Review Article

Partial adrenalectomy: evaluation and management—a clinical practice review

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Abstract: Since the initial description of adrenalectomy, surgical management of adrenal masses has continued to evolve. In this article, the clinical evaluation, indications for partial adrenalectomy, surgical approaches and technical aspects of partial adrenalectomy, and outcomes are reviewed. The advantages and disadvantages of different operative approaches are discussed in the context of performance of pADX, including anterior, posterior, laparoendoscopic single site (LESS) surgery and robot-assisted approaches. Finally, post-operative management and outcomes are reviewed. The published literature (English language) was reviewed by searching PubMed between the years January 1, 1990 to December 31, 2021. Expert consensus and personal experiences were included to highlight nuances in planning and management. Partial adrenalectomy, in specific situations, is preferred to bilateral total adrenalectomy to avoid the need for long-term steroid supplementation, as steroid dependence is associated with decreased quality of life and increased morbidity and mortality. Various types of adrenal pathology may involve both adrenal glands, either concurrently or sequentially, especially in those with hereditary syndromes. Advancements in understanding the underlying disease processes, indications and contraindications to pADX, and minimally invasive surgery, including robotic assistance and other intraoperative adjuncts, have allowed for more widespread offering of pADX to appropriate patients. Partial adrenalectomy is a safe and effective operation in patients who otherwise would be relegated to bilateral adrenalectomy, permanent postoperative adrenal insufficiency and the need for lifelong steroid supplementation. Preoperative planning and intraoperative conduct of the operation are key to selecting appropriate patients and managing patients over the long-term, especially for those expected to have disease recurrence due to genetic mutations.

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Introduction

Since the first planned adrenalectomy was performed by Perry Sargent in 1914, surgical approach and techniques have evolved (1). In 1992, Gagner and colleagues described a laparoscopic approach to adrenalectomy (2,3). Since then, the technique of performing minimally invasive adrenalectomy has been refined, becoming the gold standard for excision of most benign adrenal pathology (4,5). Various types of adrenal pathology may involve both adrenal glands, either concurrently or sequentially,

especially in those with hereditary syndromes. Bilateral adrenalectomy results in lifelong steroid dependence, and some can develop Addisonian crisis. A small percentage die due to lack of sufficient steroids. Steroid dependence has also been associated with decreased quality of life, decreased resistance to stress and infection, and osteoporosis (6-10). Preservation of some of the adrenal cortex via partial (sometimes called cortical-sparing) adrenalectomy (pADX) has been advocated for in specific circumstances to minimize the need for steroid dependence (6,7). Attempts at adrenal autotransplantation (similar to parathyroid autotransplantation) have seen limited success for various reasons (11).

Partial adrenalectomy is a surgical technique in which adrenal pathology is removed while preserving a portion of vascularized adrenal tissue to maintain adrenocortical hormone homeostasis (12). The frequency of need for partial adrenalectomy is low and few clinicians have a thorough understanding of the considerations when contemplating partial adrenalectomy. Approximately 30% of a normal size adrenal gland is required to maintain steroid homeostasis (7,13-15). While pADX by traditional open approaches has been performed for many years, the first report of pADX performed by a minimally invasive laparoscopic approach was in 1997 by Janetschek *et al.* (16). Subsequently, pADX has also been performed by the retroperitoneoscopic approach as well (17). While previous adrenalectomy reviews often mention partial adrenalectomy, most concentrate on the need for postoperative steroid supplementation and recurrence rates (17,18). Additionally, much has been learned over the past two decades about the biologic basis of adrenal diseases, and indications and contraindications to partial adrenalectomy have changed (17,19). In this review, we discuss indications and contraindications to partial adrenalectomy, preoperative and intraoperative considerations including intraoperative adjuncts to identify the gland, plan resection and evaluate post-resection remnant viability. Outcomes associated with pADX are also discussed.

Methods

The published literature (English language) was reviewed by searching PubMed between the years January 1, 1990 to December 31, 2021. Expert consensus and personal experiences were included to highlight nuances in planning and management.

Discussion

Indications and contraindications

Partial adrenalectomy is most often considered in patients who have or have the potential to develop bilateral adrenal disease requiring surgical excision of functional tumor(s) producing excess adrenal hormone. Those most likely to develop bilateral adrenal disease are those with germline genetic mutations affecting the adrenal gland, such as those with MEN2, VHL, NF-1, SDHx, and other syndromes (20). Partial adrenalectomy can be pursued (multiple times if needed and technically feasible) depending on the size and position of nodules within the bilateral adrenal glands in order to maintain steroid homeostasis for as long as possible (8-10,12,15-18). Eventually, all portions of both adrenal glands may need removed, at which time (hopefully much later in life), the patient would be entirely reliant on steroid supplementation. While many patients with inadequate steroid production do well (whether secondary to surgery, autoimmune, infectious, or infiltrative etiologies), steroid management can be difficult. The longer cortical function can be preserved, the better.

