ADRENALECTOMY

Abdelrahman A. Nimeri, M.D., and L. Michael Brunt, M.D., F.A.C.S.

The surgical approach to the adrenals has evolved substantially over the past decade with the development and refinement of techniques for performing laparoscopic adrenalectomy. At present, the majority of adrenal tumors are removed laparoscopically because minimally invasive approaches result in reduced pain, faster recovery, and fewer complications and because the rate of adrenal malignancy is low. Nevertheless, open adrenalectomy still has a role in the management of selected patients with large or malignant tumors. With both open adrenalectomy and laparoscopic adrenalectomy, several different surgical approaches to the adrenals are possible. Regardless of the particular approach followed, the keys to successful adrenalectomy are the same: proper patient selection for operation, a solid understanding of adrenal pathophysiology, and a thorough knowledge of adrenal anatomy.

Anatomic Considerations

The adrenal glands are retroperitoneal organs that lie along the superomedial aspects of the two kidneys. Each gland comprises two discrete anatomic and functional units: the adrenal cortex, which is the site for synthesis and secretion of cortisol, aldosterone, and adrenal androgens; and the medulla, which is derived from the neural crest and is the site for synthesis of the catecholamines epinephrine and norepinephrine. A normal adrenal gland typically weighs between 4 and 6 g and measures approximately 4 to 5 cm by 2 to 3 cm by 0.5 to 1 cm. The right adrenal is relatively pyramidal in shape, whereas the left is somewhat flattened and is more closely applied to the kidney. Grossly, the adrenals may be distinguished from the surrounding retroperitoneal fat by their golden-orange color, which is a result of the high intracellular lipid content. The glands have a fibrous capsule but are relatively fragile and can be easily cracked or fragmented with surgical manipulation.

RIGHT ADRENAL

Anteriorly, the right adrenal is partially covered by the liver and the right triangular ligament. The gland abuts the inferior vena cava (IVC) medially and may, in part, lie posterior to the lateral aspect of the vena cava. Inferiorly, the adrenal sits just above the

Figure 1  Depicted is the relation of the adrenal glands to adjacent structures. (IVC—inferior vena cava)
upper pole of the kidney. The diaphragm forms the posterior and lateral boundaries of the gland.

The blood supply of the right adrenal is derived from branches of the inferior phrenic artery, the right renal artery, and the aorta [see Figure 2]. Typically, multiple small branches enter the gland along its superior, medial, and inferior aspects. Arterial branches from the aorta generally course posterior to the vena cava before entering the adrenal. Each adrenal is drained by a single central vein. On the right, this vein is short (1 to 1.5 cm long), runs transversely, and joins the lateral aspect of the inferior vena cava. In some cases, a more superiorly located accessory adrenal vein may enter either the IVC or one of the hepatic veins. Control of the adrenal vein is the most critical aspect of right adrenalectomy, in that the short course of this vessel makes it susceptible to tearing or avulsion from the IVC.

**LEFT ADRENAL**

The spleen and tail of the pancreas overlie the anterior and medial borders of the left adrenal. The inferolateral aspect of the gland lies over the superomedial aspect of the left kidney, to which it is more closely applied than the right adrenal is to the right kidney. The inferior aspect of the adrenal is in close proximity to the renal vessels, especially the renal vein. As on the right side, the posterior aspect of the adrenal rests on the diaphragm.

The arterial blood supply of the left adrenal is similar to that of the right adrenal [see Figure 2]. The left adrenal vein is longer than the right adrenal vein and runs somewhat obliquely from the inferomedial aspect of the gland to enter the left renal vein. The inferior phrenic vein courses in a superior-to-inferior direction just medial to the adrenal and usually joins the left adrenal vein cephalad to its junction with the renal vein.

**Preoperative Evaluation**

**INDICATIONS FOR OPERATION**

The main indications for adrenalectomy are well established [see Table 1]. Any adrenal lesion that either is hypersecretory for one of

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**Table 1**  **Indications for Adrenalectomy**

<table>
<thead>
<tr>
<th>Lesion/Condition</th>
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<tr>
<td>Aldosteronom</td>
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<tr>
<td>Cushing syndrome</td>
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<tr>
<td>Cortisol-producing adenoma</td>
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<tr>
<td>Primary adrenal hyperplasia</td>
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<tr>
<td>Failed treatment of ACTH-dependent Cushing syndrome</td>
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<tr>
<td>Pheochromocytoma</td>
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<tr>
<td>Sporadic or familial</td>
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<tr>
<td>Malignant pheochromocytoma</td>
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<tr>
<td>Nonfunctioning incidental lesion</td>
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<tr>
<td>≥ 4–5 cm or atypical radiologic appearance</td>
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<tr>
<td>Adrenal metastasis</td>
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<tr>
<td>Solitary, unilateral in the absence of extra-adrenal cancer</td>
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<tr>
<td>Adrenal cortical carcinoma</td>
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<tr>
<td>Adrenal sarcoma</td>
</tr>
<tr>
<td>Adrenal myelolipoma (only if symptomatic or enlarging)</td>
</tr>
<tr>
<td>Miscellaneous other lesions (atypical cysts, ganglioneuromas)</td>
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the adrenal hormones or appears to be malignant or possibly malignant should be removed. In selected cases, it may be appropriate to remove adrenal metastases if they are solitary and if there is no evidence of extra-adrenal metastatic disease. Nonfunctioning adrenal lesions that appear to be benign on the basis of their size (< 4 cm) and their appearance on computed tomography or magnetic resonance imaging need not be removed unless they enlarge during follow-up. Adrenal myelolipomas and cysts usually can be diagnosed radiographically and should not be removed unless they cause symptoms.

