Retroperitoneoscopic Anatomical Adrenalectomy

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1 Overview

More than 90% of adrenal tumors are benign lesions and small in size. It has a complex anatomy due to the deep location and closely related to many important structures including liver, spleen, pancreas, inferior vena cava and renal vessels. Open adrenectomy requires 20–30 cm length skin incision to resect a 2–3 cm tumors. This is a complicated surgery with high risk of mortality when injury to major vessels and vital organs. Laparoscopic technology, has gained great popularity worldwide for its prominent minimally invasive advantages including less traumatic, quick recovery, minimal postoperative pain, shorter hospital stay and small scar. With the evidences from large number of clinical trials and multi-center comparative analysis, it has replaced the open surgery as the mainstream surgical approach in the era of minimally invasive surgery due to its safety and reliability [1].

Laparoscopic adrenalectomy can be performed either transperitoneally or retroperitoneally. At present, surgeons from foreign countries such as Europe and United States prefer transperitoneal approach Adrenal exposure is the main problem for transperitoneal laparoscopic adrenalectomy that involves mobilization of few vital organ. This surgery is relatively complicated, and prone to adjacent organs injury. Although lower than open adrenectomy, its reported complication rate is approaching 10.3%. Furthermore it consumes long operation duration and requires long learning curve [2, 3]. In China, most laparoscopic adrenalectomies are performed through retroperitoneal approach [4, 5]. In comparison to transperitoneal approach, studies have shown that retroperitoneal approach have the advantages of less bleeding, faster recovery, and less postoperative ileus [6]. However, limitations of retroperitoneal laparoscopic adrenalectomy include small operative space, difficulty in locating the adrenal gland, especially obese patients, and poor blood vessels exposure [1]. The author had systematically studied anatomy of adrenal gland within the retroperitoneal space and its surgical application since 2000, to improve surgical dissection of adrenal gland retroperitoneally. There are three relatively avascular spaces around the three surfaces of the adrenal gland, which are ventral, dorsal and renal surface. Retroperitoneal laparoscopic anatomical adrenalectomy was described; these three anatomical planes were sequentially dissected to expose the adrenal gland. By dissecting these anatomical planes, vital organs and major vessels adjacent to adrenal gland can be clearly identified, adrenal gland and vessels will be fully exposed, operation time can be shortened and complication rate is significantly reduced. Principles that should be comply when performing adrenalectomy include early localization and complete exposure of adrenal gland, dissection along the adrenal capsule, and minimal direct contact with adrenal gland and tumor and exposure of suprarenal vein [4, 7]. Up to date, our center had completed about 3000 retroperitoneal laparoscopic adrenalectomies with variety of adrenal diseases.

2 Indications and Contraindications

1. **Indications** Retroperitoneal laparoscopic anatomical adrenalectomy is suitable for most adrenal surgical diseases, including:
   (a) Hypercortisolism and primary hyperaldosteronism due to adrenocortical carcinoma or hyperplastic diseases;

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(b) Hypercatecholaminism due to adrenal medullary hyperplasia and adrenal pheochromocytoma;
(c) Nonfunctioning incidentaloma bigger than 3 cm, including adrenal cyst, adrenal medullary lipoma, ganglioneuroma, etc.;
(d) Localized adrenal malignant carcinoma without obvious local invasion on capsule or vessel;
- Solitary metastatic adrenal carcinoma with specific primary lesion [8].

2. **Contraindications** Common contraindications including
(a) Obvious invasion into surrounding organs or distant metastasis is detected before the surgery;
(b) Patient with uncorrected coagulopathy.
(c) Patient who are medically unfit for surgery [8].

Giant adrenal tumor with abundant of blood supply are challenging for laparoscopic approach. Adrenal tumors more than 10 cm in diameter, was once considered as a contraindication of laparoscopic surgery [3, 9]. But with the accumulation of experience in laparoscopic adrenalectomy, case reports regarding successful resection of large adrenal tumor are increasing in number. Other relative contraindications include obesity, pregnancy and previous upper abdomen surgery. The largest tumor that was resected by author was 14 cm in diameter, high level of laparoscopic was required to performed such operation [2, 4, 10, 11].

3 Perioperative Management

1. **General preparations** include routine preoperative investigations, qualitative and localization examinations required for a definite diagnosis:
(a) Routine preoperative investigations include full blood count, renal profile, liver function test, coagulation profile, serum blood glucose, blood cross match and urine FEME.
(b) Qualitative and localization examinations: The diagnosis of adrenal disease requires both of these examinations. This part of the examination can be completed with the co-management from endocrinologist colleague. Currently in our centre, endocrine examinations are performed by endocrinologist. Patient will be transferred to urology ward for adrenal surgery after fully investigated. Qualitative diagnosis is combination of patient's clinical presentation, physical examination, and selective adrenal hormone levels. Corticosteroid tests include the serum cortisol level and its metabolites, serum ACTH, aldosterone, renin-angiotensin-aldosterone, and other Medulla hormone tests include serum adrenaline, norepinephrine, catecholamine, 24-h urine VMA and other. Localization diagnosis can be done with color Doppler ultrasound, multiphases CT scan and MRI. MRI provides better images for pheochromocytoma through the high intensity transient signals on the tumor with T2-weighted images. 131I-MIBG (131 meta-iodobenzyl guanidine) examination is confirmation test for bilateral pheochromocytoma and atypical pheochromocytoma [3].

2. **Special preparation** Patients with functional adrenal tumors always have varying degrees of endocrine and metabolic disorders that will increase the risk general anesthesia, due to complex pathophysiological changes caused by endocrine dysfunction.
(a) **Preoperative preparation of primary hyperaldosteronism patients**

The principles include blood pressure control, correction of electrolyte imbalance and hypokalemic alkalosis, maintain normal serum potassium level and normal ECG tracing.

The approaches are:
(1) Oral intake of spironolactone, 40~60 mg, tds or qid.
(2) Oral intake of potassium 4~6 g od
(3) Antihypertensive drugs should be started for patients with severe hypertension to control blood pressure. Generally, patient undergoes tumor resection and unilateral adrenalectomy due to aldosteronoma or adrenal hyperplasia does not require hormone supplements [12].

(b) **Preoperative preparation of patients with Cushing's syndrome**

Hormone supplements are given to control blood pressure and blood glucose, to correct electrolyte turbulence and acid-base disturbance; prophylaxis antibiotic is prescribed as well. Hormonal replacement therapy is the most important treatment, IM cortisone acetate 100–200 mg is injected at the night before surgery and morning of surgery day. Another 100 mg cortisone acetate injection is given again soon after the surgery. Intramuscular cortisone acetate injection is given every 8 h for the first 2 days after the surgery, then once for every 12 h for the next 2 days. Subsequently, cortisone acetate 25 mg is given orally twice a day as maintenance dose, together with fluorocortisone 0.1 mg Qd for 1 month or longer [5, 13, 14].

(c) **Preoperative preparation of patients with hypercatecholaminism:** The principles of preparation are vascular bed expansion, control of blood pressure and plasma volume expansion.

The approaches are:
(1) α adrenergic receptor blocker is given preoperatively to expand the peripheral blood vessels. Oral prazosin tds is given for 10–14 days before surgery; phenoxybenzamine 10 mg tds or qid can be given and gradually increased to the sufficient dose to prevent the hypertensive episode.

(2) Patients with tachycardia or arrhythmia, can be added with cardiovascular selective β receptor blocker when the effect of α adrenergic receptor blocker is stable. Preoperative heart rate should be controlled at less than 90/min.
(3) Expanding the plasma volume and controlling the blood pressure before operation can prevent intraoperative fluctuations of blood pressure, promote postoperative stabile blood pressure recovery. Intravenous volume can be expanded by giving 1000~2000 mL intravenous fluid with crystalloid colloid ratio of 2:1.
(4) Atropine should be avoided during surgery due to its vagal inhibition effect that can increase the heart rate and induce arrhythmias [3].

4 Operating Procedure

(1) Anesthesia and patient position

Operation is performed under general anesthesia with tracheal intubation, nasogastric tubes and urinary catheter are inserted. Patient is positioned to lateral decubitus position with extended flank. For the patients with suspected hypercatecholaminism, central venous line and arterial line should be inserted to monitor central venous pressure and radial artery pressure; big bore intravenous line should be inserted for medication infusion and fluid resuscitation.

