MINIMALLY INVASIVE SURGERY

LAPAROSCOPY, THERAPEUTIC ENDOSCOPY AND NOTES
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Over the last two decades, there has been an evolution toward less invasive procedures and therapies. Surgeons have embraced laparoscopy, VATS, and robotics. Gastroenterologists are taking on more difficult problems and teaming up with surgeons to offer POEM and NOTES. Instruments and techniques used by interventional radiologists, cardiologists, and endoscopists are expanding the armamentarium of the surgeon. We envision a new subspecialty which will one day meld the training of the laparoscopist, endoscopist and interventional radiologist. *Minimally Invasive Surgery: Laparoscopy, Therapeutic Endoscopy and NOTES* is the first comprehensive textbook to bridge advanced laparoscopy and endoscopy.

Our research has led to a better understanding of tumor implantation during pneumoperitonium, the accuracy of laparoscopic radiofrequency ablation, and the technical advances offered by new operations such as endoscopic parathyroidectomy, laparoscopic aortic surgery, laparoscopic Heller myotomy, biliary enteric stenting, gastric banding, laparoscopic gastric bypass and NOTES. Working with trainees, our basic science research has studied novel applications of fibrin glue, the physiology and health utility of weight loss surgery, 3-dimensional modeling using novel jet printers, and the development of simulators and validation of team training using simulation. Many of our findings are incorporated into the chapters which have been written by former trainees.

*Minimally Invasive Surgery: Laparoscopy, Therapeutic Endoscopy and NOTES* features beautiful color illustrations and high resolution photos. Each chapter is succinct and yet captures the key points of the procedure. The book is current, with innovative procedures such as robotic surgery and NOTES. We hope you enjoy the read!

Daniel B Jones
Lead Editor
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I would not have been in a position to edit a book like this had I not worked with such an inspiring team throughout my career. Since the mid-1990s, I have had the great fortune to be mentored by pioneers in minimally invasive surgery (MIS), including Nathaniel Soper, James Fleshman, Ralf Clayman, and L. Michael Brunt at the Washington University Institute for Minimally Invasive Surgery. After my training, I had the privilege of working alongside research and clinical MIS fellows who have advanced the field of minimal access surgery and bariatric surgery. UT Southwestern Center for Minimally Invasive Surgery in Dallas graduated Daniel Scott, Elizabeth Hamilton, Leonardo Villegas and Craig Chang. The Section for Minimally Invasive Surgery at Beth Israel Deaconess Medical Center is proud to have research trainees Ashish Patel, Shishir Maithel, Marcos Molina as well as MIS clinical fellows Benjamin Schneider, Vivian Sanchez, Thomas McIntyre, Michael Edwards, James Ellsmere, Ronit Grinbaum, Scott Rehrig, Kinga Powers, Shawn Tsuda, Limaris Barrios, Henry Lin, Robert Lim, Jamie Adair, Robert Andrews, Arpan Goel, Raul Gupta, Abe Frech, Omar Yusef Kudsi, Souheil Adra, Jaisa Olasky, Hussina Wakily, Robert Sung, and Steven Henriques. Research collaborators include David Provost, George Blackburn, Stephanie Jones, Christina Wee, Survanu De, Ram Chuttani, and Steve Schwartzberg.

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Daniel B Jones
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INTRODUCTION

The first report of a patient undergoing laparoscopic adrenalectomy was published in July of 1992 describing a laparoscopic left adrenalectomy in a 47-year-old man with hyperaldosteronism. In October of 1992, Gagner and coauthors described in a letter to the editor of the New England Journal of Medicine three patients who underwent successful laparoscopic adrenalectomy. One of the patients was a 52-year-old woman with Cushing’s syndrome who underwent a laparoscopic left adrenalectomy for a 3-cm adrenal mass. The second patient was a 38-year-old man who underwent laparoscopic bilateral adrenalectomy for Cushing’s disease caused by a pituitary adenoma after two failed attempts at trans-sphenoidal adenoectomy. The third patient, a 60-year-old man, underwent a laparoscopic right adrenalectomy for a 3.5 cm pheochromocytoma. The patient’s blood pressure was stable during the procedure, no blood transfusion was needed, and the operative time was 2 hours. From these initial experiences, the authors concluded that ‘the laparoscopic approach can be used successfully for the surgical removal of adrenal tissue’. The authors’ conclusion has indeed been proven correct during the relatively short time that has elapsed after the initial reports of laparoscopic adrenalectomy.

The interest in and trend toward laparoscopic adrenalectomy, as opposed to open adrenalectomy, is illustrated by the large number of papers on the subject, both original articles and reviews, that have been published after the initial descriptions of the procedure. For example, the number of articles cited by PubMed in October 2011 (<20 years after the first reports) under the search words ‘laparoscopic adrenalectomy’ was 1,617. The ongoing interest in and development of laparoscopic adrenalectomy is reflected by the fact that almost 100 papers on laparoscopic adrenalectomy were published during the first 9 months of 2011 alone.