Partial adrenalectomy can be considered for clearly benign non-functional tumors, but benign non-functional tumors are not usually removed unless they are growing (21). If they have grown to an extent where surgery is required, they are often too large to leave a meaningful normal remnant. If partial adrenalectomy is considered when growth is confirmed and likely to continue, operating when the nodule is smaller can lead to higher success rates of pADX.

Partial adrenalectomy is most often performed in patients diagnosed with pheochromocytoma (PCC) secondary to MEN2A, MEN2B, SDHx, VHL, and NF-1 (8-10,12-14,18). These patients may develop unilateral or bilateral PCCs at any time during their lives. Other indications for pADX include those with unilateral benign cortisol, androgen, estrogen or non-germline mutation driven catecholamine producing tumors. These may be less common indications, but pADX can be considered if there is sufficient normal appearing remnant tissue. Creating remnant tissue from known abnormal tissue (portions of tumor) in these situations is not recommended.

Some have suggested pADX for primary aldosteronism (18,19,22-24); however, recent immunohistochemical work has revealed that autonomous aldosterone production does not always originate from an adenoma visualized on imaging, but instead from the normal appearing portion of the gland or both normal and abnormal appearing areas (25).

The distribution of aldosterone synthase has been noted to correlate with specific mutations driving abnormal aldosterone production and varies by sex and race. As the call for routine immunohistochemical assessment of the entire adrenal gland for aldosterone synthase (CYP11B2), not just nodules, to better elucidate the etiology of excess aldosterone production has only recently been published by an international group of pathologists, the incidence of excess aldosterone production outside of a nodule is yet to be clarified but is at least 10% and likely higher (26). More investigation in this area is needed to better understand if there is a role for pADX in these patients.

Additional considerations for pADX include bilateral macronodular adrenal hyperplasia (BMAH), primary pigmented nodular adrenocortical disease (PPNAD) and other micronodular hyperplasia. The role for pADX in those with BMAH and PPNAD is still emerging, but unilateral total adrenalectomy with contralateral pADX has been found to have better outcomes with regard to controlling excess cortisol secretion compared to unilateral adrenalectomy alone. With some adrenal tissue remaining, the need for lifelong steroid supplementation can be avoided versus those undergoing bilateral adrenalectomy. However, there is the potential for growth of remnant tissue over time and recurrence of hormone excess given these disorders are driven by mutations that remain within the remnant tissue similar to the situation of mutation-driven PCCs. The advantages and disadvantages of allowing for potential recurrent hormone excess and how to subsequently treat it (medication *vs.* completion adrenalectomy) according to age, comorbidities and other considerations must be made on a case-by-case basis. The durability of this approach for these specific disease types requires additional study (27). Lastly, partial adrenalectomy is *contraindicated* when there is any concern for carcinoma.

Clinical evaluation

Evaluation of adrenal disorders should proceed in a standardized fashion, including a thorough history and physical examination. The history should focus on signs and symptoms suggestive of hormone excess, including those associated with excess cortisol, catecholamines, androgens, estrogens and catecholamines. The medical history can provide clues to adrenal diagnoses. The surgical history may help inform selection of an operative approach. The social history can be used to assess for issues that may affect interpretation of adrenal biochemistry (alcoholism can falsely elevate cortisol levels, catecholamine levels can be affected by illicit drug use and other medications) along with in-hospital and post-discharge planning. A thorough family history should be taken in anyone being evaluated for an adrenal disorder, and it is particularly important in helping determine who may need to be referred to a licensed genetic counselor prior to surgery. A known germline mutation is often what prompts consideration of pADX. If a germline mutation is identified preoperatively, understanding the phenotype resulting from a particular mutation is helpful to guide timing and extent of surgery.