(2) Right adrenectomy (all the images are taken from one patient)
   (a) Preparation of retroperitoneal space and trocars configuration are described in detail in Chap. 1.
   (b) Mobilization of retroperitoneal adipose tissue from Gerota's fascia is described in detail in Chap. 1 (Fig. 2.1).
   (c) Gerota's fascia is incised longitudinally just posterior to peritoneal reflection, superiorly from the indentation that is the meeting point of peritoneal reflection and psoas muscle to iliac fossa inferiorly (Fig. 2.2).
   (d) Avascular space between the perirenal fat capsule and the anterior layer of prerenal fascia is dissected as first anatomical plane; the white loose areolar tissues should be identified for entering the correct plane.
   (e) First anatomical plane is bluntly dissected; blood vessel is divided with ultrasonic apparatus. The dissection is advanced medially to expose the anterior surface of adrenal gland or tumor. This step is critical for the early localization of adrenal tumors. For right sided adrenectomy, dissection should be medially advanced from the adrenal gland to expose the inferior vena cava (Figs. 2.3, 2.4, and 2.5).

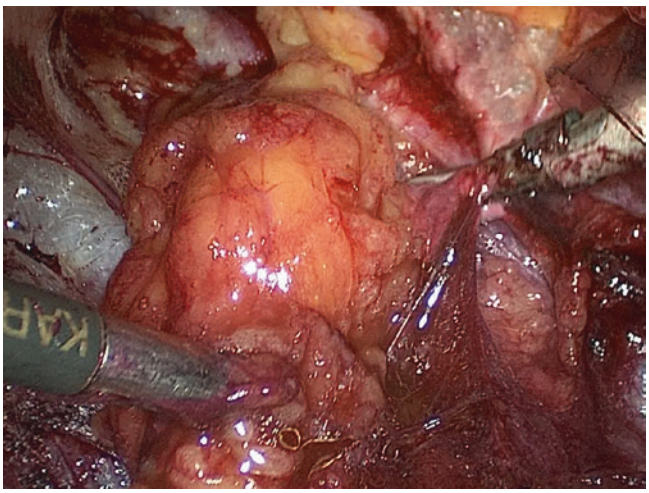

Fig. 2.1 Mobilization of retroperitoneal adipose tissue

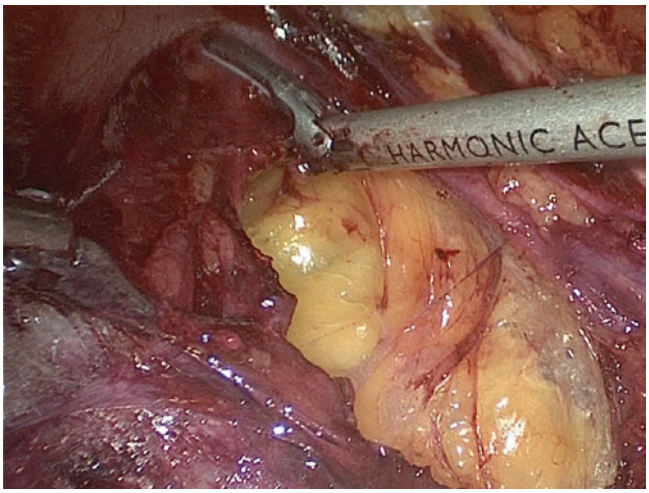

Fig. 2.2 Longitudinal incision at the Gerota's fascia

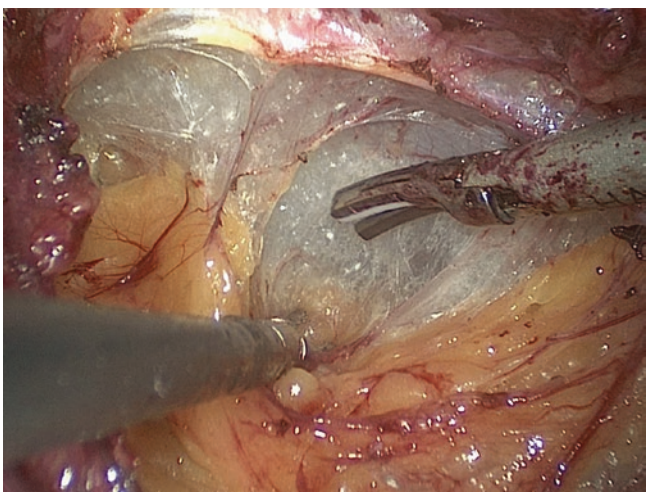

Fig. 2.3 Dissection of the first anatomical plane and identification of white loose areolar tissue

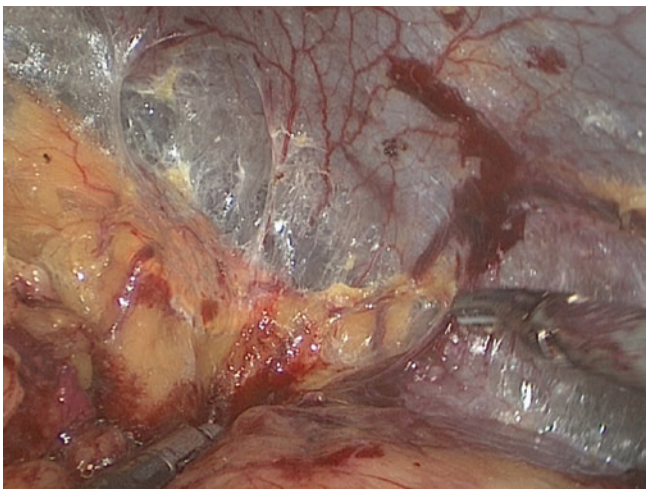

Fig. 2.4 Medial dissection of first anatomical plane and exposure of facies ventralis of the adrenal grand

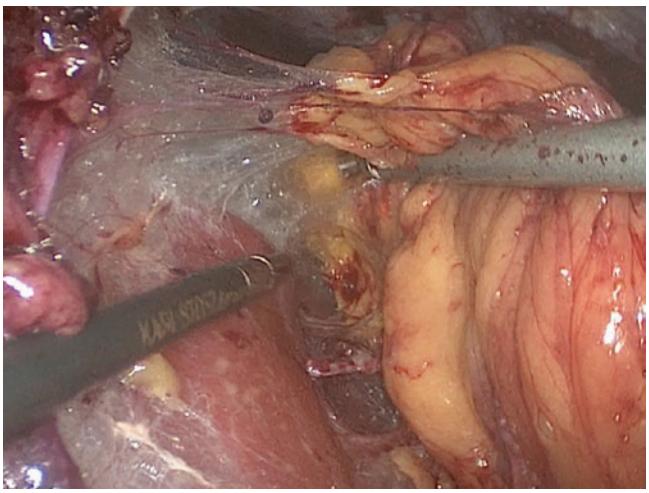

Fig. 2.6 Second anatomical plane dissection and tumor exposure

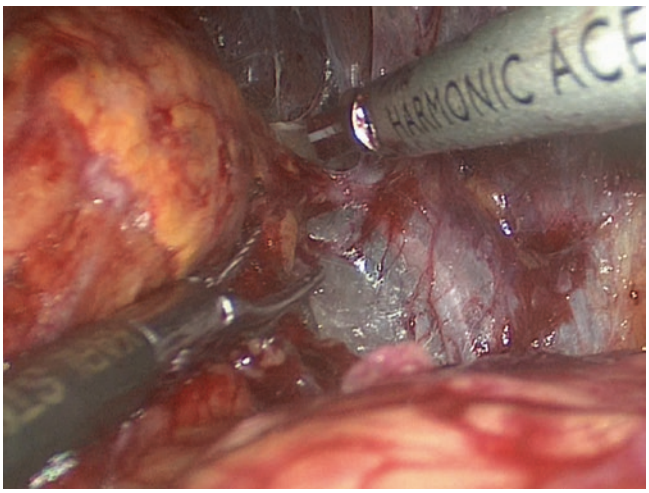

Fig. 2.5 Medial dissection of first anatomical plane is advanced until identification of inferior vena cava

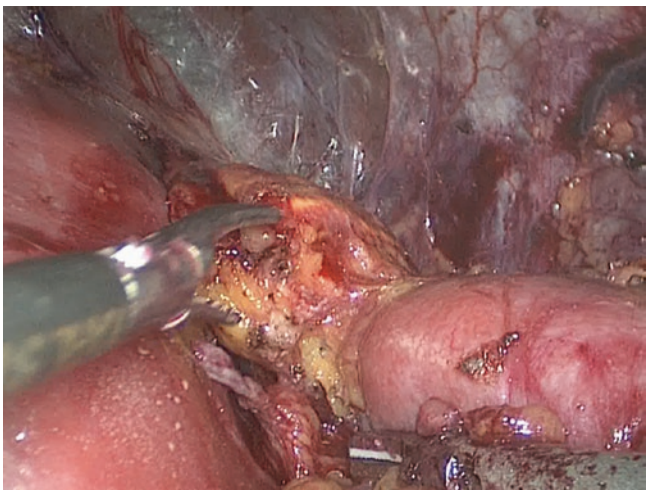

Fig. 2.7 Adipose tissue excision at the upper pole of kidney

(f) The second anatomical plane is a relatively avascular space posterior to the kidney, which is located between the perirenal fat capsule and posterior perirenal fascia. This plane is dissected superiorly to meet the first separation layer, and dissected medially to the medial surface of upper pole of kidney. Blood vessels from the psoas muscle can be divided with ultrasonic apparatus, or ligated with Hem-O-Lok clips. The vessels do not need to be divided if they do not affect the surgery. Dissection of this plane is to expose the facies lateralis of the adrenal gland and enlarge the operating space. Some tumors are posteriorly located, and can only be exposed by separating this plane (Fig. 2.6).

