6 Robotic Adrenal Surgery

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6.1 Introduction

In the past decade, laparoscopic adrenalectomy has been established as the standard of care for benign adrenal disease [13, 16, 17, 19, 43, 49] and increasingly considered for malignant disease [34, 44, 46]. First described in 1992 [13], laparoscopic adrenalectomy has been shown to be safe, to reduce patient morbidity, to decrease costs, and to shorten convalescence compared with open surgery [20, 26, 37, 39, 49]. Both transperitoneal and retroperitoneal approaches to laparoscopic adrenalectomy have been shown to be safe and effective [38].

Robotic-assisted laparoscopic techniques have concurrently achieved prominence in urological surgery. Robotic surgery has several potential advantages compared with laparoscopy including improved range of motion, easier instrument manipulation, stereoscopic three-dimensional vision, powerful magnification, and improved ergonomics. Robotic surgery shares many of the advantages of laparoscopy including decreased postoperative pain, shorter convalescence, and improved cosmesis. Robotic techniques have been employed in particular for urological procedures that require intracorporeal suturing and reconstruction, i.e., radical prostatectomy and pyeloplasty [30, 33]. Although adrenalectomy is an extirpative procedure that does not require reconstruction, it requires careful dissection along major vessels (i.e., aorta, renal vessels, vena cava) and intraabdominal organs (i.e., liver, spleen, kidney). By improving the speed and safety of dissection, the robot has been considered beneficial for adrenal surgery by some authors [10, 11, 45]. Also for practitioners without significant laparoscopic experience, robotic techniques may be easier to learn and more intuitive than laparoscopy and may enable more practitioners to perform advanced minimally invasive procedures such as adrenalectomy [41].

The first robotic adrenalectomy was reported in 2001 by Horgan and Vanuno [24]. Since then, robotic adrenalectomy has been shown to be safe and feasible [45] and may have advantages in certain instances over laparoscopy [4]. Robotic techniques may facilitate identification of small and often numerous adrenal vessels [18] and visualization and dissection of the short right adrenal vein [48]. While there have been no prospective randomized studies comparing laparoscopic and robotic adrenalectomy, there have been numerous case series of robotic adrenalectomy [4, 36, 47] and comparisons between the two techniques [1, 4, 36]. While robotic adrenalectomy has not been proven superior to laparoscopy by objective data, it may be a reasonable option for selected patients, particularly at high-volume robotic centers, and may assist practitioners without substantial laparoscopic experience.

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In this chapter, indications for minimally invasive adrenalectomy are reviewed, followed by a discussion of techniques for both right and left robotic adrenalectomy. Literature pertaining to robotic adrenalectomy and comparisons with the laparoscopic procedure are reviewed. Lastly, considerations for technique and training are discussed as well as the future of minimally invasive adrenal surgery.

6.2 Indications

Laparoscopic adrenalectomy has become the standard of care for benign adrenal masses and is increasingly considered for selected malignant lesions [9, 21, 34, 49]. As studies have shown that robotic adrenalectomy is safe and feasible, it may be indicated in cases where laparoscopic adrenalectomy would be performed. Indications for minimally invasive adrenalectomy are diverse and include adrenal masses >6 cm and up to 15 cm depending on surgeon skill and comfort, smaller lesions suspicious for malignancy, or in younger patients to avoid the stress of serial follow-up, lesions that increase in size on serial imaging, and hormone-secreting tumors [12, 44, 50]. Contraindications to minimally invasive adrenalectomy are controversial though typically include infiltrative adrenal masses, involvement of large vascular structures or significant involvement of adjacent organs, and tumors of large size (e.g., >10–15 cm). Disseminated metastatic disease or peritoneal carcinomatosis generally contraindicates surgical management of adrenal malignancy. There is further discussion of minimally invasive management of adrenal malignancy below.

Incidental adrenal masses are found on CT scan in up to 4 % of patients [3, 23]. Numerous algorithms for evaluation and management of adrenal incidentalomas have been published [23, 50]. Decision making regarding these lesions is based on numerous criteria including size, radiographic characteristics, and testing for secretory tumor [49].