Most of the conditions for which adrenalectomy is indicated are amenable to a laparoscopic approach. However, the role of laparoscopy in patients with large adrenal tumors (> 6 to 8 cm) or potentially malignant primary adrenal lesions remains controversial. In the presence of a locally invasive tumor, a laparoscopic approach is contraindicated because of the need to perform en bloc resection of the tumor and any adjacent involved structures.

COMMON ADRENAL TUMORS

A brief review of the pertinent clinical and biochemical features of the various hypersecretory adrenal tumors [see Table 2] will facilitate evaluation of adrenal lesions (including adrenal incidentalomas) and planning for adrenal surgery.

**Aldosteronoma**

Primary hyperaldosteronism is the most common form of secondary hypertension, and aldosterone-producing adenoma is the most common hypersecretory adrenal tumor. The prevalence of this diagnosis is much higher than was previously thought, reaching levels as high as 12% of hypertensive individuals in some series. The classic finding in primary hyperaldosteronism is hypertension in conjunction with hypokalemia, but many patients have a normal or low-normal serum potassium level. Therefore, any patient who becomes hypertensive at an early age or who has malignant or difficult-to-control hypertension should be screened for this diagnosis. Screening consists of measuring plasma aldosterone concentration (PAC) and plasma renin activity (PRA). A PAC-to-PRA ratio higher than 20 to 30, in conjunction with a plasma aldosterone concentration higher than 15 ng/dl, is suggestive of the diagnosis and should be confirmed by measuring 24-hour urine aldosterone levels while the patient is on a high-sodium diet. A 24-hour urine aldosterone level higher than 12 µg/24 hr in this setting is confirmatory.

Because 25% or more of cases of primary hyperaldosteronism may be idiopathic as a result of bilateral adrenal hyperplasia and should therefore be managed medically and not surgically, the next step should be imaging with thin-section (3 mm cuts) CT or MRI. The finding of a discrete unilateral adenoma larger than 1 cm on CT in conjunction with a normal contralateral adrenal is sufficient localization to allow the surgeon to proceed with adrenalectomy. If CT shows bilateral nodules, bilateral normal adrenals, or a unilateral nodule smaller than 1 cm, then adrenal vein sampling for aldosterone and cortisol should be done to determine whether an unilateral gradient of increased aldosterone production exists.

**Cortisol-Producing Adenoma**

Approximately 20% of cases of Cushing syndrome are related to increased production of cortisol by an adrenal cortical tumor. Adrenal Cushing syndrome is most commonly attributable to adenoma but may also result from adrenal cortical carcinoma or primary adrenal hyperplasia. The classic features of full-blown Cushing syndrome are usually obvious and include centripetal obesity, moon facies, hypertension, purple skin striae, proximal muscle weakness, osteopenia, and amenorrhea. Not all patients present with advanced clinical signs, however, and the high prevalence of hypertension and obesity in the general population necessitates liberal use of diagnostic testing.

### Table 2 Clinical and Diagnostic Features of Common Adrenal Tumors

<table>
<thead>
<tr>
<th>Adrenal Tumor</th>
<th>Clinical Presentation</th>
<th>Biochemical Testing</th>
<th>Preferred Method of Imaging/Localization</th>
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<tbody>
<tr>
<td><strong>Aldosteronoma</strong></td>
<td>Hypertension ± hypokalemia</td>
<td>Elevated PAC with suppressed PRA (PAC/PRA &gt; 20–30)</td>
<td>Thin-section (3 mm) adrenal CT</td>
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<td>Urine aldosterone &gt; 12 µg/24 hr</td>
<td>Adrenal vein sampling</td>
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<tr>
<td></td>
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<td>Urine potassium &gt; 30 mEq/24 hr</td>
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<tr>
<td><strong>Cortisol-producing adenoma</strong></td>
<td>Centripetal obesity, moon facies, hypertension, purple skin striae, osteopenia, plethora, amenorrhea</td>
<td>Elevated 24-hr urinary free cortisol</td>
<td>Abdominal CT</td>
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<tr>
<td></td>
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<td>Nonsuppressed low-dose dexamethasone test</td>
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<td>Decreased plasma ACTH</td>
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<tr>
<td><strong>Pheochromocytoma</strong></td>
<td>Severe episodic hypertension or hypertension with spells of tachycardia, headache, anxiety, and diaphoresis</td>
<td>Elevated plasma fractionated metanephrines or urinary catecholamines and metabolites</td>
<td>MRI (T2-weighted sequences showing bright-appearing adrenal lesion)</td>
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<td>(18) MBG scan or Octreoscan if MRI is negative or if malignant or extra-adrenal tumor is suspected</td>
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<tr>
<td><strong>Adrenal cortical carcinoma</strong></td>
<td>Cushing syndrome, vitilizing features, local pain or mass</td>
<td>24-hr urinary free cortisol and metabolites</td>
<td>CT of chest/abdomen/pelvis</td>
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<tr>
<td></td>
<td></td>
<td>Plasma DHEA-sulfate</td>
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<tr>
<td><strong>Adrenal metastasis</strong></td>
<td>None (often seen on follow-up imaging) or local pain</td>
<td>Plasma fractionated metanephrines and low-dose DM test to exclude functioning lesion</td>
<td>Abdominal CT, PET imaging to evaluate for extra-adrenal metastatic disease</td>
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<td></td>
<td></td>
<td>FNA biopsy only if unresectable</td>
<td></td>
</tr>
<tr>
<td><strong>Myelolipoma</strong></td>
<td>None; occasionally local pain</td>
<td>None if radiographic appearance is unequivocal for myelolipoma</td>
<td>Presence of macroscopic fat on CT or MRI</td>
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</table>