(g) Part of the perirenal fat at the upper pole is excised to expose the kidney surface. This step is important to identify the third anatomical plane, especially for obese patients; this step can be skipped for thin patient (Fig. 2.7).

(h) Space between the surface of upper pole and periadrenal adipose tissue at the base of adrenal gland is identified as the third anatomical plane, the periadrenal adipose tissue is retracted upward gently, and dissected from the surface of upper pole. Right suprarenal vein will be expose after the base of adrenal gland is fully dissected and retracted. The right suprarenal vein travels obliquely into the vena cava. Suprarenal vein is ligated with Hem-O-Lok clip and divided (Fig. 2.8).

(i) There are many adrenal artery branches at the base of adrenal gland. The base of adrenal gland is dissected with combination of blunt and sharp dissection, blood vessel must be isolated, ligated and divided (Fig. 2.9).

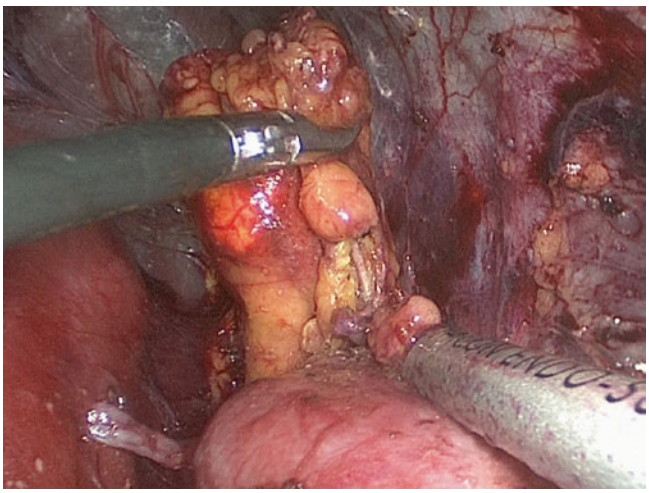

Fig. 2.8 Dissection of the third anatomical plane

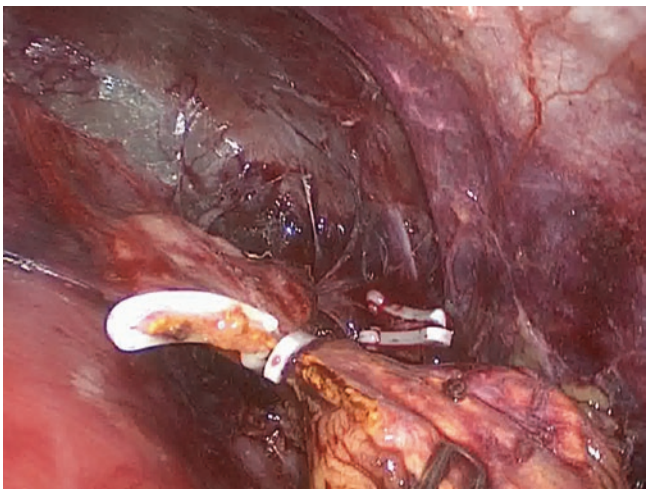

Fig. 2.10 Adrenal gland along tumor margin was clipped with Hem-O-Lok clips and tumor was excised from adrenal gland

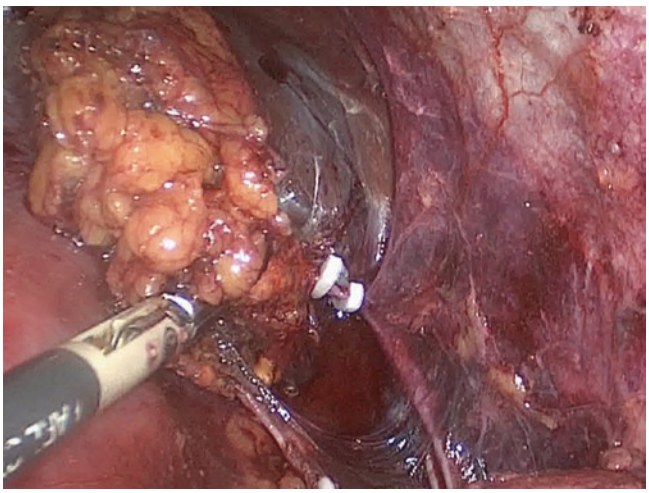

Fig. 2.9 Ligation of suprarenal vein with Hem-O-Lok clips

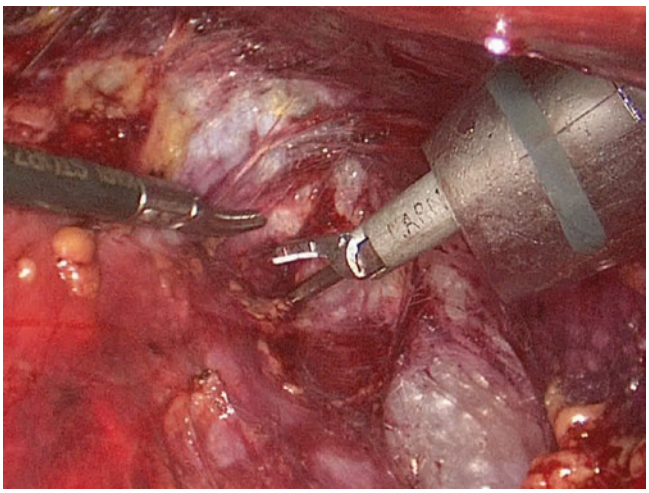

Fig. 2.11 Mobilization of retroperitoneal adipose tissue

(j) Adrenal gland along tumor margin is clipped with Hem-O-Lok clips and tumor is excised from adrenal gland. Adrenal gland should be preserved as much as possible during the excision. For upper pole adrenal tumor, adhesive tissue between the upper pole of adrenal gland and diaphragm for complete tumor exposure and excision. Pneumoperitoneum pressure is reduced to 3~5 mmHg to check and secure hemostasis. Tumor is removed through skin incision from third trocar incision within a specimen bag (Fig. 2.10).

(3) Left adrenalectomy

(a) Preparation of retroperitoneal space and trocars configuration are described in detail in Chap. 1.

(b) Mobilization of retroperitoneal adipose tissue from Gerota's fascia is described in detail in Chap. 1 (Fig. 2.11).

(c) Gerota's fascia is incised longitudinally just posterior to peritoneal reflection, superiorly from the indentation that is the meeting point of peritoneal reflection and psoas muscle to iliac fossa inferiorly (Fig. 2.12).

(d) Avascular space located between the perirenal fat capsule and the anterior layer of prerenal fascia is dissected as the first anatomical plane; the white loose areolar tissues should be identified when entering the correct plane. The dissection is advanced medially to expose the anterior surface of adrenal gland or tumor. This step is critical for the early localization of adrenal tumors (Figs. 2.13 and 2.14).

(e) The second anatomical plane is the relatively avascular space posterior to the kidney, which is located between the perirenal fat capsule and posterior perirenal fascia. This plane is dissected superiorly to