Traditionally, adrenal masses >6 cm are considered likely to harbor malignancy and should be removed, although that size threshold has been lowered to 4 cm by some authors [49]. Adrenal tumors >6 cm have 92 % likelihood of malignancy [7]. Size is the best single indicator of malignancy, although its sensitivity and specificity are imperfect [44]. Younger patients may have a lower threshold for adrenalectomy based on higher lifetime risk of cancer, e.g., patients less than 50 years old with 3- to 5-cm mass may warrant adrenalectomy [15]. Size criteria for laparoscopy versus open surgery vary depending on the skill and experience of the laparoscopist as well as patient factors. Dissection of larger lesions is frequently more difficult based on increased vascularity and confined working space, and the risk of malignancy increases with the size of the adrenal tumor which may deter many surgeons from pursuing minimally invasive interventions [27].

Imaging characteristics on CT or MRI help to discriminate benign from malignant adrenal lesions. Adrenal adenomas are generally homogeneous with distinct margins compared with malignant lesions which are typically heterogeneous with irregular margins. Adenomas may be indicated by low attenuation (<10 HU) from lipid content as well as by rapid washout of contrast medium [29, 50]. Unfortunately, radiographic characteristics of benign and malignant lesions may overlap; thus, imaging tests by themselves may not be completely reliable [15, 29].

Hormonally active adrenal tumors necessitate adrenalectomy. In general, hormone secretion is investigated for lesions >1 cm [23] by a combination of history, physical exam, and laboratory testing including serum electrolytes, 24-h collection of urinary catecholamines or their breakdown products, and urinary free cortisol [49]. Functional tumors can be subclinical, and screening, even without clinical evidence, is warranted.

Minimally invasive adrenalectomy for primary or secondary adrenal malignancy is controversial, but recent literature indicates a growing willingness to treat selected lesions laparoscopically [27]. Infiltrative disease or other signs of malignancy have traditionally been considered absolute contraindications to minimally invasive resection based on the need for “radical adrenalectomy” [21, 27, 28, 44]. Radical adrenalectomy involves en bloc resection including periadrenal fat and potentially neighboring organs. This type of resection may be feasible for selected patients in skilled laparoscopic hands, but the patient should be counseled on the possibility of conversion to open surgery. Conversion should be performed if there is any intraoperative doubt regarding completeness of resection [35]. Not disrupting the adrenal capsule and not grasping tumor or adrenal tissue is imperative if malignancy is suspected [21, 40, 44].

There is growing literature on the minimally invasive resection of isolated adrenal metastases [6]. The adrenal may be the site for metastases from lung cancer, renal cell carcinoma, melanoma, breast, and colon cancer. Adrenal metastases are generally confined to the capsule and may require simple, rather than radical, adrenalectomy for complete resection [6, 51]. Long-term disease-free survival from metastatic disease can occur following laparoscopic resection of isolated adrenal metastases [31, 32, 49], and oncological outcomes may be equivalent to the open approach for selected populations [51]. Risk of recurrence at trocar sites is minimal with no recurrences noted in several studies of laparoscopic adrenalectomy for metastasis [46].

Primary adrenal malignancy is generally considered a contraindication to minimally invasive adrenalectomy because of the high risk of locoregional recurrence [51]. There are reports of intraperitoneal dissemination and local recurrence following laparoscopic treatment of primary adrenal malignancy. It is not clear whether these resulted from tumor selection, operative technique, or other factors [6, 44]; however, if complete resection can be performed, laparoscopic resection of adrenocortical carcinoma may be equivalent to open surgery in terms of local recurrence and survival [35]. Complete resection may be difficult to achieve because of the locoregional aggressiveness of these tumors and the requirement for regional lymphadenectomy [51]. Proper staging and selection of patients with suspected malignancy are critical. Contraindications may include extensive infiltration, caval thrombus, pheochromocytoma metastatic to periaortic nodes, bulky locoregional lymphadenopathy, and tumors >15 cm [6, 12, 35]. Survival following laparoscopic resection of malignant tumors may improve when lesions are <5 cm [35]. Regarding the risk of port-site metastases, this risk can generally be minimized by meticulous laparoscopic technique and appropriate patient selection [35]. It is critical to follow long-term these patients for recurrence, and further prospective data regarding minimally invasive therapy for adrenal malignancy is required.

Intraoperative ultrasound may assist in staging and other aspects of minimally invasive adrenalectomy. Its potential uses include helping to locate the gland, confirm pathology, identify the adrenal vein, and examine the contralateral adrenal gland [12, 15].

Needle biopsy of an adrenal mass is not generally recommended. It may be unreliable in distinguishing malignant from benign tumors [21, 28]. Additionally, it presents the risk of hemodynamic instability from an unrecognized pheochromocytoma, adhesions making future resection more difficult, and possibly tumor seeding [21, 28].