*ACTH—adrenocorticotropic hormone  DHEA—dehydroepiandrosterone  DM—dexamethasone  FNA—fine-needle aspiration  MBG—metaiodobenzylguanidine  PAC—plasma aldosterone concentration  PET—positron emission tomography  PRA—plasma renin activity*
Suspected Cushing syndrome should be evaluated initially by measuring 24-hour urinary free cortisol levels or by administering a single low-dose dexamethasone test. If plasma cortisol does not fall to a level below 3 to 5 μg/dl the morning after administration of 1 mg of dexamethasone at 11 P.M., Cushing syndrome is a strong possibility and further testing is required. Once the diagnosis of hypercortisolism is established, plasma levels of adrenocorticotropic hormone (ACTH) should be measured to differentiate ACTH-dependent (resulting from increased ACTH production by a pituitary tumor or an ectopic source) from ACTH-independent (primary adrenal) causative conditions. The plasma ACTH level should be in the low-normal or suppressed range in patients with primary adrenal (resulting from increased ACTH production by a pituitary tumor or an ectopic source) from ACTH-independent (primary adrenal) causative conditions. The plasma ACTH level should be in the low-normal or suppressed range in patients with primary adrenal tumors, whereas it is normal or elevated in patients with ACTH-dependent Cushing syndrome. Imaging should then be carried out with CT (or MRI) to localize the adrenal tumor.

**Pheochromocytoma**

Pheochromocytoma should be suspected in any patient who experiences either severe episodic hypertension or hypertension that is associated with spells of tachycardia, headache, anxiety, and diaphoresis. Biochemical evaluation consists of measuring urinary concentrations of catecholamines and metabolites (e.g., metanephrine and normetanephrine), plasma concentrations of fractionated metanephrines, or both. MRI is our preferred imaging modality for suspected pheochromocytomas because of the typical bright appearance these tumors exhibit on T2-weighted sequences. Occasionally, radionuclide imaging with iodine-123–metiodylbenzylguanidine (123I-MIBG) or octreotide scintigraphy is necessary to localize an extra-adrenal pheochromocytoma.

**Adrenocortical Carcinoma**

Adrenocortical carcinomas are rare, with an incidence of approximately one per 1.5 to 2.0 million in the general population. These tumors are typically large (> 6 to 8 cm) at diagnosis, and most patients have advanced (stage III or IV) disease at presentation. Consequently, patients often have a mass or complain of abdominal or back pain. A significant percentage of patients with adrenocortical carcinoma present with evidence of hormone overproduction in the form of Cushing syndrome or virilizing features. Complete surgical resection offers the only chance for cure; thus, the role of laparoscopic adrenalectomy in the treatment of adrenocortical carcinoma remains controversial [see Troubleshooting, Large Tumors, below].

**Adrenal Incidentaloma**

Adrenal incidentalomas are the adrenal lesions most frequently referred to surgeons and are seen on 1% to 5% of all abdominal CT scans. Practical, current recommendations for evaluation and management of patients with incidentally discovered adrenal lesions are available. The common adrenal incidentaloma is a nonfunctioning cortical adenoma for which adrenalectomy is not usually required. All patients with adrenal incidentalomas should be screened for hypercortisolism by administering an overnight low-dose dexamethasone test and for pheochromocytoma by measuring plasma concentrations of fractionated metanephrines or urine levels of catecholamines and metanephrines. Patients who are hypertensive or hypokalemic should also undergo testing for hyperaldosteronism with measurement of plasma aldosterone and renin levels. Some patients with adrenal incidentalomas are found to have subclinical Cushing syndrome with evidence of autonomous corticoid steroid production, as demonstrated by lack of suppressibility with a dexamethasone test and by low plasma ACTH levels. These patients do not exhibit the classic features of Cushing syndrome but do have a high incidence of hypertension, diabetes, and osteoporosis. Adrenalectomy is generally indicated if the operative risk is suitably low. Supplemental corticosteroids should be given before, during, and after operation because contralateral adrenal function is often suppressed and adrenal insufficiency may ensue.

The nonfunctioning adrenal lesion should also be assessed for malignant potential on the basis of its size and appearance on diagnostic imaging. Cortical adenomas typically have low attenuation values (< 10 Hounsfield units) on unenhanced CT imaging and show loss of signal intensity on MRI chemical-shift imaging sequences. Needle biopsy is not useful in differentiating benign from malignant primary adrenal lesions and is rarely indicated. Adrenal biopsy should never be done unless a pheochromocytoma has first been excluded biochemically. Most experts recommend removing any nonfunctioning adrenal lesion larger than 4 to 5 cm unless the radiographic appearance of the lesion is diagnostic of a cyst or myelolipoma. Smaller tumors should be followed with imaging at 4 and 12 months after the initial presentation.

**Operative Planning**

**PREPARATION FOR OPERATION**

Preoperative preparation of the patient for adrenalectomy entails control of hypertension and correction of any electrolyte imbalances. Patients with a pheochromocytoma should receive 7 to 10 days of alpha-adrenergic blockade with phenoxybenzamine to minimize any exacerbation of hypertension during the operation. The usual starting dosage is 10 mg twice daily, which is increased by 10 to 20 mg/day until the hypertension and tachycardia are controlled and the patient is mildly orthostatic. Patients with Cushing syndrome or subclinical Cushing syndrome should receive perioperative dosages of stress steroids. Mechanical bowel preparation is not routinely employed.

**CHOICE OF PROCEDURE**

The retroperitoneal location of the adrenals renders them accessible via either transabdominal or retroperitoneal approaches. The choice of surgical approach in any given patient depends...
on a number of factors, including the nature of the underlying adrenal pathology, the size of the tumor, the patient’s body habitus, and the experience of the operating surgeon. For the vast majority of adrenal lesions, laparoscopic adrenalectomy is preferred. Most centers favor the transabdominal lateral approach to laparoscopic adrenalectomy, which has the advantages of a large working space, familiar anatomic landmarks, and widespread success. Some centers, however, prefer a retroperitoneal endoscopic approach. The advantages of this technique are that the peritoneal cavity is not entered, there is no need to retract overlying organs, and the incidence of postoperative ileus may be lower. The disadvantages are that the retroperitoneal approach employs a smaller working space, is more difficult to learn with fewer anatomic landmarks for orientation, and is usually restricted to tumors smaller than 5 cm.