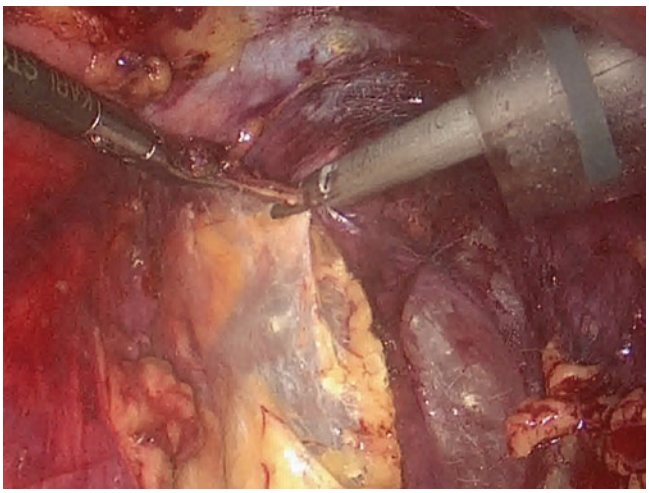

Fig. 2.12 Longitudinal incision at the Gerota's fascia

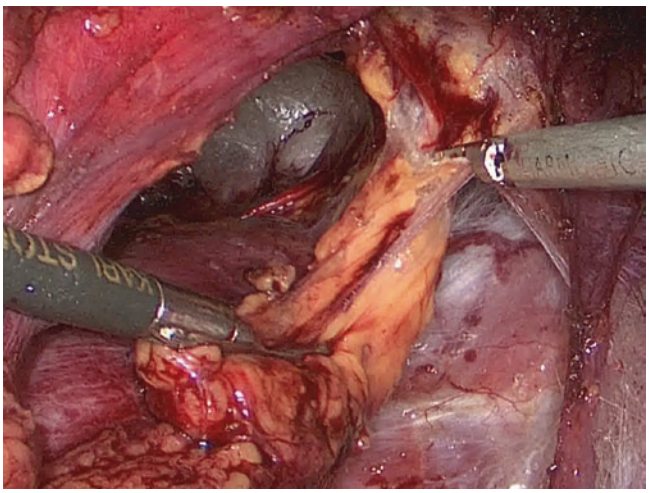

Fig. 2.15 Dissection of second anatomical plane

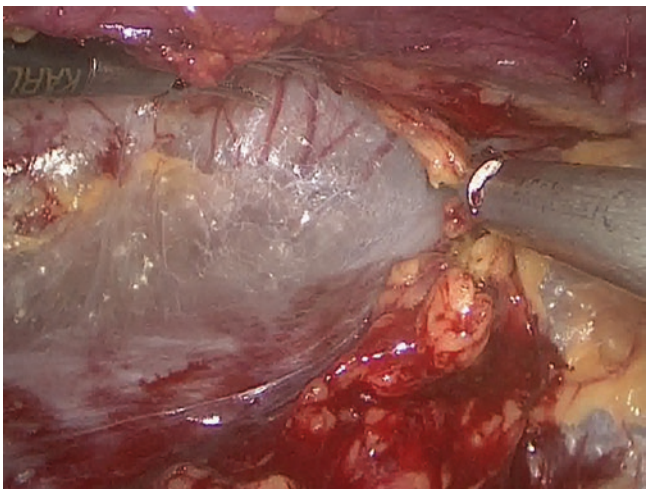

Fig. 2.13 Dissection of the first anatomical plane and identification of white loose areolar tissue

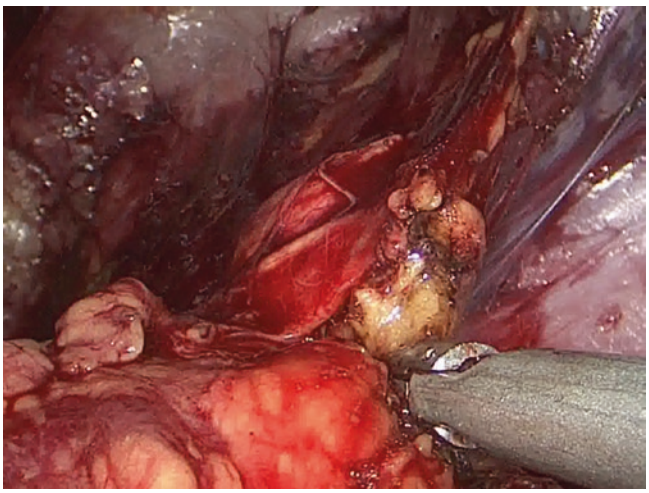

Fig. 2.16 Dissection of the third separation plane

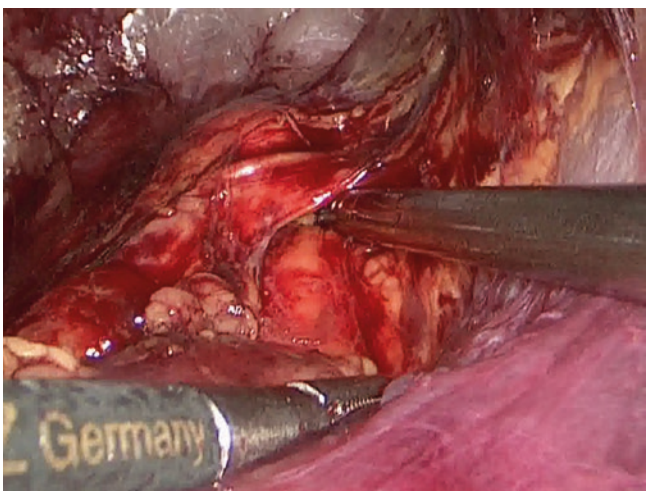

Fig. 2.14 Tumor exposure at the first anatomical plane

meet the first anatomical plane and dissected medially to the medial surface of the upper pole of kidney. Dissection of this plane is to expose the facies lateralis of the adrenal gland and enlarge the operating space. Some tumors are posteriorly located, and can only be exposed after separating this plane (Fig. 2.15).

(f) Space between the surface of upper pole and the adipose tissue at the base of adrenal gland is identified as the third anatomical plane. The periadrenal adipose tissue is retracted upward gently, and dissected from the surface of upper pole. Left suprarenal vein will be expose after the base of adrenal gland is fully dissected and retracted. The adhesive tissue between the upper pole of adrenal gland and diaphragm tissue is preserved for suspension of the adrenal gland (Fig. 2.16).

(g) There are many adrenal artery branches under the adrenal gland. The base of adrenal gland is dissected

with combination of blunt and sharp dissection; blood vessel must be isolated, ligated and divided. Suprarenal vein is completely exposed. The left suprarenal vein that travels vertically into the renal vein is ligated and divided as indicated. Ligation of suprarenal vein is not indicated when it does not affect the tumor excision (Fig. 2.17).

(h) Adrenal gland along tumor margin is clipped with Hem-O-Lok clips and tumor is excised from adrenal gland. Adrenal gland should be preserved as much as possible during the excision. For upper pole adrenal tumor, adhesive tissue between the upper pole of adrenal gland and diaphragm for complete tumor exposure and excision. Pneumoperitoneum pressure is reduced to 3~5 mmHg to check and secure hemostasis. Tumor is removed through skin incision for third trocar within a specimen bag (Figs. 2.18 and 2.19).

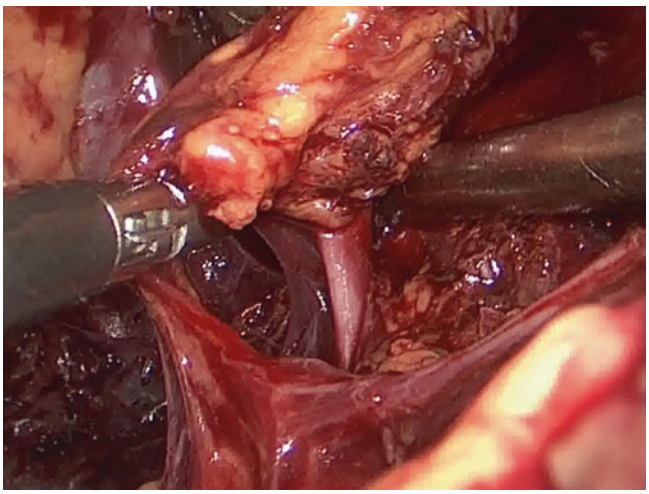

Fig. 2.17 Complete exposure of the left suprarenal vein

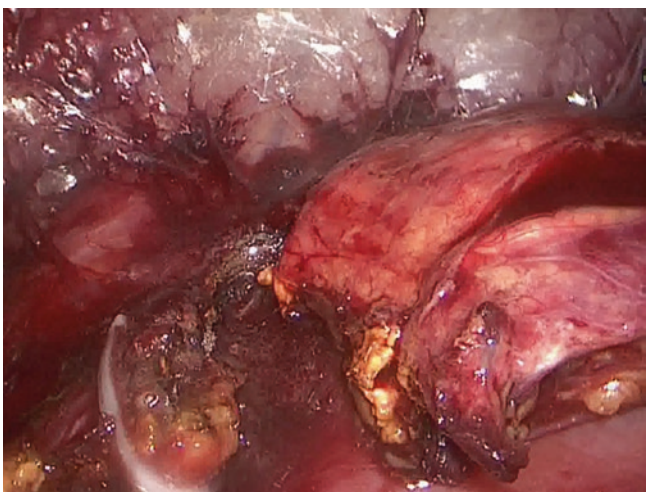

Fig. 2.18 Adrenal gland along tumor margin was clipped with Hem-O-Lok clips and tumor was excised from adrenal gland