6.3 Operative Technique

Our technique for robotic adrenalectomy is based on the transperitoneal approach with the patient in the semilateral position. We utilize the Da Vinci Surgical System. Standard preoperative precautions are taken for these patients including sequential compression devices to bilateral lower extremities, generous padding to all pressure points, and prophylactic antibiotics.

6.3.1 Right Robotic Adrenalectomy

The patient is placed in the left lateral decubitus position with proper padding of the left arm and the arm board at 90°. The right arm is placed over the left arm with appropriate padding, and the table is flexed at the level of the kidneys. The abdomen and right flank are prepped and draped. Robot, side, and console surgeon positions are outlined in Fig. 6.1, and patient positioning in Fig. 6.2. Trocar placement is illustrated in Fig. 6.3.

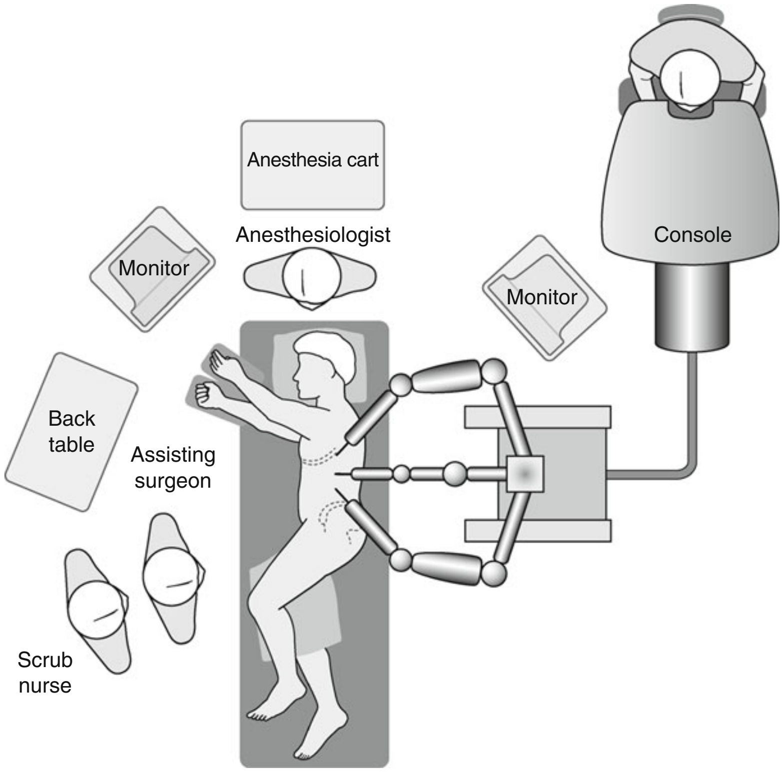

Fig. 6.1 Operating room setup for robotic adrenalectomy

We prefer to utilize the 30° down-angled camera, a Maryland bipolar dissector in the left hand, and hot shears in the right hand. The side surgeon uses a combination of suction, irrigation, and small bowel atraumatic graspers. In addition, the side surgeon is responsible for placing hemo-lock clips and firing the endovascular GIA when necessary.

The steps for this procedure parallel that of laparoscopic right transperitoneal adrenalectomy. The lateral attachments of the liver are incised with hot shears, and traction is placed superiorly on the liver by the assistant with the shaft of a wavy grasper, fan retractor, or Genzyme triangle retractor. The posterior peritoneal attachments at the inferior edge of the liver are incised from the vena cava to the lateral side wall. The liver is further mobilized superiorly until the superior edge of the adrenal gland is identified and isolated off the underlying psoas muscle. The liver is then placed on self-retained superior retraction by either grasping the side wall with a wavy grasper and utilizing the shaft of the instrument to support the right lobe of the liver or placing a fan or Genzyme retractor to support the right lobe and securing either retractor to a self-retaining arm secured to the operative bed. Next, the colon and duodenum are identified and reflected medially using a combination of blunt and sharp dissection exposing the vena cava from the liver's inferior edge to the renal vein.

With adequate exposure now obtained and the superior adrenal gland, vena cava, and renal vein isolated as landmarks, attention is directed toward securing the adrenal vein. Note that no traction has been placed on the adrenal gland. The superior angle made by the renal vein and cava is skeletonized so that a suction probe can be placed within that angle and gentle traction placed on the adrenal gland laterally. Simultaneously, either the side surgeon or console surgeon with a Cartier forceps in the right hand retracts the vena cava medially. This opens up the space between the cava and medial edge of the adrenal gland so that the adrenal vein can be identified (Fig. 6.4). Again, blunt and sharp dissections are used to open up this plane and isolate the adrenal vein. Once isolated, a Weck clip or endovascular stapler is used to secure and divide the vein.