The only absolute contraindications to laparoscopic adrenalectomy are local tumor invasion and the presence of regional lymphadenopathy. A large tumor (≥ 8 to 10 cm), a suspected primary adrenal malignancy, and a history of previous nephrectomy, splenectomy, or liver resection on the side of the lesion to be removed are all indicators that a case is likely to be more difficult and should be considered relative contraindications to a laparoscopic approach in all but the most experienced hands. Portal hypertension is also a contraindication to a laparoscopic approach because of the dilated collateral vessels in the retroperitoneum.

Options for open adrenalectomy include transabdominal, flank, posterior retroperitoneal, and thoracoabdominal approaches. The lateral flank approach and the posterior retroperitoneal approach have been replaced by laparoscopic approaches and are now rarely used. A posterior retroperitoneal adrenalectomy is done through a hockey-stick incision in the back, with subperiosteal resection of the 12th rib. This approach has low morbidity and yields adequate exposure of the adrenal gland, but the visual field is often limited, and there is a high incidence of residual incisional complaints. The current consensus is that open posterior retroperitoneal adrenalectomy is indicated only in patients who require bilateral adrenalectomy but are not candidates for laparoscopic adrenalectomy. Most large or malignant adrenal tumors that necessitate an open approach can be removed via an anterior abdominal incision, usually a unilateral or bilateral subcostal incision (with subxiphoid extension if necessary); a thoracoabdominal incision is rarely needed.

### Operative Technique

**LAPAROSCOPIC ADRENALECTOMY**

#### Transabdominal Approach

**Patient positioning** A gel-padded bean-bag mattress is placed on the operating table before the patient enters the room. The patient is placed in the supine position, general anesthesia is induced, and sequential compression stockings are placed. A urinary catheter is inserted for monitoring of urine output, and the stomach is decompressed with an orogastric tube. Invasive monitoring is not usually necessary unless the patient has a vasoactive pheochromocytoma, in which case an arterial line is routinely placed.

Next, the patient is moved into a lateral decubitus position with the affected side up [see Figure 3]. A soft roll is placed underneath the chest wall to protect the axilla. The bean-bag mattress is molded around the patient and the legs are wrapped in a foam pad to minimize all pressure points. The patient is secured to the operating table with tape placed across the padded lower extremities and a safety strap across the pelvis. The operating table is then flexed at the waist. The combination of the lateral position, the flexed operating table, and the reverse Trendelenburg position facilitates placement of the laparoscopic ports and provides optimal access to the superior retroperitoneum.

**Equipment** Our preferred instrumentation for laparoscopic adrenalectomy is as follows [see Table 3]. An angled (30°) laparoscope, preferably 5 mm in diameter, is used to optimize viewing angles. One 10/12 mm port is employed to allow insertion of a clip applier and extraction of the specimen; the other ports can all be 5 mm if a 5 mm laparoscope is employed. The principal instruments needed for dissection and hemostasis areatraumatic graspers, an L-hook electrocautery, and a medium-large clip applier. An ultrasonic coagulator is not essential for a right adrenalectomy, but it may facilitate mobilization of the splenic ligaments and dissection of the adrenal from the retroperitoneal fat during a left adrenalectomy. An endovascular stapler should be available for a right adrenalectomy because it will occasionally be needed to divide the right adrenal vein. Other essential items are a suction-irrigation device and an impermeable specimen retrieval bag.

**Initial access and placement of trocars** Because the patient is in a lateral position, initial access to the peritoneal cavity is usually achieved in a closed fashion with a Veress needle. After insufflation to a pressure of 15 mm Hg, a 5 mm direct-view trocar is placed to afford direct visualization of the peritoneal cavity. An open insertion technique may be used instead, but this approach requires a larger incision and is hindered somewhat by the bulky overlapping muscle layers in the subcostal region. Open insertion at the umbilicus is an option in some patients.

The initial access site is generally at or somewhat medial to the anterior axillary line about two fingerbreadths below the costal margin [see Figure 4]. Subsequent ports should be placed at least 5 cm apart to allow freedom of movement externally. The most dorsal port should be approximately at the posterior axillary line. It is helpful to outline the anterior and posterior axillary lines with a marker before the patient is prepared to ensure that the ports are positioned properly. Whereas four ports are required for a right adrenalectomy, a left adrenalectomy can be done with either three or four ports, depending on the surgeon’s preference and experience. On the left side, the splenic flexure of the colon usually must be mobilized before the fourth port (the most dorsal one) can be inserted.

### Table 3 Instrumentation for Laparoscopic Adrenalectomy

<table>
<thead>
<tr>
<th>Instrumentation</th>
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<tr>
<td>Veress needle</td>
</tr>
<tr>
<td>Angled (30°) laparoscope</td>
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<tr>
<td>5 and 12 mm laparoscopic ports</td>
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<tr>
<td>5 mm liver retractor for right adrenalectomy</td>
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<tr>
<td>L-hook electrocautery</td>
</tr>
<tr>
<td>Atraumatic graspers, blunt dissector</td>
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<tr>
<td>Right-angle dissector</td>
</tr>
<tr>
<td>Medium-large clip applier</td>
</tr>
<tr>
<td>Ultrasonic coagulator for left adrenalectomy (optional)</td>
</tr>
<tr>
<td>Suction irrigation cannula</td>
</tr>
<tr>
<td>Specimen extraction bag</td>
</tr>
<tr>
<td>Laparoscopic ultrasonography device*</td>
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<tr>
<td>Endovascular stapler*</td>
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*Not routinely needed but should be available.*
Right adrenalectomy  Step 1: exposure of right adrenal gland and vein. The key to exposure of the right adrenal gland is extensive division of the right triangular ligament of the liver. This maneuver should be continued until the liver can be easily elevated and retracted medially and both the right adrenal and the IVC are visible. A retractor is then inserted through the most medial port to hold the right lobe of the liver up and away from the operative site.