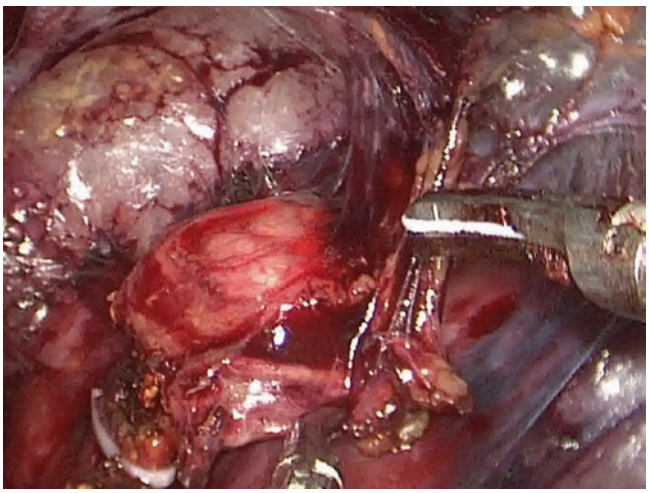

Fig. 2.19 Incision of the adhesive tissue between the upper pole of adrenal gland and diaphragm

5 Precautions

1. The adrenal gland located at the subdiaphragmatic area is high in position, retroperitoneal adipose tissue should be mobilized until subdiaphragmatic area for better exposure of the adrenal.
2. The retroperitoneal surgery space should be fully prepared for maximum working space. Retroperitoneal anatomical landmarks such as peritoneum reflection, psoas muscle, and diaphragm must be accurately identified. Perirenal fascia should be incised as high as possible for maximum exposure of adrenal.
3. Important steps of anatomical laparoscopic adrenalectomy includes sequent dissection of the three relatively avascular spaces and early localization of adrenal gland. Early localization of adrenal gland can provide good guidance on subsequent dissection to avoid contact and incision on adrenal gland [15].
4. Identification of loose white areolar tissue is crucial to ensure dissecting at the correct anatomical plane [4, 7].
5. Avascular anatomical plane should be dissected with combination of blunt and sharp dissection. Blood vessels should be divided with ultrasonic apparatus, surgical field should be kept clear from blood [16].
6. Arteriar suprarenales superiors is the adhesive tissue between the adrenal upper pole and diaphragm that can maintain superior retraction of adrenal gland; it should only be incised after adrenal vein ligation.
7. For patients with less perirenal fat, it is relatively easier to identify the adrenal gland during dissection of first anatomical plane, dissection of second anatomical plane can be started from upper pole of kidney to the facies lateralis of adrenal gland.

8. The adrenal tissue is brittle and fragile; it should be avoided from direct clamping to prevent surface bleeding, rupture of adrenal gland or tumor and adjacent tumor seeding. Retraction should be done by clamping periadrenal adipose tissue.
9. Suprarenal vein must be clearly expose for ligation. It should be ligated with Hem-o-Lok clips. Right suprarenal vein is short; attention of care must be given during dissection. Author had experience with adrenal tumor which was encased by suprarenal vein and infiltrated inferior vena cava. This tumor was excised en-bloc with the wall of vena cava by using linear cutter stapler.
10. Anatomical planes must be fully dissected to maximize the potential anatomical space around the kidney and adrenal gland. The adrenal gland and tumor must be fully exposed to accurately assess the characteristics of tumor for the decision of total or partial resection of adrenal. Adjacent organ must be clearly identified to avoid injury [17–19].
11. The primary aims in preoperative preparation of pheochromocytoma are to control blood pressure and blood volume. The patient should be given plasma volume expansion before the surgery to prevent hypotension caused by postoperative vasoconstriction. Good communication and cooperation with anesthetic colleague intraoperatively is important for stabilizing the intraoperative blood pressure [3].

6 Postoperative Management

Vital signs are closely monitored; nasogastric tube and urinary catheter can be removed soon postoperatively. The retroperitoneal drain can be removed when minimal output.

Electrolyte imbalance and blood pressure should be closely monitored for patients with primary aldosteronism. Electrolyte imbalance must be promptly rectified. Blood pressure can be manifest as following scenarios:

1. Blood pressure stabilizes in normal range after surgery.
2. Blood pressure normalizes, subsequently has a paradoxical rise. This situation can be effectively controlled with antihypertensive drugs are effective.
3. Electrolyte imbalance is corrected, however, blood pressure is not significantly reducing, antihypertensive drugs need to be started.

If the symptoms of aldosterone cannot be alleviated significantly after surgery, daily spironolactone 200~400 mg can be given. The symptoms are generally will be controlled [12].

Patients with hypercatecholaminism may have risk of acute hypotension after surgery, especially during position chance. Blood pressure should be monitored continuously. During episode of hypotension, intravenous fluid and inotropic drugs are given to maintain the blood pressure. Blood glucose should be monitored to prevent harmful impact from hypoglycemic attack [20].

Patients with Cushing's syndrome may have acute adrenal insufficiency after the surgery. Steroidal hormone can be given under a strict protocol; serum electrolytes and sugar must be regularly checked. During Addison's crisis, patient must be resuscitated and the dosage of steroidal hormone should be increased.

For patients with hypercortisolism, the ability of tissue healing is low and wound is susceptible to infections, that will subsequently lead to poor wound healing. Patient should be encouraged to perform regular lung exercise to avoid atelectasis and pulmonary infection [13].

7 Complications

The overall complications rate is lower for laparoscopic adrenal surgeries in comparison to open approach as intraabdominal organs and large vessels injury can be avoided in laparoscopic retroperitoneal adrenal surgery. Intraoperative or postoperative bleeding is a common complication [21–23].

1. Trochar insertion-related complications: These complications usually occur during creation of pneumoperitoneum and insertion of first trocar. Epigastric vessels, major vessels, solid organs and bowels are at risk of injury.
   (a) Epigastric vein injury. Bleeding from epigastric vein is usually self-limiting through compression of trocars.
   (b) Intraperitoneal organ injury: Liver and spleen injuries are the commonest. Small intestine injury commonly happens as well. Intestine injury can be primary closed with interrupted suturing by using 4-0 absorbable suture under sufficient bowel preparation. Other solid organ injuries are managed according to respective principle of organ injury management.
   (c) Injury of blood vessels: Major vessels injury due to trocar penetration require conversion to open surgery. Vessels are repaired according to the principle of vascular surgery. The following precaution steps should be taken to prevent major vessels injury.
      (1) Competent training for laparoscopic surgery
      (2) Familiarity with surface anatomy
      (3) Preoperative insertion of nasogastric tube and urinary catheter to avoid the distention of hollow viscous
      (4) Sufficient pneumoperitoneum pressure
      (5) Anterior retraction of abdominal wall to keep the abdominal wall away from bowel

(6) For patients with previous history of abdominal surgery, trocars should be inserted through Hasson technique [14].