Fig. 6.2 Patient positioning for robotic right adrenalectomy

With the medial border of the adrenal now dissected off the vena cava and the superior border dissected off the liver's edge, attention is paid to releasing posterior and inferior attachments. Gerota's fascia is incised over the upper pole of the right kidney and dissected down to the psoas muscle. At this step, the side surgeon utilizes either the Ligasure or Harmonic to divide these attachments as well as all posterior attachments (Fig. 6.5) while the console surgeon provides exposure with Maryland dissector and Cartier forceps. Finally, the lateral attachments are divided with either hot shears, Harmonic, or Ligasure (Fig. 6.6). The adrenal is placed in an endocatch bag and removed from the Hassan trocar site.

Once the gland is out, the bed is reinspected for bleeding (Fig. 6.7) with pneumoperitoneum decreased to 5 mmHg, mean arterial pressure raised to 90, and 30 mmHg of positive ventilation delivered. Once hemostasis is confirmed, all ports are removed under direct vision and closed appropriately.

6.3.2 Left Adrenalectomy

Positioning, trocar placement, and instrument preference are almost identical to the right side (Fig. 6.3). The first step is to mobilize the colon and spleen widely and medial to the aorta so that

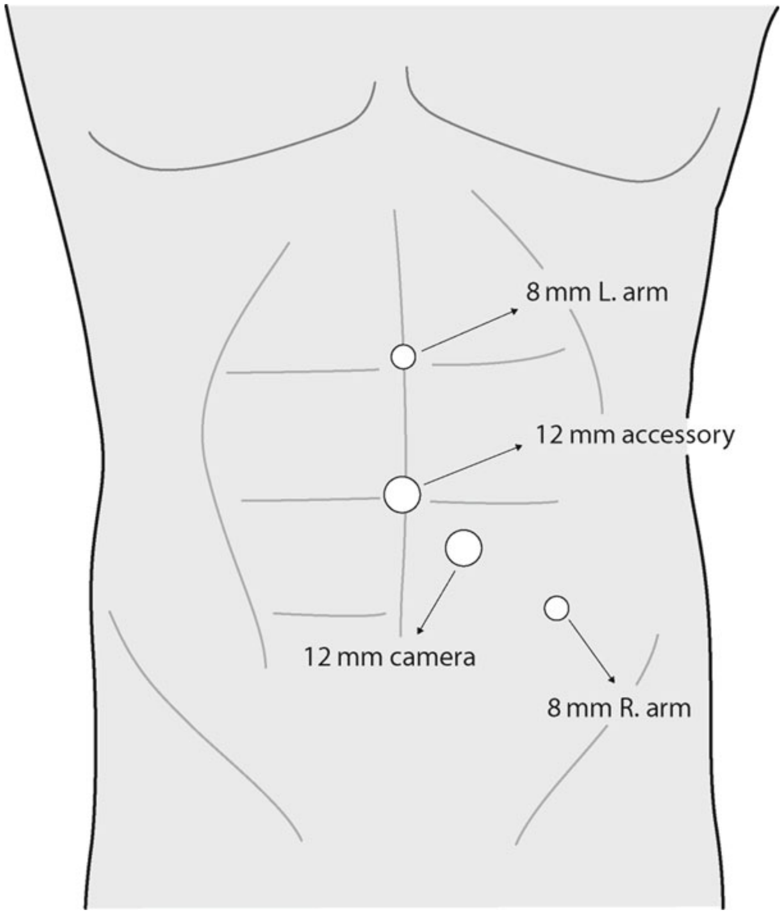

Fig. 6.3 Left trocar configuration (reverse for right)