Next, the plane between the medial border of the adrenal and the lateral aspect of the IVC is developed. An L-hook cautery is used for gentle elevation and division of the peritoneum and the small arterial branches here [see Figure 5]. The adrenal is pushed laterally with an atraumatic grasper to apply traction to the dissection site; however, the gland itself should not be grasped, because it is fragile and the capsule and adrenal parenchyma are easily fractured. At all times, it is imperative to know where the lateral border of the IVC is, both to ensure that the dissection is extra-adrenal and to avoid injuring the IVC. The right adrenal vein should come into view as the medial border is dissected.

Step 2: isolation, clipping, and division of right adrenal vein. The right adrenal vein is first exposed by gentle blunt spreading, and a right-angle dissector is then used to isolate enough of the vein’s length to permit clip placement [see Figure 6]. A medium-large clip is usually sufficient for securing the vein, though sometimes it is necessary to use larger clips or even an endovascular stapler. (We use an endovascular stapler primarily in cases in which the tumor is located in the medial area of the adrenal and the vein must be taken along with a portion of the IVC junction.) Usually, two clips are placed on the IVC side and one or two on the adrenal side, depending on the length of vein available. Meticulous hemostasis throughout the dissection is important: even minimal bleeding will stain the tissue planes and make the dissection more difficult and potentially treacherous.

Step 3: mobilization and detachment of specimen. Once the adrenal vein is divided, dissection is continued superiorly and inferiorly with the L-hook cautery. The numerous small arteries that enter the gland at its superior, medial, and inferior margins can be safely cauterized, but larger branches may have to be clipped. Superiorly, as the adrenal is mobilized, the musculature of the posterior diaphragm is exposed and serves as a marker of the proper plane for the posterior dissection. Inferiorly, the dissection should stay close to the margin of the adrenal so as not to injure branches of the renal hilar vessels. The inferior dissection then proceeds in a medial-to-lateral direction as the gland is elevated off the superior pole of the right kidney. The remaining attachments to the back muscles and the retroperitoneal fat are relatively avascular and can be divided with the electrocautery.

Once the specimen has been detached, it is placed in an impermeable bag. The retroperitoneum is then irrigated and inspected for hemostasis and for secure placement of the clips on the IVC.

Step 4: extraction of specimen. The fascial opening at the 10/12 mm port site is enlarged somewhat, and the specimen bag is removed through this site. For larger tumors, a remote extraction site (e.g., the umbilicus or the suprapubic region) may be a preferable alternative. Large pheochromocytomas may be morcellated within the entrapment bag and removed piecemeal, but ideally, cortical tumors and metastatic lesions should be extracted intact to permit full pathologic examination.

Left adrenalectomy  Step 1: exposure of left adrenal gland and vein. The splenic flexure of the colon is mobilized. The lateral attachments of the flexure are divided to allow placement of the fourth port (if needed), and the colon is then released from the

Figure 4  Laparoscopic adrenalectomy: transabdominal approach. Shown is the recommended port site placement for laparoscopic adrenalectomy (here, left adrenalectomy). Dashed lines indicate the costal margin and the anterior and posterior axillary lines.

Figure 5  Laparoscopic right adrenalectomy: transabdominal approach. Depicted is the anatomic exposure for right adrenalectomy. The liver is retracted medially, and the right triangular ligament of the liver is divided with an L-hook electrocautery.
inferior pole of the spleen and away from the left kidney. Next, the splenorenal ligament is incised from the inferior pole of the spleen to the diaphragm to allow full medial rotation of the spleen and provide access to the left retroperitoneum [see Figure 7]. It is important not to dissect lateral to the kidney; doing so will cause the kidney to tilt forward and will interfere with exposure. Once the spleen is completely mobilized, it should fall medially, with minimal or no retraction needed to keep it out of the operative field. Division of the ligaments can be accomplished more quickly and with less bleeding if an ultrasonic coagulator is used.

At this point in the dissection, the tail of the pancreas should be visible, along with the splenic artery and vein. The plane between the pancreas and the left kidney is then developed. The adrenal is located on the superomedial aspect of the kidney just cephalad to the tail of the pancreas and should be visible at this point unless there is a great deal of retroperitoneal fat (as is often the case in patients with Cushing syndrome). If the adrenal gland is not readily visible, laparoscopic ultrasonography should be employed to help locate it and to delineate the surrounding anatomy, particularly the upper kidney and the renal hilar vessels. If the dissection starts too low, the renal hilar vessels or the ureter could be injured.

Once the adrenal is visualized, the medial and lateral borders are usually defined by means of dissection with the hook cautery and division of areolar attachments and small vessels. The dissection is then continued inferiorly to locate the adrenal vein as it exits the inferomedial border of the gland [see Figure 8]. The inferior border of the adrenal often sits adjacent to the left renal vein, from which it can be separated by means of gentle blunt dissection and judicious use of the electrocautery.

Step 2: isolation, clipping, and division of left adrenal vein. Once the adrenal vein has been visualized, it is isolated, doubly clipped, and divided. Because the adrenal vein is usually joined by the inferior phrenic vein cephalad to its junction with the renal vein, it is often necessary to clip the inferior phrenic vein again as the dissection proceeds more proximally.

Step 3: mobilization and detachment of specimen. Once the left adrenal vein has been securely clipped and divided, the dissection is continued cephalad along both the lateral and the medial borders of the gland. Because of the surrounding retroperitoneal fat, it is advisable to use the ultrasonic coagulator for this part of the left-side dissection. Because the left adrenal is more flattened out on the superomedial aspect of the left kidney than the right adrenal is on the right kidney, more of the kidney will be exposed during dissection in a left adrenalectomy than in a right adrenalectomy. Finally, the posterior and superior attachments to the diaphragm and the retroperitoneal fat are divided.