In a recent review of adrenalectomies performed in this country, the annual number of adrenalectomies increased by 64% (from 3,241 to 5,323) during the period 1998–2006. One reason for this relatively dramatic increase in the number of adrenalectomies is probably an increased number of adrenal tumors discovered incidentally due to more frequent use of abdominal CT and MRI (adrenal incidentalomas). The possibility that the introduction of laparoscopic adrenalectomy may have influenced the indications for adrenalectomy has also been raised. Of note, however, during the period 1998–2006, the number of both open and laparoscopic adrenalectomies increased in an almost parallel fashion, suggesting that incidentally discovered adrenal tumors is a more likely explanation than the use of minimally invasive procedures for the increased number of adrenalectomies being performed. Interestingly, in a review of 669 adrenalectomies performed during the 3-year period 2001–2004 at 123 VA hospitals and 14 university centers, 311 cases (46%) were still performed as open procedures, demonstrating that the shift toward laparoscopic procedures during the last decade has been quite substantial.

Today, the laparoscopic approach is considered the surgical standard of care for small (<6 cm) and benign adrenal lesions. The use of minimally invasive surgery for larger and malignant adrenal tumors remains somewhat controversial. A number of excellent review articles describing techniques, patient selection, and limitations of laparoscopic adrenalectomy have been published recently. In this chapter, we will focus on some of the more important aspects of patient selection, techniques, controversies, and risks for complications. In addition, we will highlight novel approaches and indications described during the last couple of years.

PATIENT SELECTION AND PREOPERATIVE EVALUATION

Although no prospective, randomized studies have been (and probably will never be) performed comparing open with laparoscopic adrenalectomy, multiple retrospective comparative studies and case series provide strong evidence suggesting that minimally invasive adrenalectomy (MIA) offers benefits compared with open adrenalectomy. Such benefits include reduced postoperative pain and need for analgesics, shorter hospital stay and recovery time, improved cosmetic outcome and increased patient satisfaction. Recent publications describing large series of patients undergoing laparoscopic adrenalectomy support the safety and efficacy of laparoscopic adrenalectomy and minimally invasive approach is now generally considered the gold standard for the surgical management of most adrenal tumors.

Evaluation of patients with functioning adrenal tumors

A large number of patients undergoing laparoscopic adrenalectomy have the procedure done for functioning adrenal tumors. In principle, the pre- and perioperative metabolic and endocrinological management of these patients does not differ from the management of patients in the era of open adrenalectomy.

Conn’s syndrome

Conn’s syndrome is commonly (approximately 60%) caused by a solitary aldosterone-producing adenoma, frequently smaller than 2 cm in diameter. Other causes include bilateral adenomas, adrenal hyperplasia and more rarely, an adrenal carcinoma may secrete aldosterone. Patients scheduled for laparoscopic adrenalectomy for aldosterone-secreting adenoma may need correction of hypokalemia and hypertension preoperatively. Normokalemia is almost always achieved by adrenalectomy for an aldosteronoma whereas persistent hypertension has been reported in up to a third of patients, even when plasma aldosterone and renin levels are normalized after adrenalectomy. Typically, the blood pressure normalizes or shows maximal improvement 1–6 months postoperatively but can continue to improve up to 1 year after adrenalectomy. In a recent series of 33 consecutive patients undergoing laparoscopic unilateral adrenalectomy for primary hyperaldosteronism, 36% of the patients were reported as cured (normal blood pressure without medication), 50% were improved (normal blood pressure with equal or reduced number of hypertensives), and 14% had no improvement or were worse postoperatively (remaining
hypertensive with the same or more antihypertensive medications). Long-lasting preoperative disease in older females and history of essential hypertension are usually considered factors that increase the risk for persistent hypertension after adrenalectomy.

Recent studies suggest that selective venous sampling should be performed preoperatively in patients with hyperaldosteronism, even in the presence of a unilateral adrenal mass seen on CT or MRI. In a recent report, the surgical management was altered based on results from bilateral venous sampling in 50% of patients presenting with Conn’s syndrome and the initial surgical planning based on CT alone. It should be noted, however, that the need for venous sampling in all patients with Conn’s syndrome is not universally agreed upon and some authors recommend venous sampling only in patients with doubtful lateralization on CT and MRI.

Several recent studies support the use of MIA in patients with aldosterone-secreting tumors. Indeed, aldosteronomas are an ‘ideal’ indication for laparoscopic adrenalectomy since the tumors frequently are small.

### Pheochromocytoma

Pheochromocytoma was initially considered a relative contraindication for laparoscopic adrenalectomy, mainly due to the fear of hypertensive crisis caused by catecholamine release during dissection and manipulation of the adrenal gland and the pneumoperitoneum employed during the procedure. In addition, pheochromocytomas tend to be larger and more vascular than other adrenal tumors which initially further reduced the enthusiasm for MIA in these patients. Recent studies suggest, however, that pheochromocytomas can be safely managed laparoscopically provided the patients are appropriately prepared preoperatively with α-blocking agent, in some cases in combination with β-antagonist, and are carefully monitored intraoperatively. A recent study suggests that either a nonselective α1 antagonist or a selective α1 antagonist can be used as preoperative treatment with similar clinical outcomes.