2. CO_2 pneumoperitoneum-related complications
   It occurred in 2~3.5% of patients, and the incidence is higher when pneumoperitoneum duration is over 4 h. Complications include subcutaneous emphysema, hypercapnia, pneumothorax and others. There complications are less in robotic assisted adrenal surgery because robotic assisted adrenal surgery usually can be completed within 2 h.
   (1) Subcutaneous emphysema: A common complication with crepitus or feeling of grasp the snow when touching it; it is self-limiting.
   (2) Hypercapnia: Hypercapnia can occur in patients with background history of pulmonary disease; pneumoperitoneum pressure should be reduced when patient is hypercapnic.
   (3) Pneumothorax: Pneumothorax occurred when diaphragm or pleura is injured. Diaphragm defect must be repaired promptly; Chest drain must be inserted.
   Precaution steps must be taken to prevent CO_2 pneumoperitoneum related complications.
   (1) Strict control of surgical indications, especially for patients with chronic obstructive pulmonary diseases When operating on COPD patient, surgeon must maintains good communication with anesthesiologists; lung function test and blood gas analysis should be completed before the surgery.
   (2) Intraoperative pneumoperitoneum pressure should be maintained between 10~14 mmHg. COPD patients should be operated by experience surgeon to shorten the operation time.
   (3) Airway pressure, arterial blood gas and haemodynamic parameters should be closely monitored for patients with pulmonary or cardiovascular diseases. Surgery should be converted to open or terminated when patient cannot tolerate with CO_2 pneumoperitoneum.
3. Injuries of blood vessels: Blood vessels injury are common complications with 0.7~5.4% incidence.
   (1) Injuries of adrenal arteriole: Electrocoagulation or titanium clipping can secure this bleeding.
   (2) Injury of suprarenal vein: Injury of suprarenal vein may involve the vena cava or left renal vein. The suprarenal vein should be carefully mobilized. Increasing the pneumoperitoneum pressure can provide temporally tamponade for the bleeding from left renal vein or vena cava to repair the defect. When bleeding unable to be secured laparoscopically, surgery must be converted to open surgery without hesitation. Blood transfusion rate can be used as an indicator for intraoperative and postoperative bleeding, reported blood transfusion rate of laparoscopic adrenal surgery is from 2 to 10%
   (3) Injury of renal veins: Left renal vein is at higher risk of injury due to insertion left suprarenal vein into the left renal vein. The defect usually can be repaired laparoscopically.
   (4) Injuries of vena cava: This complication occurs in right adrenal surgery; the right suprarenal vein travers vertically and inserts into the vena cava. Vena cava may be injured during mobilization of right suprarenal vein
   (5) Splenic vessels injury: It can occur in left adrenal surgery. Some of the splenic vein injury can be repaired; while splenectomy is required for splenic artery injury [24].
4. Adjacent organs injury include injury to liver, spleen, pancreas, kidney, and large bowel.
   (1) Liver and spleen injury: Liver and spleen can be injured during mobilization for adrenal exposure. Liver injury may occur during of trocar insertion. Most of the injuries are superficial and can be secured with electrocautery. Liver excision is required for en bloc removal of adrenal tumor when there is liver infiltration, liver defect need to be repaired to secured the hemostasis.
   (2) Pancreatic tail injury: Pancreatic tail may be presumed and excised as adrenal specimen by beginner surgeon due its adjacency and similar appearance to adrenal gland. Surgeon must alert about abnormal drainage fluid. Serum and body amylase should be sent to confirm the diagnosis. Drainage tubes have to keep for a longer duration up to 3 months; most of the pancreatic leakage can be healed with conservative management.
   (3) Renal injuries: The adrenal gland is closely related to superior pole of kidney. Kidneys can be injured when dissecting the adrenal base. Bleeding from superficial renal injury usually can be secured with, hemostatic agent and bipolar electrocautery. Deep renal defect must be sutured to secure the bleeding. Nephectomy is indicated when adrenal tumor infiltrates to kidney. Possibility of nephrectomy should be included in preoperative consent taking.
   (4) Bowel injury: Prompt detection of bowel injury is critical. Small intestine injury can be primary sutured with 4-0 absorbable suture under sufficient bowel preparation. Colostomy is required for colon injury. Bowel injury can be prevented with anatomy familiarity and gentle mobilization.
5. Diaphragm and pleura injury: Diaphragm defect must be repaired and chest drained must be inserted.
6. Postoperative hormone-related complications: Functioning adrenal tumors contribute to most cases in

adrenal surgery, about 1% of the patients may have postoperative hormone-related complications. Patients with Cushing's syndrome will be complicated with Addison's crisis when corticosteroid supplement is insufficient.

7. Other complications include wound infection, intra-abdominal infection, pulmonary infection, incisional hernia and others.
   (1) Wound infection: Wound infection is managed with regular dressing and orally antibiotic. Wound infection can be prevented with strict intraoperative aseptic technique.
   (2) Intra-abdominal infection: It is rare, but common in patients with previous history intra-abdominal infection; it may be aggravated during inadequate intraabdominal drainage or presence of residual blood clot. It is managed with sufficient drainage and antibiotics; peritoneal lavage should be performed as indicated.
   (3) Pneumonia: It is common in patients with preexisting pulmonary diseases. Preventive measures include incentive spyrometry, active expectorant, regular chest physiotherapy and early mobilization. Patient with low pulmonary reserve should have intensive care unit backup preoperatively. Chest physician should be consulted for complicated pneumonia.
   (4) Incisional hernia: The incidence of incisional hernia at the trocar insertion site is relatively low, accounted for 0.77~3%. Most of the hernias occur at the extended abdominal incision for specimen retrieval. Proper wound closure is the key prevention. Incisional hernia is managed according to the principle of incision hernia management.

8 Technical Status

1. Selection of surgical approaches

   At present there are four kinds of approaches for laparoscopic adrenal surgery, that are transperitoneal anterior, transperitoneal lateral flank, retroperitoneal lateral flank and retroperitoneal posterior lumbar approaches. The transperitoneal approach was first introduced by Gagner, and subsequently was widely utilized worldwide. Transperitoneal approach offer obvious anatomical landmarks and large operating space. For transperitoneal anterior approach, patient is positioned in a supine position; this approach offer familiar intraoperative view where intraabdomen structures remain at anatomical position. More trocars are required for mobilization and retraction of adjacent organs to expose the adrenal.

   Retroperitoneal lateral flank approach offers direct access to the adrenal without interference of intraabdominal organs. This approach maybe not affected by adhesion from previous intraabdominal surgery. However retroperitoneal space is small and lack of identifiable anatomical landmarks, this limitation may increase the difficulty in blood vessels identification and exposure. Retroperitoneal approach is more challenging in obese patients due to excess of adipose tissue within the retroperitoneal space. Bilateral lesions can be operated simultaneously in retroperitoneal posterior lumbar approach without changing of positions, selection of this routes is highly dependent on surgeons' surgical experience [1, 6, 25].

2. Training: Anatomical laparoscopic adrenal surgeries had proven its reproducibility by following the standardize surgical steps. We had successfully trained over 100 trainees to perform this operation in our center. Trainees will be trained for basic laparoscopic skills through laparoscopic simulator as initial step, followed by laparoscopic animal model training. Finally, they will be supervised to perform retroperitoneal laparoscopic adrenalectomy during clinical training. Our training showed that junior doctors without experience in open surgery experience can master this surgery successfully after formal training [26, 27].
3. Adrenal-sparing surgery: Adrenal-sparing surgery was traditionally performed for bilateral hereditary paraganglioma (multiple endocrine neoplasm type 2 and Von Hippel-Lindau syndrome), to preserve the adrenal cortical function, and avoid the lifelong hormone replacement therapy. In recent years, some authors had applied it in other types of adrenal tumors such as aldosteronoma. Technically, adrenal-sparing surgery can be applied to single peripheral tumor less than 2 cm in diameter. Bleeding from the excisional adrenal surface can be secured by bipolar coagulation, ultrasonic apparatus and Hem-o-Lok clips. Larger tumors or potentially malignant tumors are absolute contraindications for adrenal-sparing surgery due to risk of tumor seeding. Laparoscopic adrenal-sparing surgery has proven its safety and feasibility; however, it still associates with minimal risk of tumor residual leading to postoperative recurrence. Thus, preoperative imaging study for careful case selection and intraoperative optimal tumor excision is crucial [28].
4. Laparoscopic surgery for pheochromocytoma

   Pheochromocytoma once was a contraindication for laparoscopic surgery. The restriction factors of pheochromocytoma for laparoscopic surgery include abundant of vascular supply, potential malignancy, intraoperative blood pressure fluctuation, potential rupture of tumor's capsule and tumor seeding. With accumulation of experience in laparoscopic adrenal surgery, laparoscopic excision pheochromocytoma had been widely performed. During excision of adrenal pheochromocytoma, tumor contact should be avoided to prevent

blood pressure fluctuation due to release of catecholamines vasoactive substances into systemic circulation. Most western authors prefer transperitoneal approach to have early and easy access to suprarenal vein. However, base on our experiences, early access and ligation of suprarenal vein in excision of pheochromocytoma is not necessary. During adrenal gland dissection, surgical instruments are usually contact with periadrenal adipose tissue instead of adrenal gland itself, thus the tumor is less stimulated. After dissecting the three anatomical plane, the operating space will be sufficient enough for good exposure of suprarenal vein.

When performing surgery for pheochromocytomy, it is important to recognize the pathological changes of feeding vessels to adrenal pheochromocytomas; there are mainly two type of pathologic changes in local vessels of large pheochromocytoma. Surface vessels of the tumor are abundant and dilated covering the tumor; these vessels are easily bled when contacted. Basilar vessels of the tumor are proliferated and dilated as well, these vessels enter the base of tumor in pyramid appearance (Figs. 2.23 and 2.24). It is important to identify these abnormal vessels and dissect them gently during pheochromocytoma surgery; these vessels bleed easily and the bleeding is tremendous. These vessels should be clipped instead of eletrocauterized. Most of the pheochromocytoma can be excised through laparoscopic retroperitoneal approach by dissecting the three anatomical plane and careful handling of the blood vessels. We had reported our experience in laparoscopic excision of a 13 cm pheochromocytoma retroperitoneally [3, 29].

*(Figures 2.20, 2.21, 2.22, 2.23, and 2.24 showed retroperitoneal laparoscopic excision of a 8 cm right pheochromocytoma.)