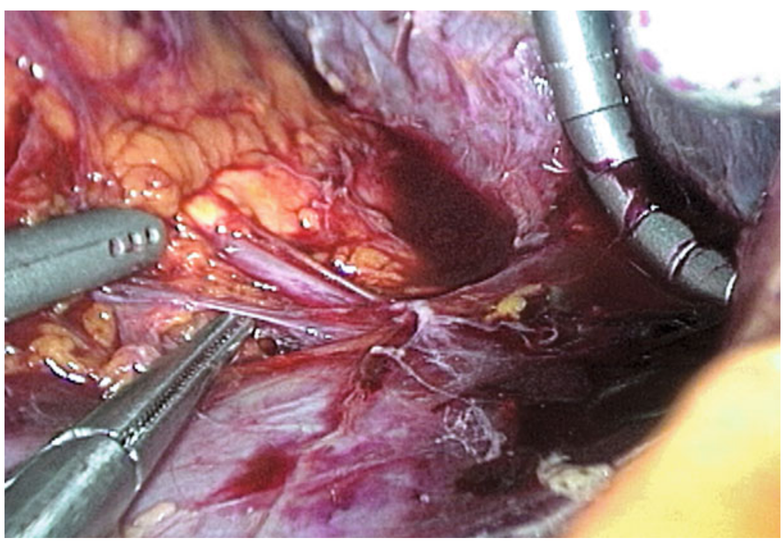

Fig. 6.4 Identification of right adrenal vein

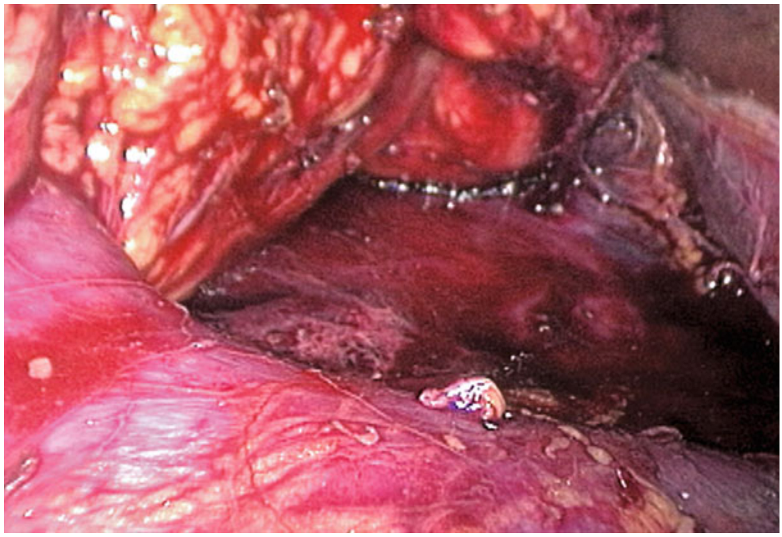

Fig. 6.5 Released superior medial and posterior attachments of right adrenal gland

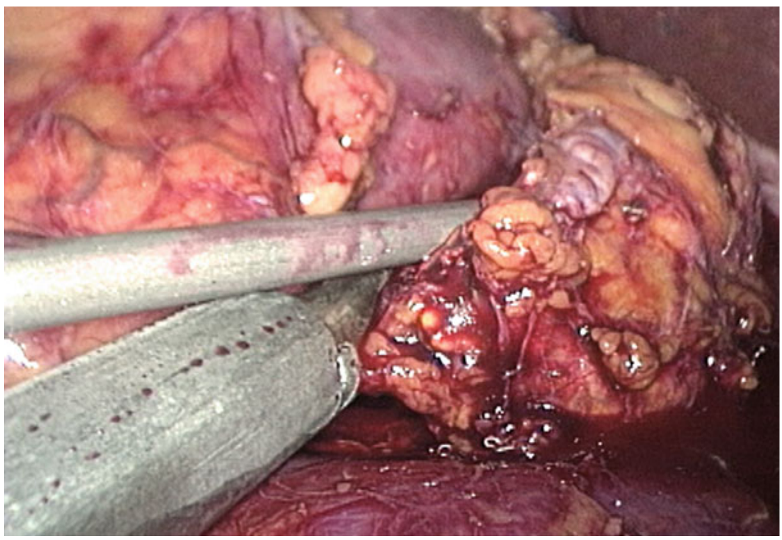

Fig. 6.6 Release of inferior attachments of right adrenal gland

the adrenal gland and renal hilum are exposed. This is accomplished by incising the lateral peritoneal attachments of the colon on the anterior surface of the kidney and exposing Gerota's fascia. The posterior peritoneal incision is carried inferiorly to the lower pole of the kidney and superiorly to the spleen, and the colon is mobilized medial to the aorta with a combination of blunt and sharp dissection. The side surgeon places gentle superior traction on the spleen, and the console surgeon retracts the kidney inferiorly, opening up and exposing the splenorenal attachments which are incised sharply including the lateral splenic attachments. The spleen is mobilized superiorly and medially with a combination of blunt and sharp dissection while the side surgeon places constant medial and superior traction. Adequate exposure is obtained when the superior edge of the adrenal gland is identified and isolated off the underlying psoas muscle. The spleen is then placed on superior retraction by either grasping the side wall with a wavy grasper and utilizing the shaft of the instrument to support the spleen or placing a fan or Genzyme retractor to support the spleen and securing either retractor to a self-retaining arm secured to the operative bed.