In a recent report, Shen et al (2010) described their 15-year experience with laparoscopic adrenalectomy for pheochromocytoma in 102 patients. They reported successful laparoscopic resection in 90% of the patients over this period of time with an average tumor size of 5.3 cm, a mean operative time of 3.1 hours and a mean hospital stay of 2.5 days. Other studies as well suggest that adrenal pheochromocytomas can be safely removed with a laparoscopic approach.

Not only is there an agreement that pheochromocytomas can be safely resected with minimally invasive techniques, but even large pheochromocytomas (up to 11 cm) have been successfully removed laparoscopically.

### Cushing’s syndrome

Patients with Cushing’s syndrome may present with unilateral or bilateral adrenal adenomas, micro- and macronodular adrenal hyperplasia, or adrenal hyperfunction caused by pituitary adenoma (Cushing’s disease). The different modes of presentation will decide whether the patient needs a unilateral or bilateral adrenalectomy. In a recent review, 164 patients undergoing 197 laparoscopic adrenalectomies for Cushing’s syndrome between 1996 and 2006 were identified with a mean operative time of 267 minutes, a mean blood loss of 208 mL, and a mean hospital stay of 3.9 days. Special consideration regarding patients undergoing laparoscopic adrenalectomy for Cushing’s syndrome include the potential need for preoperative correction of metabolic abnormalities, such as hyperglycemia, hypokalemia, and alkalosis, and management of nutritional derangements, such as hypoalbuminemia and muscle catabolism. Patients with hypercortisolemia have increased risk of wound infection and poor wound healing (risks that further support the use of laparoscopic adrenalectomy in patients with Cushing’s syndrome).

Not infrequently, patients who undergo unilateral adrenalectomy for cortisol-secreting adenoma need postoperative glucocorticoid treatment due to suppression of ACTH release and hypofunction of the contralateral adrenal gland. Patients who undergo bilateral adrenalectomy for Cushing’s syndrome (or for any other reason) need replacement with both mineralocorticoids and glucocorticoids postoperatively.

### Evaluation of patients with nonfunctioning adrenal tumors

A substantial number of patients being considered for laparoscopic adrenalectomy are patients with adrenal incidentalomas. Most of these lesions are nonfunctioning and benign and the clinical challenge is to distinguish these tumors from malignant adrenal tumors. Although imaging characteristics, including shape and density, are important factors in the discrimination of malignant from benign adrenal incidentalomas, the size of the lesion is frequently used as a criterion for resection. The size threshold for resection of adrenal incidentalomas has varied between 2.5 cm and 6 cm. In a recent analysis of 198 adrenalectomies performed during an 18-year time period, the correlation between tumor size and malignancy was examined. A total number of eight malignant adrenal tumors were identified with the tumor size ranging from 4–14 cm (mean tumor size being 8 cm). Based on their observations, the authors concluded that a 4 cm threshold for adrenalectomy should be applied to patients with nonfunctioning adrenal incidentalomas.

Although studies have defined certain thresholds for surgical removal of adrenal incidentalomas, the management of these lesions remains a subject of debate. On one hand, concern has been expressed that with the benefits of the laparoscopic approach, more liberal indications are used for adrenalectomy in patients with apparently benign lesions. On the other hand, malignancy may be present in adrenal tumors smaller than the threshold (6 cm) commonly used in many earlier studies. Incidentally detected cancer has been reported in lesions between 3–5 cm and even smaller. Because of the excellent results of laparoscopic adrenalectomy for small lesions, several authors have recommended that laparoscopic adrenalectomy should be considered for young patients at low operative risk presenting with incidentalomas measuring 3–5 cm.

### Laparoscopic surgery for malignant adrenal tumors

Malignant adrenal tumors are relatively rare and are more frequently found in patients with large adrenal masses. Adrenal cancers can be nonfunctioning or functioning. Malignant tumors can arise from the adrenal cortex (adrenocortical carcinoma) or medulla (malignant pheochromocytoma) or may be metastatic from a known primary cancer (most commonly breast or lung cancer or malignant melanoma). Previously, evidence or strong suspicion of adrenal malignancy was considered contraindications for the laparoscopic approach with some reports describing local recurrence, trocar port-site seeding, widespread peritoneal dissemination and death after laparoscopic
adrenalectomy for cancer. Interpretation of those and similar reports need to be done with caution, however, because it is unclear whether the minimally invasive approach itself was responsible for the poor outcome in these cases. Some adrenal cancers (in particular the adrenocortical carcinomas) are quite aggressive and may recur locally or give rise to widespread intraperitoneal dissemination even after open adrenalectomy. Another reason why malignancy was commonly considered a contraindication for laparoscopic adrenalectomy previously is the fact that malignant adrenal tumors are often large and may therefore be technically challenging both to resect and extract without rupture of the tumor capsule with spread and extra-adrenal implantation of cancer cells.