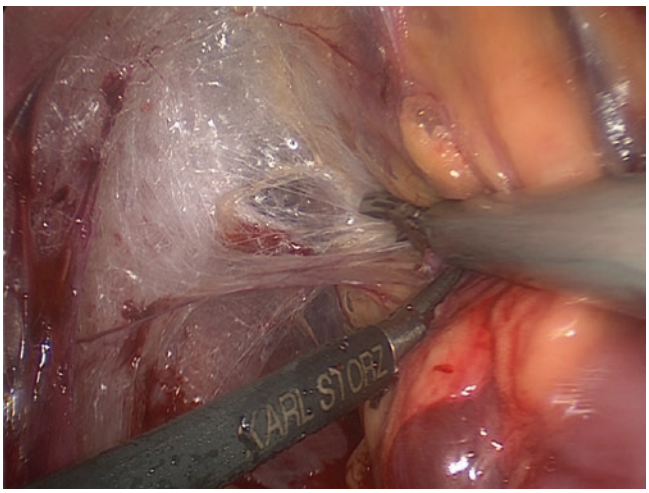

Fig. 2.21 Dissection of second anatomical plane

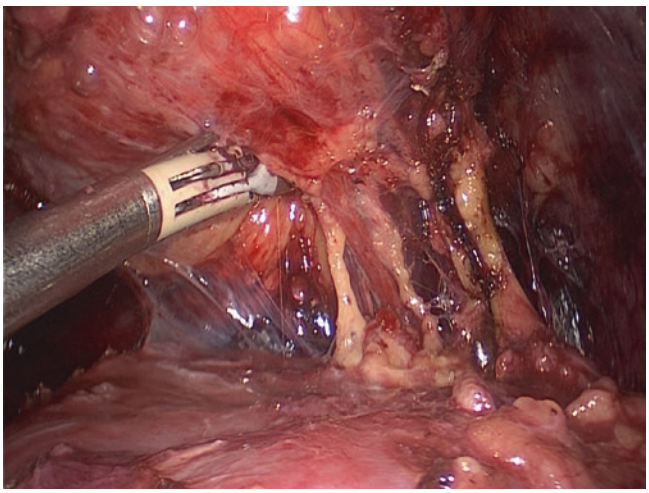

Fig. 2.22 Dissection of third anatomical plane dissection

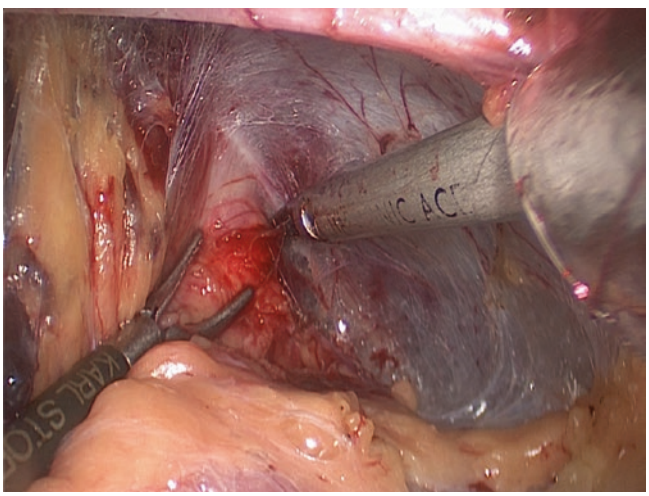

Fig. 2.20 Dissection of first anatomical plane which is the ventral surface of tumor

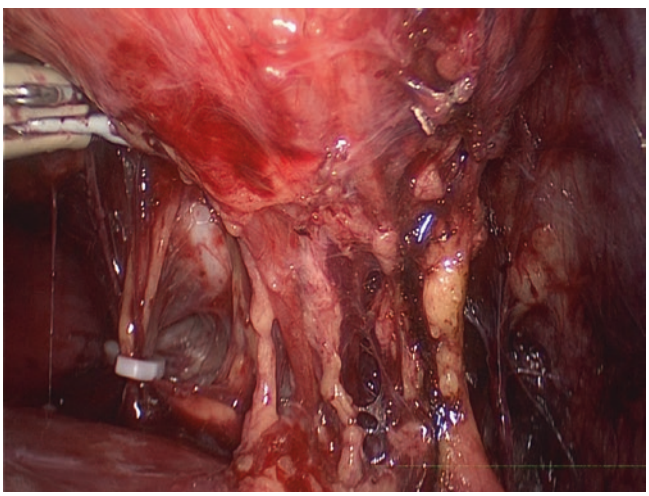

Fig. 2.23 Basilar vessels dissection and ligation (The 'Left corner' of pyramid)

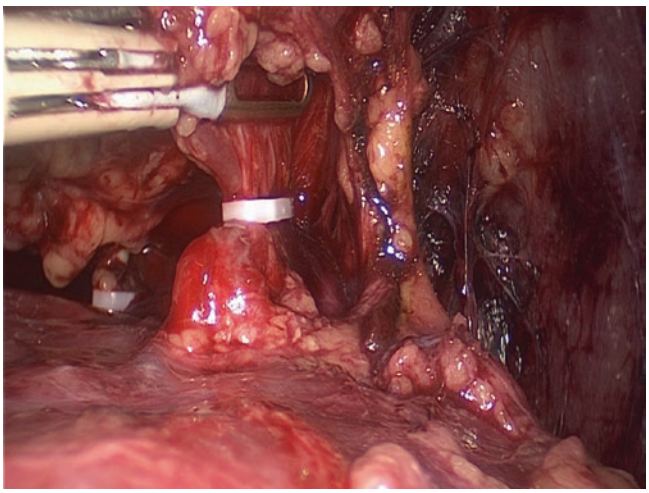

Fig. 2.24 Basilar vessels dissection and ligation (The 'Right corner' of pyramid)

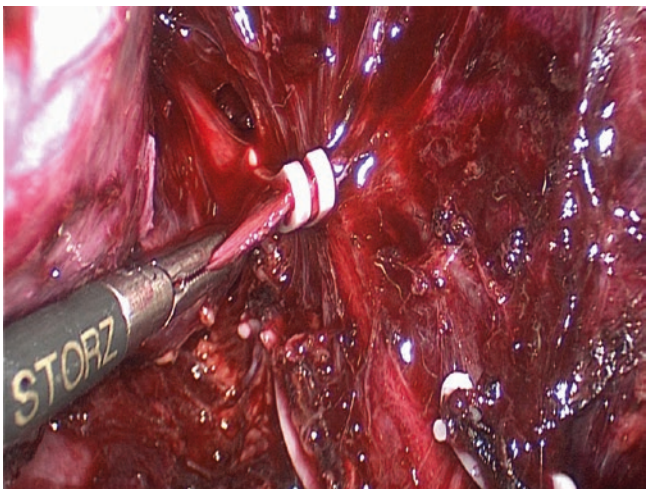

Fig. 2.25 Right suprarenal vein traveled vertically into the vena cava

5. Laparoscopic surgery of giant adrenal tumor

   Adrenal tumors bigger than 6 cm are traditionally operated in open approach. With the advancement of laparoscopic technology and accumulation of laparoscopic surgery experience, laparoscopic surgery for giant adrenal tumor is ventured. We had experience in performing retroperitoneal laparoscopic adrenalectomy for a 14 cm adrenal tumor. Some important principles must be complied when performing laparoscopic surgery for giant adrenal tumor.

   (a) Sufficient preoperative patient preparation: For giant pheochromocytoma, intravenous fluid should be given to expand intravenous volume preoperatively, phenoxybenzamine 10 mg tds to qid should be given for 2 weeks to control blood pressure. Dosage of phenoxybenzamine should be increased over a short period of time. Patients with suspected pheochromocytoma should be prepared with plasma volume expansor as well [25].

   (b) Selection of routes: The author prefers retroperitoneal route to avoid mobilizing the intraperitoneal organs. However, retroperitoneal route has limitation in surgical space, worse for giant tumor. It is important to avoid peritoneal perforation; gas pressure from the peritoneal cavity can significantly reduce the retroperitoneal space.

   (c) Tumor dissection: Operating steps are similar as other adrenal surgeries where the three anatomical planes are dissected in order. Giant tumor should be seen once first anatomical plane was dissected. Bleeding is common due to abundant of dilated at the tumor surface and dense adhesion at the anatomical plane. If bleeding unable to be secured and the exposure is affected, dissection should be stopped at bleeding area and continued at other area. It is not necessary to follow the regular dissection order once tumor is found [29].

   (d) Exposure of suprarenal vein: Suprarenal vein is difficult to be exposed in giant adrenal tumor. Anatomical familiarity and maximum anatomical plane dissection are critical. Right suprarenal vein is shorter and travels vertically into the vena cava (Fig. 2.25). During dissection of third anatomical plane, the tumor base is retracted upward, dissection is progressed medially until the lateral border of vena cava and medially of adrenal to expose right suprarenal vein. Left suprarenal vein is longer and travels obliquely into the left renal vein. It usually can be exposed when dissection of third anatomical plane approaching medial border of adrenal [29].

