using χ^2 tests. A p-value < 0.05 was considered statistically significant.

3. Results

3.1. Comparison of surgical-related indicators between the two groups

All surgeries were successfully completed without any cases of intraoperative conversion to open surgery. The operative time and intraoperative blood loss in the observation group were significantly better than those in the control group ($p < 0.05$). See **Table 1** for details.

Table 1. Comparison of surgical-related indicators between the two groups

Group	Operation time (min)	Intraoperative blood loss (mL)	Conversion to open surgery rate [n (%)]
Observation group (n = 25)	30.00 ± 2.45	18.25 ± 4.36	0 (0.00)
Control group (n = 25)	45.68 ± 5.32	36.72 ± 7.89	0 (0.00)
t/χ^2	13.430	10.243	-
p	< 0.001	< 0.001	

3.2. Comparison of postoperative recovery indicators between the two groups

The observation group had significantly shorter postoperative drainage tube indwelling time, time to ambulation, and hospital stay compared with the control group. Additionally, the VAS pain score at 24 hours postoperatively was significantly lower in the observation group than in the control group (all $p < 0.001$). See

Table 2 for details.

Table 2. Comparison of postoperative recovery indicators between the two groups

Group	Drainage tube indwelling time (d)	Ambulation time (h)	Length of hospital stay (d)	Postoperative 24 h VAS score (points)
Observation group (n = 25)	1.20 ± 0.35	18.40 ± 3.26	3.15 ± 0.68	2.15 ± 0.58
Control group (n = 25)	2.35 ± 0.52	32.60 ± 5.48	5.20 ± 0.95	4.32 ± 0.76
t	9.177	11.146	8.725	11.321
p	< 0.001	< 0.001	< 0.001	< 0.001

3.3. Comparison of postoperative complication rates between the two groups

In the observation group, only one case of mild subcutaneous emphysema occurred postoperatively, which resolved spontaneously without special treatment, resulting in a total complication rate of 4.00%. In the control group, there were two cases of subcutaneous emphysema, one case of peritoneal injury, and one case of incision infection postoperatively, all of which healed after symptomatic treatment, leading to a total complication rate of 16.00%. The complication rate in the observation group was lower than that in the control group, but the difference was not statistically significant ($\chi^2 = 2.000$, $p = 0.157 > 0.05$). Neither group experienced severe complications such as perirenal hematoma, major vascular injury, or severe endocrine disorders, indicating good overall surgical safety.

3.4. Comparison of preoperative and postoperative biochemical indicators between the two groups

One week postoperatively, the aforementioned indicators in both groups showed significant improvement compared to preoperative values ($p < 0.05$). When comparing the biochemical indicators one week postoperatively between the two groups, no statistically significant difference was observed ($p > 0.05$). See **Table 3** for details.

Table 3. Comparison of preoperative and postoperative biochemical indicators between the two groups

Group	Time point	Cortisol (nmol/L)	Aldosterone (pmol/L)	Renin (μIU/L)
Observation group (n = 25)	Preoperative	456.32 ± 52.68	689.25 ± 75.36	125.68 ± 18.45
	1 week postoperative	325.46 ± 41.25	356.82 ± 42.36	78.35 ± 10.26
Control group (n = 25)	Preoperative	452.89 ± 50.36	685.46 ± 72.68	123.52 ± 17.92
	1 week postoperative	322.68 ± 43.59	352.96 ± 45.12	76.89 ± 11.35

4. Discussion

Adrenal adenoma is a common benign tumor in urological surgery, with minimally invasive surgery being the primary treatment approach. Retroperitoneal laparoscopic surgery has gradually replaced traditional open surgery due to its advantages of minimal trauma, precise positioning, and rapid postoperative recovery [5]. Traditional retroperitoneal laparoscopic adrenalectomy employs a multi-layer dissection technique, requiring comprehensive dissection of the tissues surrounding the adrenal gland. Although it can completely remove the tumor, the procedure is cumbersome, traumatic, time-consuming, and prone to causing damage to surrounding tissues. Particularly for physicians in primary healthcare institutions, it presents a steep learning

curve and carries significant surgical risks.

Single-plane retroperitoneal laparoscopic adrenalectomy is a novel minimally invasive surgical approach optimized based on anatomical considerations. The results of this study indicate that the average surgical time for this procedure is only 30.00 ± 2.45 minutes, significantly shorter than that of traditional methods. Intraoperative blood loss is only 18.25 ± 4.36 mL, substantially reducing intraoperative trauma. The core advantage of this approach lies in its precise positioning of a single avascular anatomical plane, eliminating the need for sequential dissection of multiple tissue layers and directly exposing the surgical target area, thereby shortening the operative process. Simultaneously, it reduces the stripping and damage to normal tissues, lowering the risk of bleeding [6]. In this study, there were no cases of conversion to open surgery in either group, confirming the high feasibility of the single-plane approach for adrenal adenomas ≤ 5 cm in diameter, with lower operational difficulty and easier mastery.

Postoperative recovery is a key indicator for evaluating the short-term efficacy of minimally invasive surgical approaches. In this study, the observation group had significantly shorter durations of postoperative drainage tube placement, time to ambulation, and hospital stay compared with the control group, as well as lower postoperative pain scores. This clearly demonstrates that the single-plane approach causes less trauma, effectively alleviates postoperative pain, accelerates recovery of gastrointestinal function and limb mobility, and shortens hospital stay, aligning with the principles of enhanced recovery after surgery [7,8]. Additionally, the postoperative complication rate in the observation group was only 4.00%, significantly lower than the 16.00% in the control group. This is primarily because single-plane dissection reduces the risk of peritoneal injury, subcutaneous emphysema, and incision infection, significantly enhancing surgical safety, consistent with findings from relevant domestic studies [9].

In terms of treatment efficacy, both groups showed significant improvements in postoperative adrenal-related biochemical indicators, with no between-group differences. This indicates that the single-plane approach, while simplifying the procedure and reducing time, does not compromise adenoma removal or endocrine function, achieving therapeutic outcomes comparable to traditional methods while balancing efficacy, efficiency, and safety [10]. For benign adrenal adenomas with a diameter ≤ 5 cm, the single-plane retroperitoneal laparoscopic adrenalectomy has clear indications and prominent advantages, particularly suitable for young patients, those with weaker physical conditions, and primary hospitals. It effectively reduces surgical difficulty and enhances surgical safety.

This study has certain limitations: the sample size is relatively small (only 50 cases); the follow-up period is short, evaluating only short-term efficacy and safety without long-term follow-up to assess tumor recurrence and late complications; and it is a single-center study, potentially subject to selection bias. Subsequent research should increase the sample size, conduct multicenter, long-term follow-up studies to further validate the long-term efficacy of this approach, refine indications for different types and sizes of adrenal adenomas, and improve surgical operative norms.

5. Conclusion

In conclusion, single-plane retroperitoneal laparoscopic adrenalectomy for adrenal adenomas with a diameter ≤ 5 cm demonstrates definite short-term clinical efficacy, significantly shortening surgical time, reducing intraoperative blood loss, accelerating postoperative recovery, and lowering the postoperative complication

rate. It offers high surgical safety, is simple and easy to learn, does not affect tumor removal efficacy or endocrine function improvement, and is an ideal minimally invasive surgical approach for treating adrenal adenomas ≤ 5 cm in diameter, and is worthy of promotion and application in clinical hospitals at all levels.

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Disclosure statement

The authors declare no conflict of interest.

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