Metastatic cancers to the adrenals are usually considered to behave more favorably (locally) than primary adrenal cancers. Because solitary adrenal metastases are typically small and confined within the adrenal gland, laparoscopic resection has been advocated recently, provided, of course, that there is no evidence of local recurrence or additional spread from the primary tumor. For primary adrenal cancers, if complete resection seems to be technically feasible, a laparoscopic approach is an acceptable initial approach in experienced hands. If preoperative imaging gives rise to suspicion of periadrenal invasion, an open approach should be used for the adrenalectomy. Similarly, if the initial exploration during attempted laparoscopic resection suggests that the tumor is infiltrating surrounding structures, the procedure should be converted to open adrenalectomy as soon as possible to reduce the risk of tumor fragmentation and dissemination of malignant cells. Of note, the best surgical approach for adrenal malignancies continues to be debated and it is possible that the use of laparoscopic procedures for this condition will continue to evolve in the future.

Laparoscopic adrenalectomy for large tumors

A tumor size of 6 cm has been commonly used as an upper limit for laparoscopic adrenalectomy. For masses larger than 6 cm, an open approach has been recommended previously, both because of concern for malignancy in large adrenal tumors, and because of potential technical difficulties associated with dissection and extraction of larger tumors.

With increasing experience, minimally invasive surgeons keep ‘pushing the envelope’ and successful resections of larger tumors are being reported. For example, in a recent report of 30 patients having laparoscopic adrenalectomy for unilateral pheochromocytoma, almost a third of the tumors were greater than 6 cm. Although there was a tendency toward a higher conversion rate to open procedure among the patients with tumors greater than 6 cm, there were no significant differences in operative time, blood loss, intraoperative hemodynamic changes, or length of hospital stay between patients having tumors greater or smaller than 6 cm. In another recent report, the successful laparoscopic resection of an 8.6 cm pheochromocytoma was described in a morbidly obese man, further supporting the concept that a size greater than 6 cm does not necessarily need to be a contraindication for laparoscopic adrenalectomy in experienced hands. Interestingly, Assalia and Gagner (2004) suggested that an appropriate upper limit for laparoscopic adrenalectomy may be a tumor size of 10–12 cm.

**TECHNICAL ASPECTS**

In principal, the MIA can be performed using a transperitoneal or retroperitoneal approach. The transperitoneal approach can be anterior or lateral and the retroperitoneal approach can be posterior (also called lumbar or dorsal) or lateral. The lateral transperitoneal approach seems to be the most commonly used technique and because the resection of a left and right adrenal mass differs in several important aspects, left and right lateral transperitoneal laparoscopic adrenalectomies are described in greater detail here. Detailed descriptions of other surgical approaches can be found elsewhere.

**Left lateral transperitoneal laparoscopic adrenalectomy**

The patient is placed on the operating table in a lateral decubitus position with the left side up. The table is flexed about 30º at the waist to enlarge the working space between the iliac crest and lower ribs. By placing the patient in reverse Trendelenburg, adjacent organs are retracted away from the upper abdomen by gravity, facilitating the port placements and subsequent exposure of the left adrenal gland. The surgeon and the camera operator face the patient’s abdomen and the assistant surgeon is behind the patient’s back. Three or four ports are placed under the left costal margin approximately 5 cm apart (Figure 17.1). Pneumoperitoneum is created by using a Veress needle or a Hasson cannula placed somewhat medial to the anterior axillary line about two finger breadths below the costal margin (we prefer using the Hasson technique to minimize the risk of injury to the spleen, left kidney, and colon). After creation of the pneumoperitoneum (15 mmHg), a 30º camera is inserted and the abdomen is inspected. The camera is then used to allow for the insertion of the additional ports under direct vision. One of the additional ports should be an 11 mm port to allow for the insertion of a surgical clip applier and the other two are 5 mm in size. The most lateral port should be placed after mobilization of the splenic flexure of the colon to avoid injury. Using a combination of scissors, ultrasonic coagulation, and hook cauterie, the splenic flexure is mobilized by incising the splenocolic
ligament and the lateral attachments of the splenic flexure of the colon (Figure 17.2). Because the patient is in the lateral decubitus position, the splenic flexure will fall away from the operative field by gravity.

Next, the lateral attachments of the spleen and the splenorenal ligament are incised up to the level of the diaphragm using a combination of ultrasonic coagulation, scissors, and a hook cautery. The spleen and the tail of the pancreas fall downwards/medially, exposing the area where the left adrenal gland will be found. The posterior peritoneum overlying the left adrenal gland and upper pole of the left kidney is then incised, thereby exposing the left adrenal gland. In obese patients, retroperitoneal fat may make it difficult to identify the adrenal gland in which case intraoperative ultrasound may be helpful. The inferior aspect of the adrenal gland is dissected free and the adrenal vein is carefully isolated, secured with vascular clips (two clips placed proximally toward the renal vein and one clip distally), and divided with scissors (Figure 17.3). In case a large adrenal vein is encountered, an endoscopic GI stapler may be used to secure the vein. The adrenal gland is then dissected free from surrounding tissues circumferentially starting along the lateral and superior borders using ultrasonic coagulation or hook cautery. The inferior phrenic vein courses along the medial aspect of the adrenal gland and may need to be secured separately. During the dissection, the adrenal gland itself is manipulated by grasping the periadrenal fat or by gently pushing the gland with the instrument being careful not to violate the adrenal capsule in order to avoid spillage of tumor cells. After the gland has been completely dissected free from surrounding tissues, it is placed in a plastic specimen bag and retrieved through one of the 11 mm port sites. If the tumor is large, the port site may need to be bluntly dilated and rarely two of the port sites may need to be combined to a larger incision. The operative field is irrigated and inspected for hemostasis and secure placement of the clips. The fascia and skin are closed in the usual fashion using absorbable sutures.