Step 4: extraction of specimen. Once the gland is free, the retroperitoneum is inspected and the specimen extracted as in a right adrenalectomy. If there is any possibility that the pancreatic parenchyma may have been violated, a closed suction drain is left in place.

Retroperitoneal Approach

Retroperitoneal endoscopic adrenalectomy can be carried out with the patient in either a lateral or a prone position. In general, this technique is more challenging to learn than transabdominal adrenalectomy, the working space is more cramped, and it is easier for surgeons to become disoriented unless they have experience working in the retroperitoneum. On the other hand, the retroperitoneal approach allows surgeons to avoid having to reposition patients for bilateral adrenalectomy (if the prone position is used), and it may simplify access in patients who have previously undergone extensive upper abdominal procedures.

Initial access is usually achieved through open insertion of a 12 mm port into the retroperitoneum either (1) just lateral or inferi-
or to the tip of the 12th rib (for the prone position) or (2) in the midaxillary line about 3 cm above the iliac crest (for the lateral position). A potential advantage of the lateral approach is that it can be converted to a transperitoneal approach if difficulty is encountered.

Once the retroperitoneum is entered, a balloon device is deployed to create an initial working space, which is further developed by means of CO₂ insufflation and blunt dissection. The second and third ports are then placed [see Figure 9]. The principles of dissection are the same as in a transabdominal adrenalectomy [see Transabdominal Approach, above]. Laparoscopic ultrasonography may be useful for defining the upper portion of the kidney and the adrenal gland and tumor.

OPEN ADRENALECTOMY

Of the four approaches to open adrenalectomy [see Operative Planning, Choice of Procedure, above], the anterior transabdominal approach is the preferred method for any tumors that are too large to be removed laparoscopically and for all invasive adrenal malignancies. The incision most commonly used is an extended unilateral or bilateral subcostal incision, though a midline incision is also an option [see Figure 10]. The extended subcostal incision yields exposure of both adrenal glands, as well as the rest of the peritoneal cavity. If necessary, it may be extended superiorly in the midline to the xiphoid to provide better upper abdominal exposure for full mobilization of the liver and access to the hepatic veins and the vena cava. The exposure obtained with this incision is sufficient for all but the most extensive adrenal malignancies. If the tumor involves the vena cava, the incision may be extended into a median sternotomy to provide access to the superior vena cava and the heart. The classic thoracoabdominal incision, which extends from the abdomen up through the seventh or eighth intercostal space and through the diaphragm, provides excellent exposure but is associated with increased incision-related morbidity and is rarely used.

Much of the exposure and dissection is the same as in a laparoscopic adrenalectomy; however, because open adrenalectomy is often employed for removal of particularly large tumors, some additional maneuvers may be necessary to achieve adequate exposure and vascular control. For example, it may be helpful to elevate the flank with a roll or a bean-bag mattress and then flex the operating table to open up the space between the costal margin and the iliac crest. Once the abdomen is entered, exploration is carried out for the presence of metastatic disease.

Exposure of the adrenal on the right side is achieved by dividing the right triangular ligament of the liver, as in the laparoscopic approach. The hepatic flexure of the colon is also reflected inferriorly. With large tumors, a Kocher maneuver should be performed to afford better exposure of the vena cava and the renal vessels. The remainder of the dissection proceeds in much the same manner as in a laparoscopic right adrenalectomy. For suspected adrenal malignancies, a wide resection should be carried out, with removal of periadrenal fat and lymphatic tissue and any suspicious lymph nodes. For tumors that appear to involve the vena cava, vascular control of both the IVC proximal and distal to the tumor and the renal veins should be achieved before the lesion is removed.

Open left adrenalectomy entails mobilization of the splenic flexure of the colon and division of the splenorenal ligament. The spleen, tail of pancreas, and the stomach are reflected medially en bloc to expose the left kidney and the left adrenal. The left adrenal vein is ligated with clips or silk ties near its junction with the renal vein. The remainder of the dissection proceeds as in a laparoscopic left adrenalectomy. For left-side primary adrenal
malignancies, periaortic lymphatic vessels and lymph nodes should be removed along with the specimen. If a large left-side tumor is invading adjacent structures, removal may require en bloc resection of the spleen, the distal pancreas, and the kidney.

Troubleshooting

INABILITY TO LOCATE ADRENAL

The adrenal is usually not difficult to find on the right side, where it should be visible once the right hemiliver has been mobilized. Important landmarks on that side are the IVC, which is medial to the adrenal, and the kidney, which is inferior to the adrenal. Once these structures have been identified, the location of the adrenal should be apparent. In contrast, the adrenal can be difficult to find on the left side, especially if the tumor is small or the patient is obese. To locate the left adrenal, the splenorenal ligament should be fully divided, and then the plane between the kidney and the tail of the pancreas should be developed, with the tail of the pancreas rotated medially. As dissection proceeds superiorly, the adrenal can be visually distinguished from the retroperitoneal fat by its golden-orange appearance. If the adrenal is not yet visualized at this point, laparoscopic ultrasonography should be used to verify the locations of the superior pole of the left kidney and the renal vessels. Ultrasonography should also be able to image the adrenal gland and tumor within the retroperitoneal fat [see Figure 11].