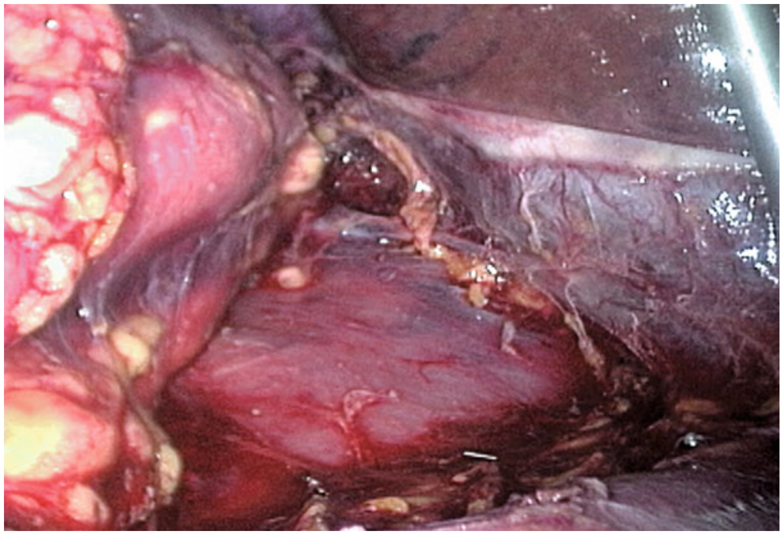

Fig. 6.7 Inspection of right adrenal bed after adrenalectomy

With adequate exposure now obtained, attention is directed toward securing the adrenal vein. The renal vein is first identified and skeletonized. Useful landmarks to identify the renal vein are the gonadal vessel and/or aorta, or a laparoscopic Doppler probe may help to isolate its signal. Once the renal vein is isolated, the adrenal vein is easily identified entering its superior border. The adrenal vein is then divided between Weck clips or with an endovascular stapler. With the vein controlled, a suction probe can be placed within the angle between the renal and adrenal vein and gentle traction placed on the adrenal gland laterally. Simultaneously, either the side surgeon or the console surgeon with a Cartier forceps in the right hand retracts the pancreas and colon medially, opening up the medial attachment of the adrenal overlying the aorta and psoas muscle. We prefer to divide these attachments with Harmonic scalpel, Ligasure, or endovascular GIA since multiple vessels run in these attachments. With the medial border now dissected free and the superior border dissected off the spleen, attention is paid to releasing posterior and inferior attachments. Gerota's fascia is incised over the upper pole of the left kidney and dissected down to the psoas muscle. At this step, the side surgeon utilizes either the Ligasure or Harmonic to divide these attachments as well as all posterior attachments while the console surgeon provides exposure with Maryland dissector and Cartier forceps. Finally, the lateral attachments are divided with hot shears, Harmonic, or Ligasure. The adrenal is placed in an endocatch bag and removed from the trocar site.

Once the gland is out, the bed is reinspected for bleeding with the pneumoperitoneum decreased to 5 mmHg, mean arterial pressure raised to 90, and 30 mmHg of positive ventilation delivered. Once hemostasis is confirmed, all ports are removed under direct vision and closed appropriately.

6.4 Results

There have been numerous small case series (Table 6.1) and several comparison studies between robotic and laparoscopic adrenalectomy (Table 6.2). The number of patients in these studies has ranged from 1 to 30. Robotic adrenalectomy has been assessed in these limited series with regard to complication rate, operative time, length of stay, cost, and other variables. Comparison studies have been particularly limited in terms of patient selection, number of patients, and methodology. These studies demonstrate that robotic adrenalectomy is safe and effective, and while laparoscopic adrenalectomy is the standard of care for benign adrenal lesions,