Right lateral transperitoneal laparoscopic adrenalectomy

The patient is placed on the operating table in a lateral decubitus position with the right side up. The table is flexed 30º at the waist. The surgeon and the camera operator usually stand anterior to the patient (facing the patient’s abdomen) and the assistant surgeon stands on the opposite side of the table. Pneumoperitoneum is created with a veress needle or a Hasson trocar. Four ports are placed subcostally approximately 5 cm apart (Figure 17.4). The first port is placed just medial to the anterior axillary line about two fingerbreadths below the costal margin. A 30º camera is inserted through the first port and after inspection of the abdomen, the remaining ports are inserted under direct vision.

The subhepatic peritoneum is incised using scissors, ultrasonic coagulation, or hook cautery (Figure 17.5). A fan retractor is inserted through the most medial trocar and the liver is retracted superiorly and medially. If needed, the right liver lobe is mobilized further by incising the triangular ligament up to the level of the diaphragm which allows for further retraction of the right liver lobe medially. The adrenal gland is located in the perinephric fat at the superior pole of the right kidney and posterolateral to the inferior vena cava. The dissection begins by developing the plane between the right adrenal gland and the inferior vena cava. Great care is taken to avoid injury to the vena cava which may cause rapid and significant bleeding and that may require immediate conversion to an open procedure. The right adrenal vein is short and empties directly into the vena cava (Figure 17.6). It
is carefully mobilized circumferentially using a right angle dissector and is then divided between surgical clips (double clips are placed on the vena cava side) or by using an endoscopic stapler. Dissection then continues circumferentially around the gland with additional small vessels electrocoagulated or secured with vascular clips. When the gland is completely freed, it is placed in a plastic specimen bag and retrieved through one of the 11 mm port sites. The operative field is irrigated and inspected for hemostasis and secure placement of the vascular clips. The fascia and skin at the port sites are closed in the standard fashion.

### Retroperitoneal minimally invasive adrenalectomy

Although lateral transperitoneal adrenalectomy may be the most common minimally invasive approach for laparoscopic adrenalectomy, some authors prefer a retroperitoneal technique. This can be done through a posterior or lateral approach. Potential advantages of retroperitoneal surgeries include avoiding entry into the peritoneal cavity and encountering adhesions from previous surgeries. By using a retroperitoneal approach, mobilization of the colon, liver, spleen and pancreas is not needed, thereby avoiding the risk of injury to these organs. In addition, when a retroperitoneal posterior approach is used, bilateral adrenalectomy can be performed without repositioning the patient.

Although retroperitoneal MIA is usually considered more difficult from a technical standpoint than lateral transperitoneal laparoscopic adrenalectomy, in particular in obese patients and when the tumor is located caudally close to the renal hilum, recent reports indicate that the retroperitoneal approach is gaining in popularity. A recent report

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**Figure 17.4**
Port sites for right lateral transperitoneal laparoscopic adrenalectomy.

**Figure 17.5**
Incising the subhepatic peritoneum and retracting the liver with a fan retractor expose the right adrenal gland. If needed, the right liver lobe can be further mobilized and retracted by incising the triangular ligament up to the level of the diaphragm.

**Figure 17.6**
The right adrenal vein is short and empties directly into the inferior vena cava. The adrenal vein is carefully mobilized circumferentially and divided between surgical clips with double clips placed on the vena cava side.
described posterior retroperitoneal resection of 112 adrenal tumors in 105 patients during a 10-year period staring 1997. The different types of adrenal lesions included 39 pheochromocytomas, 21 Cushing’s disease, and 20 aldosteronomas. The mean tumor size was 3.1 cm and the mean operative time was 100 minutes. The blood loss was reported to be minimal (median of 5 mL) and the authors concluded that retroperitoneal MIA can be performed with similar outcomes as achieved with transperitoneal laparoscopic adrenalectomy.

In a recent review of MIA, Nehs and Ruan (2011) suggested that retroperitoneal adrenalectomy is best suited for patients with a history of previous abdominal surgeries and who have small tumors in the most cranial portion of the adrenal gland. The procedure, however, is not ideal for obese patients, large tumors, or for adrenal masses located near the hilum of the kidney. Based on the experience with 38 posterior retroperitoneal and 38 lateral transperitoneal minimally invasive adrenalectomies, Lombardi et al (2008) concluded that neither procedure can be considered preferable overall. It was suggested that in cases of bilateral adrenalectomy and previous abdominal surgery, posterior retroperitoneal adrenalectomy may offer some advantages. Ultimately, however, the surgeon’s preference and experience will continue to guide this choice.