BLEEDING

The best means of managing bleeding problems during adrenalectomy is prevention. Important measures for minimizing bleeding risk include obtaining good exposure of the operative field and employing meticulous dissection and gentle handling of the adrenal and surrounding structures. When bleeding does occur, it may be from the adrenal veins, the adrenal gland itself, the IVC, the renal veins, the liver, the pancreas, the spleen, or the kidney. For bleeding during laparoscopic adrenalectomy, the first maneuver should be to tamponade the bleeding site with an atraumatic instrument. If this maneuver is successful, dissection should be directed away from the bleeding site for a while, until better exposure of the area can be obtained. Major hemorrhage from the IVC or the renal veins that is not immediately controlled should be managed by prompt conversion to open adrenalectomy (see below). Lesser bleeding may also be an indication for conversion to open adrenalectomy if it obscures the tissue planes and thereby increases the risk of inadvertent entry into the adrenal gland or tumor.

CONVERSION TO OPEN ADRENALECTOMY

Conversion to open adrenalectomy may sometimes be necessary because of bleeding, failure to progress with the dissection, or a locally invasive tumor. If the patient is in the lateral decubitus position, conversion may be accomplished by means of a subcostal incision extended into the flank. With the patient on a bean-bag mattress, the operating table can be rotated out of the straight lateral plane so that the patient comes to occupy more of a hemilateral position. If the procedure is a bilateral adrenalectomy, then either a bilateral subcostal incision or a midline incision may be employed after the patient has first been returned to more of a supine position. For this reason, it is important to extend the initial preparation and draping past the midline of the abdomen. Alternatively, if the conversion is not being done on an urgent
basis because of bleeding, the port sites may be closed, and the patient may then be moved into the supine position, reprepared, and redraped.

An option that may be considered before conversion to an open procedure is the use of a hand access port. A hand-assisted technique may be particularly useful for larger, noninvasive tumors that are harder to manipulate with laparoscopic instruments. The location of the incision for the hand port may vary according to the patient’s body habitus; generally, however, an ipsilateral subcostal location medial to the working ports allows adequate hand access while preserving visualization through the more lateral ports.

**LARGE TUMORS**

Large adrenal tumors (> 6 to 8 cm) are more difficult to remove than smaller ones because they are bulkier and more vascular and because they are harder to manipulate and retract. Accordingly, the dissection should stay extra-adrenal, and care must be exercised during manipulation to avoid entering the tumor. Although surgeons have not yet had a great deal of experience with hand-assisted laparoscopic adrenalectomy, it appears that this approach may be useful for exposure and retraction of large tumors and may facilitate extraction of large specimens. Laparoscopic ultrasonography should also be employed to verify that the tumor is well circumscribed and noninvasive. Surgeons who attempt to remove large adrenal tumors laparoscopically should be highly experienced in laparoscopic adrenalectomy techniques.

For large invasive adrenal malignancies, an open approach, involving a generous bilateral subcostal incision, is indicated, and the chest should be prepared in case a thoracoadominal or median sternotomy extension proves necessary. The important principles are to obtain wide exposure of the operative field and to control all major vessels that may be involved before removing the tumor.

**OBESE PATIENTS**

Obese patients present a particular challenge during adrenalectomy, for several reasons: initial access is more difficult; retraction and exposure are more challenging; and the copious amount of retroperitoneal fat makes it difficult to identify the adrenal and to clearly define the margins of the gland within the retroperitoneum. Our practice is to attempt to gain initial access to the peritoneal cavity by using a closed Veress needle technique. Because resting intra-abdominal pressure may be higher in obese patients, especially if they are in the lateral position, it may be necessary to increase the CO₂ pressure to 20 mm Hg temporarily until the first trocar is inserted. If it proves difficult to establish pneumoperitoneum with the Veress needle technique, the initial trocar should be placed at the umbilicus by means of an open insertion technique. The subcostal and flank ports are then inserted in the usual locations under direct vision.

On the right side, the presence of a bulky, fatty liver should be anticipated, and the locations of the port sites should be adjusted accordingly by placing them somewhat more caudal. Ample time should be taken to mobilize the liver fully so that the adrenal and the IVC can be safely accessed. On the left, the ports may be placed in the standard locations. The splenic flexure should be

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**Figure 9** Laparoscopic left adrenalectomy: retroperitoneal endoscopic approach. Shown is the recommended port site placement.

**Figure 10** Open adrenalectomy. The procedure is generally done through a unilateral or bilateral subcostal incision. For better exposure for large adrenal malignancies, the incision may be extended cephalad in the midline.
Postoperative Care

After a laparoscopic adrenalectomy, most patients are admitted to a regular nursing unit, though some patients with pheochromocytomas will need to undergo a short stay in the intensive care unit for invasive monitoring. Patients are started on clear liquids on postoperative day 1, and the diet is advanced as tolerated. The urinary catheter is usually removed on postoperative day 1. Intravenous analgesia is switched to oral analgesia as soon as the patient can tolerate oral feeding. A complete blood count is obtained on postoperative day 1 in all patients, and electrolyte levels are monitored in patients with aldosteronomas and hypercortisolism. Patients with Cushing syndrome should be given stress doses of steroids perioperatively and should be discharged on a maintenance prednisone dosage of 10 to 15 mg/day in divided doses. These patients should be advised that it may take 6 to 12 months or longer for the contralateral adrenal to recover to the point where prednisone can be discontinued. Patients undergoing bilateral adrenalectomy will need lifelong replacement therapy with a glucocorticoid (e.g., prednisone) and a mineralocorticoid (e.g., fludrocortisone acetate, 0.1 mg/day).

Postoperative management of hypertensive medications depends on the pathology of the underlying adrenal lesion. In patients with aldosteronomas, spironolactone is stopped immediately after adrenalectomy, and the other antihypertensive agents are usually continued while blood pressure is monitored closely on an outpatient basis; further medication reductions are made as clinically warranted. In most patients with Cushing syndrome, antihypertensive medications are continued, whereas in most patients with pheochromocytomas, they are not. In both sets of patients, however, close outpatient monitoring of blood pressure should be carried out in the early postoperative period. Adrenalectomy can have a dramatic impact on hypertensive control and can lead to hypotension if medications are not appropriately adjusted.