Table 6.1 Published series of robotic adrenalectomy

Reference	No. of patients	Operative time (min)	Morbidity	Conversion (%)	OR complications (%)	Median LOS (days)	APA	Pheo	Cush	Aden	Other	Cost (USD)
[47]	30	185	7	0	0	2	9	11	5	1	4	8,645 (OR)
												12,977 (hospital)
[36]	10	169	20	40 lap[b]	20[d]	5.7	3	4	0	2	1	3,466 (total)
[4]	19		15.8		0		8	4	5	2	0	NA
[1]	9	132.8		44 lap[c]	0	5.7	0	2	6	1	0	NA
[45]	2	118	50[a]	0	0	4				2		NA
[3]	14	111	21	7 open		6.7	5	2	4	2	1	NA
[2]	4	220	0	0	0	5	1	2	0	0	1	NA
[48]	1	100	0	0	0	1	0	0	0	0	1	NA
[11]	2	138	0	0	0	2.5	0	1	0	0	1	NA
[24]	1		0	0	0							NA

APA aldosteronoma, *Pheo* pheochromocytoma, *Cush* glucocorticoid adenoma, *Aden* adenoma, *LOS* length of stay

[a]Pulmonary embolism

[b]Malposition of robotic trocars (2), difficulty obtaining hemostasis (1), and prolonged operative time (1)

[c]"Owing to technical difficulties"

[d]Severe intraoperative hypertension associated with pheochromocytoma

Table 6.2 Studies comparing robotic and laparoscopic adrenalectomy

Reference	Type	No. of patients		Mean size (cm)		LOS (days)		Operative time (min)		OR complications (%)		Morbidity (%)		Total cost (USD)[a]		Conversion (%)	
		R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L
[36]	PR	10	10	3.3	3.1	5.7	5.4	169	115	20	0	20	0	3,467	2,737	40 lap[b]	0
[4]	PNR	19	14	3.0	3.3			107	86			15.8	14.3				
[1]	PNR	9						132.8	82.1	0	0					44.4	0
[5]	PNR	14	14	3.2	3.0	6.7	6.9	111	83			28	14			7 open[c]	7 open[d]

PR prospective randomized, *PNR* prospective nonrandomized
[a]OR + hospitalization
[b]Malposition of robotic trocars (2), difficulty obtaining hemostasis (1), and prolonged operative time (1)
[c]Significant bleeding from the adrenal vein
[d]Difficult dissection with a polycystic kidney

robotic techniques may provide advantages in certain settings.

Gill et al. [14] first demonstrated the feasibility of robotic adrenalectomy in an animal model. This study compared robotic adrenalectomy using AESOP and Zeus instruments in four pigs with conventional laparoscopy in three pigs. The operations were completed telerobotically from a separate room and utilized a side surgeon to change instruments and provide suction. While surgical and total operative times were significantly longer for robotic adrenalectomy, the procedure was shown to be feasible and subsequently performed in humans.

The first robotic adrenalectomy in a human subject was reported by Horgan and Vanuno in 2001 [24]. Subsequent small case series have demonstrated the safety of robotic adrenalectomy including a low intraoperative complication rate. Morino et al. [36] describe two intraoperative complications involving severe hypertension during pheochromocytoma removal. Desai et al. [11] describe an adrenal capsular tear that occurred during manipulation of the gland. Overall the complication rate between laparoscopic and robotic adrenalectomy has been approximately the same [5].

The conversion rate from robotic to open adrenalectomy has been low and comparable to the laparoscopic technique, although several robotic cases have been converted to traditional laparoscopy. Reasons for conversion have included malposition of trocars, difficulty with hemostasis, and prolonged operative time [36]. Brunaud et al. [5] noted 7 % conversion rate to open for both laparoscopic and robotic adrenalectomy, for reasons including bleeding and slow progression because of polycystic kidney disease. The conversion rate may decrease with increasing experience; in Morino et al. [36], conversion decreased from 60 % in the first five cases to 20 % in the subsequent five.

Length of hospital stay has been shown to be equivalent between robotic and laparoscopic adrenalectomy [5]. This is not surprising given that they both confer advantages of minimally invasive surgery including decreased postoperative pain and shorter convalescence.

Studies have examined both total OR time and operative time for robotic adrenalectomy. Total OR time includes setup and positioning of the robot which can be time-consuming in the early experience; however, robot positioning time may decrease as more procedures are performed [8]. Winter et al. [47] describe median robot setup time of 4 min. Brunaud et al. [5] describe similar mean duration of operating room activity for both laparoscopic and robotic procedures. Preparation and draping time will likely improve until a plateau point with increasing experience with robotic surgery.

Operative times have generally been longer for robotic versus laparoscopic adrenalectomy [1]. Morino et al. [36] attributed longer operative times to limited robotic instruments. Transition time from laparoscopic to robotic instrumentation may improve with experience [24]. Robotic adrenalectomy may confer a time advantage for obese patients. Brunaud et al. [5] noted positive correlation between patients' body mass index and duration of laparoscopic adrenalectomy, but no correlation in patients having the robotic procedure.