■ SPECIAL CONSIDERATIONS IN MINIMALLY INVASIVE ADRENALECTOMY

■ Bilateral adrenalectomy

In the majority of patients undergoing MIA, a unilateral adrenalectomy is performed. There are circumstances, however, when a bilateral adrenalectomy is indicated, including bilateral pheochromocytomas and refractory Cushing’s disease caused by pituitary adenoma, ectopic ACTH production, and micronodular and macronodular hyperplasia. Interestingly, bilateral laparoscopic adrenalectomy for Cushing’s disease caused by a pituitary adenoma was performed in one of the three patients described in the early report by Gagner et al (1992). Bilateral adrenalectomy has also been performed in patients with hyperaldosteronism caused by bilateral hyperplasia although medical treatment (spironolactone) will probably continue to remain the primary treatment in most of these patients. Bilateral adrenalectomy for bilateral metastatic disease has been reported but this condition is not widely accepted as an indication.

Different surgical approaches have been used for bilateral adrenalectomy, including anterior transperitoneal, lateral transperitoneal, and posterior retroperitoneal techniques. Lateral transperitoneal adrenalectomy is probably the most common procedure used for bilateral adrenalectomy but has the disadvantage of the need for repositioning, reperepping, and redraping of the patient between the first and second adrenalectomy. In obese patients, bilateral lateral transperitoneal adrenalectomy is sometimes performed as a staged procedure with an interval of a week up to a month between the procedures due to the complexity and excessive time involved in repositioning these patients. Although repositioning of the patient is not needed when bilateral adrenalectomy is performed using the anterior transperitoneal or posterior retroperitoneal approach, these techniques are used less frequently, possibly because they are considered more challenging from a technical standpoint. In a recent review of reports describing laparoscopic adrenalectomy, most surgeons (74%) preferred lateral transperitoneal adrenalectomy for bilateral MIA followed by retroperitoneal (18%) and anterior transperitoneal approach (8%).

■ Subtotal (cortical-sparing) adrenalectomy

Historically, total adrenalectomy (i.e. complete removal of the affected gland) has been used for the resection of adrenal masses, regardless of the size of the tumor. Recent reports, however, suggest that partial (cortical-sparing) adrenalectomy can be safely performed and may be used to avoid the side effects of potential adrenal insufficiency and steroid replacement in select cases. In a recent study, Kaye et al (2010) reviewed 22 reports that included 417 partial adrenalectomies performed 1991–2000. An increasing trend toward partial adrenalectomy was noted worldwide over the last 20 years and the majority of cases were performed laparoscopically. Most of the cortical-sparing procedures were performed for Conn’s syndrome (42%) followed by pheochromocytoma (37%), nonfunctional tumors (12%), and Cushing’s syndrome (9%). Approximately 95% of patients who underwent cortical-sparing adrenalectomy maintained sufficient adrenal steroid synthetic function.

In several studies, the operating time for partial adrenalectomy was equal to the time for total adrenalectomy. Although reports suggest that ligating and dividing the adrenal vein had no effect on the functional reserve of the adrenal remnant, in other reports, attempts were made to avoid dividing the adrenal vein under the assumption that this would better preserve the function of the residual adrenal.

From a recent review of cortical-sparing adrenalectomy, Kaye et al (2010) concluded that partial adrenalectomy should be first line treatment for small adrenal masses. The procedure is particularly appropriate for small bilateral tumors and when the patient has previously undergone total adrenalectomy on the contralateral side.

■ Laparoscopic adrenalectomy as a same-day procedure

The small incisions, minimal blood loss, and decreased postoperative pain have made it possible to perform laparoscopic adrenalectomy as an outpatient procedure in select cases. In a recent report, Mohammed et al (2009) described their experience with 17 consecutive outpatient laparoscopic adrenalectomies. The criteria used by the authors for patients to be considered for same-day procedure were age below 75 years, an ASA score of I or II, a tumor size less than 6 cm, and no evidence of pheochromocytoma or Cushing’s disease. The mean age in their case series was 52 years and the mean tumor size was 2.5 cm (range 1–5.8 cm). Thirteen patients (76%) could be discharged after a short recovery time (3–6 hours), three patients were admitted for 23 hours observation, and one patient had to be admitted for atelectases and oxygen supplementation. The pathology was consistent with aldosteronoma in 11 patients, benign adrenal cortical adenoma in three patients, subclinical Cushing’s syndrome in two patients, and renal cell carcinoma metastasis in one patient.

Nehs and Ruan (2011) concluded in their review that outpatient laparoscopic adrenalectomy may be a reasonable strategy in select patients who live close to the hospital, are reliable for follow-up, and do not have concerning co-morbidities. More recent studies also support the concept that laparoscopic adrenalectomy can be safely performed as a same-day procedure in some patients.