Biochemical testing and imaging

Biochemical evaluation should be carried out in a systematic fashion. Biochemical tests commonly obtained to assess HPA axis integrity and adrenal hormone production are well described (28) (*Table 1*). Imaging is used to determine if a nodule or mass is benign or something potentially more concerning for malignancy. An adrenal protocol computed tomography (CT) scan is most commonly ordered, but magnetic resonance imaging (MRI) is also appropriate and is better suited for heterogeneous masses where washout percentage should not be calculated. 18-FDG PET-CT can be obtained as an additional modality for masses deemed indeterminate to assist in distinguishing between benign and malignant tumors, as operative approach should be chosen according to suspected pathology. Any indeterminate mass should be treated as a malignancy until proven otherwise. 24-hour urine steroid analysis can also be of assistance in differentiating benign from malignant adrenocortical tumors. Iodine-123 meta-iodobenzylguanidine or 68-Gallium-DOTATATE scans (more sensitive) can be pursued if PCC or paraganglioma is suspected, there are bilateral adrenal abnormalities, malignancy is suspected, or a genetic mutation driving development of the PCC or paraganglioma.

Fine needle aspiration

Fine-needle aspiration of adrenal masses is not routinely recommended. FNA should only be performed when patients cannot undergo surgery, systemic therapy will be pursued and the diagnosis is in doubt, or the result will change management. FNA does not distinguish well between normal adrenal tissue and adrenocortical cancer. Its finding rarely changes treatment except in patients with potential metastases or infection (29). PCC must be ruled

Table 1 Adrenal-specific biochemical testing for evaluation of patients with adrenal disorders (initial adrenal biochemical evaluation)

Routine	Consider
Complete blood count and metabolic panel	17-OH progesterone
ACTH	17-OH pregnenolone
Aldosterone	11-deoxycortisol
Renin	Androstenedione, testosterone
1 mg DST with 0800 ACTH, 0800 cortisol, 0800 dexamethasone level +/– late-night salivary cortisol and/or 24-hour urine cortisol	Estradiol
24-hour urine free cortisol and creatinine	FSH, LH
DHEA-S	Progesterone
Testosterone (total or bioavailable)	Dopamine
Plasma and/or 24-hour urine metanephrine and normetanephrine levels, epinephrine, norepinephrine	Chromogranin

ACTH, adrenocorticotropic hormone; DST, dexamethasone suppression test; DHEA-S, dehydroepiandrosterone-sulfate; FSH, follicle-stimulating hormone; LH, luteinizing hormone.

out before any biopsy to avoid potential hypertensive crisis and/or hemorrhage (30).

Genetic testing

If pursued, genetic testing should be tailored according to identified risk factors, and patients should be referred to a licensed genetic counselor (20,31-33). In general, patients found to have PCC, paraganglioma, or adrenocortical carcinoma should be referred for genetic testing. Depending on the result, additional evaluation for related medical disorders may need pursued, and family members also need to be notified (20,34,35). Certain mutations may have stronger associations with malignancy. In SDHx syndromes, an *SDHB* mutation is associated with malignancy and metastatic disease in 40% of affected patients (20,36). Genetic testing panels are available for evaluation of the most common mutations in patients with PCC or paraganglioma. Susceptibility genes most commonly found to be mutated include *SDHB* (36,37), *SDHD* (38), *VHL* (39), *RET* (40) and *NF1* (20). Other less commonly reported genes include *SDHC*, *EGLN1/PHD2*, *KIF1*β, *SDH5*, *IDH1*, *TMEM127*, *SDHA*, *MAX*, and *HIF2*α (20). Ideally, genetic testing is performed prior to surgery, as this information informs the operative plan.

Preoperative considerations

There are several considerations when contemplating pADX. (I) Is the timing optimal to proceed with adrenal surgery? (II) Will an appropriate remnant be able to be created without compromising resection of necessary tissue and at the same time leaving an adequate remnant to maintain adequate production of adrenal hormones? (III) Will the remnant have appropriate vascular inflow and outflow after resection of a portion of the adrenal gland? (IV) If reoperation is needed, will the risk to return to the same area be prohibitive related to the amount and position of the remnant? It is preferable, though not always possible (especially with centrally placed lesions on the right), to preserve the main adrenal vein, as this allows nearly normal efflux of adrenal hormones into the systemic circulation and minimizes congestion of the remnant tissue. In the event the main adrenal vein cannot be spared, other venous outflow exists that is usually adequate, but this mandates great care intraoperatively to unnecessarily avoid disruption of this more delicate vascular supply. Vascular inflow and outflow are also dependent on individual anatomy (7,17). It is important to avoid disruption of tissue around the portion of the gland that will remain. Dependent on nodule position within the adrenal gland, the relationship of the nodule or area to be removed to the main adrenal vein, and access to the gland, it can be advantageous to operate when a nodule is smaller if pADX is desired even if the degree of hormone excess and resultant effects (hypertension, etc.) does not yet mandate it. The larger a nodule is or the more nodules present, the less likely pADX becomes (with the desired degree of postoperative cortical function) (19,41).