6. Laparoscopic adrenalectomy for adrenocortical carcinoma

   Most adrenocortical carcinoma is unresectable during diagnosis. Laparoscopic adrenalectomy is one of the treatment options for resectable adrenocortical carcinoma. Principle of resection is similar to open surgery, involved lymph nodes and infiltrated organs must be resected en bloc. The most important predictor for survival is complete tumor clearance. The five-year survival rate for patients with complete tumor clearance is 32~48%, however the average survival drops to less than 1 year for incomplete tumor clearance.

7. Laparoscopic surgery for recurrent or residual adrenal tumor

   Second operation is indicated for recurrence or postoperative residual adrenal tumors. Second adrenal surgery can be performed laparoscopically, however

the surgeon must be experience in this surgery. Retroperitoneal route certainly offers more advantages in second operation especially for patient who was operated transperitoneally during first surgery. Dense adhesion should be anticipated for second surgery; surgery should be converted to open surgery when it is difficult to proceed [30].

8. The laparoscopic treatment of metastatic adrenal carcinoma

   The incidence of metastatic adrenal carcinoma is low, Laparoscopic metastatectomy can be performed for isolated adrenal metastasis without infiltration to surrounding organ. Patient must be strictly selected with favorable prognosis of primary tumor. Principle of resection is to achieve complete tumor clearance [31].
9. Single incision laparoscopic surgery (SILS) and natural orifice transluminal endoscopic surgery for adrenal

   Retroperitoneal SILS adrenalectomy is performed based on the principle of retroperitoneal laparoscopic anatomical adrenalectomy. Its learning curve and perioperative parameter are comparable to retroperitoneal laparoscopic anatomical adrenalectomy with additional cosmetic advantage. We are also exploring transperitoneal SILS adrenalectomy and vaginal assisted natural orifice transluminal endoscopic adrenal surgery, to confirm their feasibility and safety [32–36].
10. Robot assisted adrenal surgery is discussed in Chap. 3.

References

1. Gagner M, Lacroix A, Bolte E. Laparoscopic adrenalectomy in Cushing's syndrome and pheochromocytoma. N Engl J Med. 1992;327(14):1033.
2. Mercan S, Seven R, Ozarmagan S. Endoscopic retroperitoneal adrenalectomy. Surgery. 1995;118(6):1071–5.
3. Ariyan C, Strong VE. The current status of laparoscopic adrenalectomy. Adv Surg. 2007;41:133–53.
4. Brunt LM. Minimal access adrenal surgery. Surg Endosc. 2006;20:351–61.
5. Ishidoya S, Ito A, Sakai K, et al. Laparoscopic partial versus total adrenalectomy for aldosterone producing adenoma. J Urol. 2005;174:40–3.
6. Zhang X, Fu B, Lang B, et al. Technique of anatomical retroperitoneoscopic adrenalectomy with report of 800 cases. J Urol. 2007;177:1254–7.
7. Zhang X, Zheng T, Ma X, et al. Retroperitoneoscopic surgery for adrenal cysts: a single-center experience of 14 cases. J Endourol. 2007;21(2):177–9.
8. Zhang X, Lang B, Ouyang JZ, et al. Retroperitoneoscopic adrenalectomy without previous control of adrenal vein is feasible and safe for pheochromocytoma. Urology. 2007;69:849–53.
9. Zhang X, Lang B, OuYang J-Z, et al. Retrospective comparison of retroperitoneoscopic versus open adrenalectomy for pheochromocytoma. J Urol. 2008;179(1):57–60.
10. Zheng T, Zhang X, Ma X, et al. Retroperitoneoscopic surgery for adrenal cysts: a report of 15 cases. Chin J Minim Inva Surg. 2005;5(6):431–2.
11. Zhang X. Anatomical retroperitoneoscopic adrenalectomy:operative technique and our experience. J Clin Urol. 2007;22(8):561–4.
12. Zhang X, Fu B, Lang B, et al. Technique of anatomical retroperitoneoscopic adrenalectomy. Chin J Urol. 2007;28(3):5–8.
13. Henry JF, Defechereux T, Raffaelli M, et al. Complications of laparoscopic adrenalectomy: results of 169 consecutive procedures. World J Surg. 2000;24:1342–6.
14. Permpongkosol S, Link RE, Su LM, et al. Complications of 2,775 urological laparoscopic procedures: 1993 to 2005. J Urol. 2007;177(2):580–5.
15. Rosevear HM, Montgomery JS, Roberts WW, et al. Characterization and management of postoperative hemorrhage following upper retroperitoneal laparoscopic surgery. J Urol. 2006;176(4. Pt 1):1458–62.
16. Walz MK, Alesina PF, Wenger FA, et al. Posterior retroperitoneoscopic adrenalectomy—results of 560 procedures in 520 patients. Surgery. 2006;140(6):943–8.
17. Zhang X, Lang B, Ouyang JZ, et al. Retroperitoneoscopic adrenalectomy for pheochromocytoma (report of 56 cases). Chin J Urol. 2007;28(3):149–52.
18. Zhang X, He H, Chen Z, et al. Retroperitoneal laparoscopic management of primary aldosteronism with report of 130 cases. Chin J Surg. 2004;42(18):1093–5.
19. Zhang X, Zhu QG, Ma X, et al. Application of the harmonic scalpel for retroperitoneoscopic partial adrenalectomy. Jiangsu Med J. 2002;28(6):403–4.
20. Zhang X, Ye ZQ, Chen Z, et al. Laparoscopic adrenalectomy (report of 23 cases). J Clin Urol. 2000;15(12):541–2.
21. Lang B, Zhang X, Fu B, et al. A retrospective comparative study on retroperitoneoscopic and open adrenalectomy for adrenal pheochromocytoma. Chin J Minim Inva Surg. 2007;7(8):730–2.
22. Zhang X, Ye ZQ, Song XD, et al. Laparoscopic and posterior laparsocopic adrenalectomy as compared with open adrenalectomy(report of 93 cases). Chin J Urol. 2002;23(6):332–4.
23. Wang BJ, Wu Z, Zhang X, et al. Staged laparoscopic training for performing the anatomic retroperitoneoscopic adrenalectomy. Chin J Urol. 2009;30(5):293–6.
24. Zhang X, Wang B, Zhang G, et al. Laparoscopic adrenalectomy for beginners without open counterpart experience: initial results under staged training. Urology. 2009;73(5):1061–5.
25. Baojun W, Xin M, Hong L, et al. Anatomic retroperitoneoscopic adrenalectomy for selected adrenal tumors >5 cm: our technique and experience. Urology. 2011;78(2):348–52.
26. Fu B, Zhang X, Wang GX, et al. Long-term results of a prospective, randomized trial comparing retroperitoneoscopic partial versus total adrenalectomy for aldosterone producing adenoma. J Urol. 2011;185(5):1578–82.
27. Cai W, Guo G, Li HZ, et al. The application of new technique in retroperitoneal adrenalectomy based on the new acknowledge of morbid anatomy regarding feeding vessels in large pheochromocytoma. J Minim Inv Urol. 2013;2(2):88–91.
28. Li J, Lv WC, Tian Y, et al. Laparoscopic adrenalectomy for large adrenal tumors. J Clin Urol. 2011;26(3):200–2.
29. Liao WF, Ma LL, Lu J, et al. Retroperitoneal laparoscopic re-operation in the nephron region. Chin J Minim Inva Surg. 2013;13(1):81–3.
30. Sturgeon C, Leong SP, Duh QY. Laparoscopic surgery for melanoma metastases to the adrenal gland. Expert Rev Anticancer Ther. 2004;4(5):831–41.
31. Ma X, Li H, Zhang X, et al. Modified anatomical retroperitoneoscopic adrenalectomy for adrenal metastatic tumor: technique and survival analysis. Surg Endosc. 2013;27(3):992–9.
32. Fu B, Wang GX, Zhang X, et al. Single-port Transumbilical laparoscopic surgery in urology with report of 18 cases. J Clin Urol. 2009;24(11):805–8.

33. Zhang X, Ma X, Li HZ, et al. Single-port anatomical retroperitoneoscopic adrenalectomy (report of 5 cases). J Clin Urol. 2009;24(9):647–50.
34. Zhang X, Shi TP, Li HZ, et al. Laparo-endoscopic single site anatomical retroperitoneoscopic adrenalectomy using conventional instruments: initial experience and short-term outcome. J Urol. 2011;185(2):401–6.
35. Shi TP, Zhang X, Ma X, et al. Laparoendoscopic single-site retroperitoneoscopic adrenalectomy: a matched-pair comparison with the gold standard. Surg Endosc. 2011;25(7):2117–24.
36. Zou X, Zhang G, Xiao R, et al. Transvaginal natural orifice transluminal endoscopic surgery (NOTES)-assisted laparoscopic adrenalectomy: first clinical experience. Surg Endosc. 2011;25(12):3767–72.