■ Robotic adrenalectomy

Robotic surgery is now commonly performed for prostatectomy, gynecological procedures, and more recently for colorectal procedures. The major advantage with robotic surgery is that it provides improved
visualization and instrument range in small working spaces. Not surprisingly, robot-assisted surgery has been expanded recently to MIA.

The feasibility of robotic surgery for adrenalectomy was documented in recent case reports. For example, robot-assisted retroperitoneal adrenalectomy was performed in 8 patients reported by Berber et al (2010) and in six patients reported by Ludwig et al (2010). An interesting application of robotic adrenalectomy was illustrated by a case report of a 34-year-old pregnant woman who underwent robot-assisted resection of a pheochromocytoma during the second trimester of her pregnancy. It was felt that the robot provided enhanced visualization and range of motion for dissection in the limited space displaced by the gravid uterus. Other recent reports as well support the potential use of robot-assisted adrenalectomy.

Obviously, the robotic approach to adrenalectomy is limited by the surgeon’s experience as well as by institutional resources. If the advantages of robotic adrenalectomy prove substantial in continued studies, the procedure may become more universally accepted in the future.

- **Single-incision laparoscopic surgery (SILS)** for adrenalectomy

  The SILS uses articulating instruments that are introduced through a single incision and is being increasingly applied for certain procedures, including laparoscopic cholecystectomy and colectomy. The advantage of a single incision is mainly cosmetic whereas it is uncertain whether postoperative pain is less from a somewhat wider single port site than from multiple smaller port sites. A major disadvantage is the ‘crowding’ of instruments around a single port and the difficulty to achieve adequate triangulation and exposure.

  The use of SILS and single-access retroperitoneal approach for MIA was reported recently. Walz et al (2010) described 50 patients who underwent retroperitoneal MIA through a 2-cm single incision placed below the tip of the 12th rib. Both right- and left-sided adrenal tumors were resected using this technique. A matched control group of 47 patients who underwent conventional retroperitoneal adrenalectomy using three smaller posterior incisions were included in the study. The authors reported that although the operative time was longer, the use of postoperative analgesics was reduced and the length of hospital stay was shorter after the single-access approach.

  In other recent reports, SILS was successful in lateral transperitoneal left adrenalectomy whereas the need for liver retraction necessitated one additional port when right-sided adrenalectomy was performed.

  One potential concern with SILS for adrenalectomy is whether patients will have a higher rate of hernia or other port-related morbidity from a 2–3 cm incision as compared to multiple smaller incisions. Other potential drawbacks include longer operative time, instrument congestion around the single port, and difficulties achieving adequate exposure. Because of these challenges, it may be a while before SILS gain universal popularity in MIA.

- **Natural orifice transluminal endoscopic surgery (NOTES)-assisted laparoscopic adrenalectomy**

  The ultimate procedure with regard to avoiding visible skin incisions is the NOTES-assisted procedure. Although this approach has been reported for certain procedures, including cholecystectomy and ad-pendectomy, it is still to be considered experimental. The first cases of NOTES-assisted laparoscopic adrenalectomy in human patients were reported recently. In that report, 11 patients underwent transvaginal NOTES-assisted laparoscopic adrenalectomy. In one patient who underwent surgery for Cushing’s disease, the procedure had to be converted to open surgery because of bleeding from an injury to the spleen. Except for this patient, no patients received blood transfusions. The median operative time was 102 minutes (range 80–310 minutes), the median estimated blood loss was 80 mL (range 30–800 mL), and the median size of the adrenal tumor was 4.7 cm (range 2.2–6.6 cm). Of note, although this report is described as being the first clinical experience with NOTES-assisted laparoscopic adrenalectomy, a 5-mm and a 10-mm trocar were inserted at the ‘umbilical edge’ in addition to a 10-mm trocar inserted through the posterior vaginal fornix. Although these cases may therefore not be considered ‘true’ NOTES-assisted laparoscopic adrenalectomies, recent work in experimental animals suggest that adrenalectomy using transvaginal NOTES-assisted retroperitoneal approach may be feasible.

### COMPLICATIONS

Many studies have now shown that laparoscopic adrenalectomy can be performed safely without increased risk for complications compared with open adrenalectomy. Minimally invasive approach is therefore considered the gold standard for surgical removal of adrenal masses with major contraindications limited to malignant tumors with suggestion of infiltration of surrounding structures and large (>10–12 cm) adrenal masses (although the upper size limit suggested in the literature varies and at least in part reflects the surgeon’s experience).

Complications related to laparoscopic adrenalectomy can be intra- or postoperative. In a recent thorough review of laparoscopic adrenalectomy, Assalia and Gagner (2004) analyzed complications reported in 2550 minimally invasive adrenalectomies. The overall complication rate was 9.5% and the mortality rate was 0.2%. Intra- and postoperative complications among the 2550 adrenalectomies reviewed by Assalia and Gagner (2004) are summarized in Table 17.1. Intraoperative complications accounted for almost one-third of all complications and the remainder of the complications were postoperative. Among intraoperative complications, bleeding due to vascular injury accounted for the majority of cases (adrenal vein injury in 18 cases, renal vein injury 19 cases, inferior vena cava injury 20 cases, and other vascular injuries 21 cases). Injury to organs (liver, kidney, spleen, pancreas, bowel and diaphragm) accounted for 6.4% of all complications. Other intraoperative complications included gland fragmentation and hypertensive crisis in patients with pheochromocytoma.