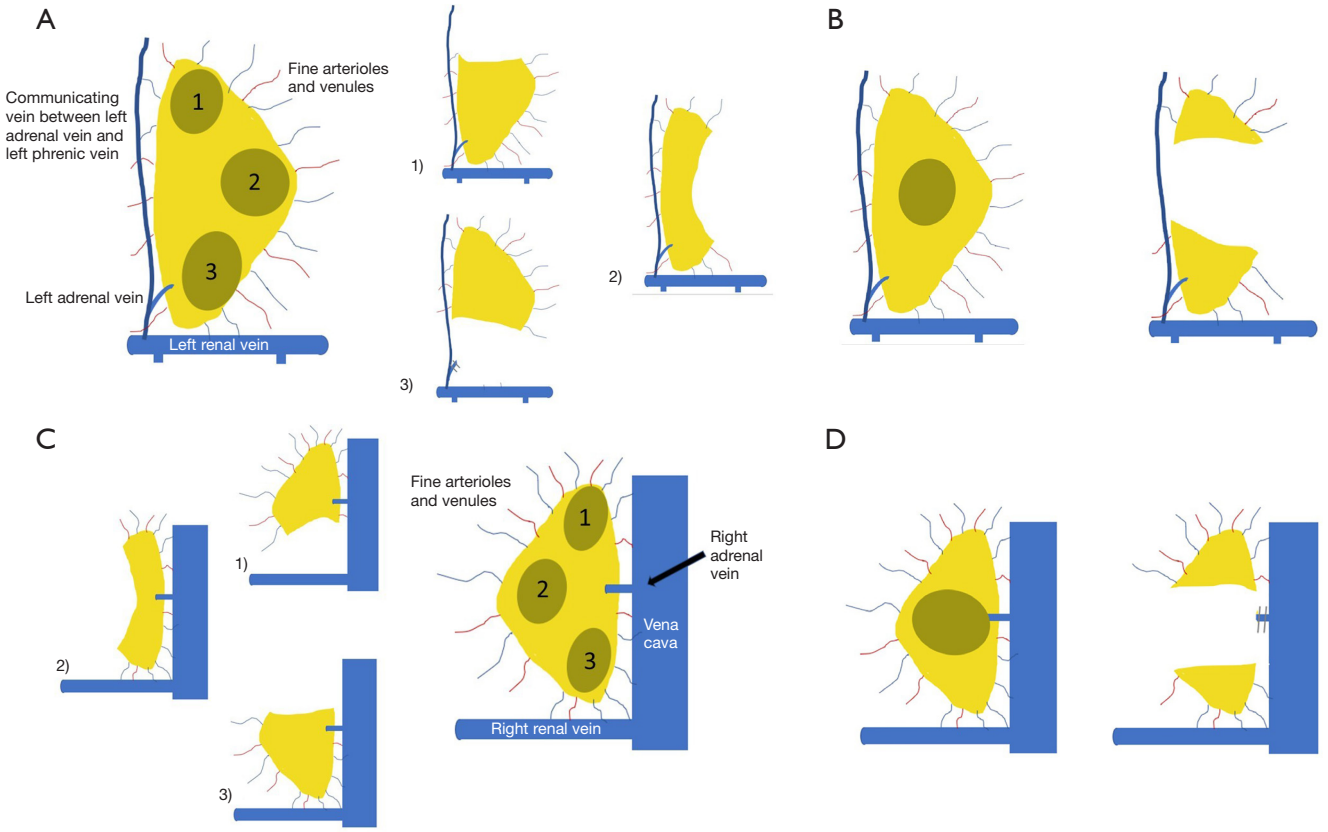

Figure 1 Examples of partial adrenalectomy according to gland side, nodule position, and venous drainage. (A) Variations in left partial adrenalectomy according to nodule position; (B) left partial adrenalectomy with centrally placed nodule; (C) variations in right partial adrenalectomy according to nodule position; (D) right partial adrenalectomy with centrally placed nodule. Fine red and blue lines represent unnamed arterial supply and venous drainage, respectively.

Surgical approaches

The optimal approach to pADX depends on patient and tumor factors as well as surgeon preference. Given that pADX is performed for benign disease, nearly all pADXs are performed utilizing minimally invasive approaches. However, an open approach may be utilized in some patients with hostile abdomens not amenable to minimally invasive approaches, when concomitant procedures need performed that are not amenable to a minimally invasive approach, and other reasons. The decision making and process of transection of the gland is no different for open versus minimally invasive approaches.