Evidence suggests that costs per patient for robotic adrenalectomy may exceed costs for laparoscopic adrenalectomy [1, 36]. The cost of purchasing and maintaining robotic systems should be integrated into cost analyses. Return on investment might be improved with higher volume and multidisciplinary use of the robot. Winter et al. [47] did not show a significant difference in hospital costs comparing robotic with laparoscopic and open adrenalectomy. They attributed lower hospital charges in the minimally invasive groups to shorter hospitalizations.

Quality-of-life measures have been studied regarding robotic versus laparoscopic adrenalectomy. Brunaud et al. [4] showed that there were no major differences in quality-of-life measures including postoperative pain between the two procedures.

From a training standpoint, robotic adrenalectomy may benefit from a more rapid learning curve compared with laparoscopy [2, 22, 25, 41]. Winter et al. [47] demonstrated a 3-min improvement in operative time with each robotic adrenalectomy. Morino et al. [36] demonstrated a decrease in conversion rate from 60 % in the first five cases to 20 % in the subsequent five. Brunaud et al. [5] noted decreased operative time with increasing experience with the robot for adrenalectomy. Corcione et al. [9] estimated that at least ten robotic procedures were necessary to master use of the robot. Based on these observations, robotic surgery may allow urologists to apply minimally invasive techniques to adrenalectomy more rapidly than laparoscopy [25].

Further investigation is required to identify the exact advantages of robotic adrenalectomy and which patients might benefit from these techniques. The few small studies making direct comparisons between robotic and laparoscopic adrenalectomy have generally concluded that laparoscopy is superior in terms of feasibility, length of procedure, and cost [36]. As robotic systems become utilized more commonly and cost and maintenance issues become less significant, the role of robotics in adrenalectomy will likely become clearer.

6.5 Considerations

Robotic techniques may present disadvantages regarding adrenal surgery. Lack of tactile feedback may result in tissue trauma including adrenal capsular tear [11]. The surgeon is compelled to rely on visual cues, and experience is required to minimize the risk of tissue injury. Some authors argue that lack of tactile feedback is balanced by improved visibility [2].

An experienced side surgeon with laparoscopic skills is necessary to assist with access, suction, and clip application or stapling, as these instruments are not yet available for robotic arms. This may present a disadvantage in community use of the robot for adrenalectomy.

Several tips are worthy of mention for robotic adrenalectomy:

1. For right adrenalectomy, the accessory port should be placed at sufficient distance from the camera port and robotic arm port to avoid interference [47]. If this accessory port is used, use of graspers in both robotic arms may be preferred [47].
2. Avulsion of the right adrenal vein is one of the most common causes of conversion and care should be taken in its isolation and control. A Statinsky clamp and 4-O Prolene on a vascular needle with a preplaced LAPRA-TY should be available if caval bleeding is encountered.
3. The left adrenal vein can always be located by first identifying the renal vein. Commonly, there are two adrenal branches off the left renal vein. Once isolated, the left adrenal vein is easier to divide because it is longer and narrower. Conversely, the right adrenal vein is easier to identify, but shorter, thus ligation is more challenging [47, 48]. Controlling the adrenal vein early is crucial to reduce the likelihood of injury during mobilization of gland.
4. In cases of bilateral adrenalectomy, the extreme articulation of the robotic arms may facilitate lateral and posterior dissection [1].

Conclusion

Data on robotic adrenalectomy demonstrate that the procedure is safe and feasible but not superior to laparoscopy in most cases. Certain advantages of robotic surgery (e.g., with intracorporeal suturing) do not apply to adrenalectomy, a primarily extirpative procedure. Nonetheless, the magnification and precision of robotic techniques may enable a more meticulous dissection during adrenalectomy. From a training standpoint, robotics may enable surgeons not extensively trained in laparoscopy to offer minimally invasive adrenalectomy to their patients [42].

There is a need for further investigation regarding the potential advantages of robotic adrenalectomy as well as more rigorous comparison with traditional laparoscopy. The role of robotics in adrenalectomy and other minimally invasive procedures should be reevaluated over time as technology changes, e.g., advances in tactile feedback, more diverse robotic instruments, and a fourth arm [36]. High-volume robotic centers that have already invested in costs of the robot may benefit most from novel applications. These centers may make robotic adrenalectomy affordable compared with other centers [47]. Furthermore, costs of equipment and maintenance may ultimately decrease with time.

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