In most routine cases, patients can be discharged within 24 hours after a laparoscopic adrenalectomy, though some patients will have to stay longer for blood pressure monitoring, for adjustment of steroid replacement therapy, or for resumption of a regular diet. After an open adrenalectomy, resumption of an oral diet takes longer, and postoperative hospital stays of 4 to 5 days are more typical.

After discharge, patients are seen in the clinic within 2 to 3 weeks for a wound check, blood pressure evaluation, and a review of antihypertensive medications. In patients who underwent adrenalectomy for an aldosteronoma, electrolyte levels and the creatinine concentration should be checked. In patients who underwent adrenalectomy for pheochromocytoma, yearly clinical and biochemical follow-up is indicated, with measurement of either plasma levels of fractionated metanephrines or urine levels of catecholamines and metanephrines. In selected patients on steroid replacement therapy who are proving difficult to wean from prednisone, an ACTH stimulation test may be necessary to assess the responsiveness of the pituitary-adrenal axis.

Complications

It appears that laparoscopic adrenalectomy has a major advantage over open adrenalectomy in terms of the incidence of postoperative complications. In a meta-analysis of 98 adrenalectomy series reported between 1980 and 2000, the overall complication rate was 10.9% with laparoscopic procedures and 25.2% with open procedures.10 This difference between the complication rates was primarily attributable to the occurrence of fewer wound, pulmonary, and infectious complications in the laparoscopic series. The most common complication of laparoscopic adrenalectomy is bleeding, which was reported in 4.7% of patients from the series reviewed in the meta-analysis. Bleeding is also the most common reason for conversion to open adrenalectomy; however, major bleeding that leads to transfusion is relatively uncommon. The risk of bleeding can be minimized by obtaining meticulous hemostasis, taking care not to grasp the adrenal gland, and handling tissue gently. If bleeding does occur, the prudent course of action is to maintain pressure on the bleeding source while obtaining better exposure or even starting the dissection in another area, rather than to resort to indiscriminate use of clips or electrocautery. The surgeon must be prepared to convert rapidly to an open procedure should major hemorrhage occur.

Other potential complications of adrenalectomy (either laparoscopic or open) include injury to the tail of the pancreas (with resultant pancreatic leakage or pancreatitis), injury to the diaphragm, and pneumothorax. Wound infections are uncommon with laparoscopic adrenalectomy. Trocar site hernias are infrequent as well, provided that the fascia is closed at all port sites that are 10 mm or larger. Deep vein thrombosis occurs in 0.8% of cases, pulmonary embolism in 0.5%.16 Pneumatic compression stockings should be used perioperatively to minimize the risk of venous thromboembolism. Renovascular hypertension from injury to the renal artery has also been reported.11,12 The operative mortality associated with laparoscopic adrenalectomy is about 0.3%.

Several cases of local or regional tumor recurrence have been reported after laparoscopic adrenalectomy. In most of these cases, the tumors removed were either suspected or unsuspected adrenal malignancies, and the extensive nature of the recurrences was probably related to aggressive tumor biology rather than to the
minimally invasive surgical technique. In some of the cases, however, the pattern of recurrence, characterized by the development of multiple intraperitoneal or port site metastases, suggested that laparoscopic dissection and pneumoperitoneum might have contributed to tumor spread.13-16 One group treated three patients for recurrent pheochromocytomatosis that developed after laparoscopic adrenalectomy.17 These patients were found to have multiple small tumor nodules in the adrenalectomy bed during open reoperation after removal of apparently benign pheochromocytomas. Fragmentation of the tumor and excessive tumor manipulation during the laparoscopic dissection were considered the probable mechanisms of tumor recurrence.

These reports highlight the need for caution in approaching large, malignant, or potentially malignant adrenal tumors. Surgeons who attempt a laparoscopic approach in this setting should be highly experienced in laparoscopic adrenalectomy techniques, and the tumor should be well circumscribed and not locally invasive. The use of a hand port may be a valuable adjunct to resection in these cases. Regardless of the specific surgical approach followed, wide excision of the lesion along with the surrounding periadrenal fat is crucial for minimizing recurrence rates in this population.

**Outcome Evaluation**

The safety and efficacy of laparoscopic adrenalectomy for the removal of small, benign adrenal tumors have been clearly established. Rates of conversion to open adrenalectomy in high-volume centers have ranged from 3% to 13%, and operating times have averaged 2 to 3 hours.9,11,18-23 Most patients are now discharged from the hospital within 24 to 48 hours after operation. Although no prospective, randomized trial comparing laparoscopic with open adrenalectomy has been carried out, several retrospective studies have consistently shown that the laparoscopic approach is associated with decreased pain, a shorter hospital stay, and a faster recovery.24-27 Complication rates have also been low, and overall, complications appear to be less common than with open adrenalectomy.10

The results of a laparoscopic approach in patients with large (> 6 cm) adrenal tumors or malignant primary or metastatic adrenal lesions have been reviewed28; generally, the conversion rates for large or malignant tumors have been higher than those reported in other laparoscopic adrenalectomy series. Overall, tumor recurrence rates after laparoscopic adrenalectomy have been low.29-33 In one series, however, local or regional tumor recurrence developed in three of five patients with adrenocortical carcinomas that were treated laparoscopically.34 Other groups have also published anecdotal reports of local tumor recurrences after resection of unsuspected adrenal carcinomas.13-16 Whether these recurrences were related primarily to the surgical technique employed or to the underlying tumor biology is unclear. It would appear, therefore, that in most cases, primary adrenal malignancies are best approached in an open fashion unless the tumor is small and well circumscribed and the surgeon is highly experienced.

## References


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Figures 1, 2, 5, 6a, 7a, 8a, 9, 10 — Tom Moore.