The majority of postoperative complications among the 2550 patients reviewed by Assalia and Gagner (2004) and undergoing MIA included bleeding and wound-related complications (see Table 17.1). About three-quarters of wound complications were acute such as hematoma and infection. Long-term wound complications included prolonged pain and hernia. Thromboembolic complications were most common among obese patients and after long procedures.

The rate of reoperation after laparoscopic adrenalectomy reported in the review by Assalia and Gagner (2004) was 1.2%. Reoperation was performed for postoperative bleeding in all cases except for one patient who underwent reoperation for acute cholecystitis. The conversion rate to open procedure was 3.6% with a range of 0–12% in the different studies that were reviewed. The most common cause for conversion to open procedure was uncontrollable bleeding (29.7%).
Table 17.1 Distribution of different types of complications in 2550 laparoscopic adrenalectomies reviewed by Assalia and Gagner (2004). The overall rate of complications among the 2550 cases was 9.5% and the figures provided in the table reflect the distribution of different types of complications in cases where a complication was encountered and are reported as per cent of total complications. *Because some patients may have had more than one complication, the sum of the individual complications listed under the different subtypes of complications may be greater than 100%

<table>
<thead>
<tr>
<th>Complication</th>
<th>(%)</th>
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<tbody>
<tr>
<td><strong>Intraoperative</strong></td>
<td></td>
</tr>
<tr>
<td>Bleeding due to vascular injury</td>
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</tr>
<tr>
<td>Adrenal vein</td>
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</tr>
<tr>
<td>Renal vein</td>
<td>0.6</td>
</tr>
<tr>
<td>Inferior vena cava</td>
<td>1.2</td>
</tr>
<tr>
<td>Other</td>
<td>1.2</td>
</tr>
<tr>
<td>Organ injury</td>
<td>3.6</td>
</tr>
<tr>
<td>Liver</td>
<td>3.6</td>
</tr>
<tr>
<td>Kidney</td>
<td>0.6</td>
</tr>
<tr>
<td>Spleen</td>
<td>0.6</td>
</tr>
<tr>
<td>Pancreas</td>
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<tr>
<td>Bowel</td>
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<td>Diaphragm</td>
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<tr>
<td>Wound</td>
<td>10.1</td>
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<tr>
<td>Long term</td>
<td>10.1</td>
</tr>
<tr>
<td>Short term</td>
<td>10.1</td>
</tr>
<tr>
<td>Infectious</td>
<td>10.1</td>
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<tr>
<td>Cardiovascular</td>
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<tr>
<td>Pulmonary</td>
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<tr>
<td>Gastrointestinal</td>
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</tr>
<tr>
<td>Urinary</td>
<td>10.1</td>
</tr>
<tr>
<td>Thromboembolic</td>
<td>10.1</td>
</tr>
<tr>
<td>Endocrine</td>
<td>10.1</td>
</tr>
<tr>
<td>Other</td>
<td>10.1</td>
</tr>
<tr>
<td><strong>Postoperative</strong></td>
<td></td>
</tr>
<tr>
<td>Bleeding</td>
<td>21.5</td>
</tr>
<tr>
<td>Wound</td>
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<tr>
<td>Long term</td>
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<tr>
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<td>Cardiovascular</td>
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<tr>
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<td>Endocrine</td>
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<tr>
<td>Other</td>
<td>9.5</td>
</tr>
</tbody>
</table>

*Because some patients may have had more than one complication, the sum of the individual complications listed under the different subtypes of complications may be greater than 100%

**FURTHER READING**

- Asher KP, Gupta GN, Boris RS, et al. Robot-assisted laparoscopic partial adrenalectomy for pheochromocytoma: the National Cancer Institute experience of the surgeon rather than the invasiveness and size of the tumor are the limiting factors for minimally invasive resection of these lesions. It is reasonable to anticipate that continued advances in the field of laparoscopic adrenalectomy will see further emphasis on even less invasive procedures, including SILS and NOTES.

**CONCLUSION**

Although high-level evidence from prospective randomized controlled studies is missing (and will probably never be generated), laparoscopic adrenalectomy appears to achieve superior results compared with open adrenalectomy with regard to recovery, patient satisfaction, improved cosmesis, morbidity, and length of hospital stay. Laparoscopic adrenalectomy therefore is universally considered the gold standard for surgical treatment of adrenal functioning and non-functioning benign tumors less than 6 cm in size. Although only relatively limited experience exists with larger (up to 10–12 cm) and malignant tumors, it appears the technical abilities and experience of the surgeon rather than the invasiveness and size of the tumor are the limiting factors for minimally invasive resection of these lesions. It is reasonable to anticipate that continued advances in the field of laparoscopic adrenalectomy will see further emphasis on even less invasive procedures, including SILS and NOTES.
Further reading