The act of transecting the adrenal gland and fashioning a remnant is preceded by assessment of the entire gland. This begins with preoperative evaluation of available imaging to understand if an adequate remnant may be created, although this is never known for sure until the operation is completed. A potential line of resection can be planned, and what vascular inflow and outflow to the remnant may remain can be understood (*Figure 1*). Fine vascular structures are often not visualized pre- or intraoperatively as they are below the limits of imaging detection or embedded within retroperitoneal adipose tissue.

Intraoperatively, identification of the gland may be aided by the use of a minimally invasive ultrasound probe or intravenous injection of indocyanine green (ICG) (usually 5 mg in 2 mL of water) (42). After IV injection of ICG, application of near infrared light at a wavelength of 750–800 nm reveals optimal visualization after approximately 5 minutes and persists for about twenty minutes. Once the adrenal gland is identified, ultrasound may be used to evaluate the gland to determine if any abnormalities in what was expected to be normal adrenal tissue are identified, as this would potentially alter the plan. While the goal is to

minimize any disturbance of fat surrounding the anticipated remnant, if any portion of normal appearing gland is directly visible, it should be examined for any unsuspected nodules. In specialized cases of micro- or macronodular hyperplasia, where abnormal areas of tissue will remain, the remnant should be created from areas with the fewest or smallest nodules if possible, aiming to reduce adrenal tissue to that of at least 30% of the size of a normal gland (if cortical function is to be preserved).

Transection of the gland may be carried out in several ways. Because the gland is well vascularized, there is some bleeding that occurs during transection. While this can be a nuisance during transection, it is usually very limited in volume. While cautery can be utilized, the lateral thermal spread can reach up to 1cm, and this can cause considerable damage to what may be a small remnant, ultimately resulting in inadequate hormone production. Staplers may be used in some cases, but because the gland is soft, it may not hold staples well, especially in thickened, hyperplastic or multinodular glands. Transection by sealing tissue with ultrasonic devices is usually very successful. Cautery to obtain hemostasis can be applied sparingly for any specific points of bleeding. It is important to minimize the number of small pieces of adrenal tissue that may dissociate themselves from the main adrenal gland during transection of the tissue, both normal and abnormal tissue, as these can seed the retroperitoneum and lead to significant difficulty in surgically curing patients if these small areas hypertrophy and lead to disease recurrence, especially in situations of hormone excess. An effort to recover small pieces of gland that separate from the remnant should be made. Hemostatic agents can be applied at the end of the case if desired. Drains are not usually placed.

The remnant may be assessed for viability at the end of the case utilizing ICG. Use of ICG and other materials in adrenal surgery has been described and can also be used earlier in the procedure to help distinguish the adrenal gland from surrounding retroperitoneal adipose tissue (42). The application of near-infrared autofluorescence during adrenal surgery is currently being investigated. Again, an effort to visualize just enough of the remnant to ensure viability should be made while avoiding complete circumferential dissection where vascular inflow and outflow may be compromised.

Operative approach to the adrenal gland is a consideration in pADX. *Table 2* lists variations between different operative approaches and other considerations when selecting an operative approach for partial adrenalectomy. Meta-analyses by Lee *et al.* and Meng *et al.* compared clinical outcomes between two minimally invasive approaches in those undergoing adrenalectomy (total and partial) and found that the retroperitoneoscopic approach is associated with comparable or shorter operative time, less bleeding, shorter length of stay, and has similar rates of conversion to open adrenalectomy (43,44). However, pADX requires additional maneuvering to examine, prepare and transect the gland. Transection may be performed in transverse or longitudinal directions depending on the position of the nodule to be removed. It is easier to remove a superior or lateral nodule, especially on the left side where the left adrenal vein can be left intact, than to work over an inferior nodule and leave a normal superior remnant. However, any nodule, including nodules situated medially in the right gland or inferiorly in the left gland that would necessitate ligation and division of the main adrenal vein can be considered for pADX.

Ports during pADX may need to be placed slightly different from normal to allow for more direct access to the lateral side of the adrenal gland. On occasion, an additional port may need to be placed to provide the best access to the gland for transection. Robotic assistance can be helpful given the 'wristed' motion of the instruments compared to limited axes of motion with conventional instruments. Robot-assisted partial adrenalectomy (RAPA) was first reported by St Julien *et al.* in 2006 (45), and various technical modifications have since been described (46,47). In a series from Asher *et al.* consisting of 12 patients, the mean operative time was 163 minutes and median tumor size was 2.7 cm (range, 1.3–5.5 cm). They recommended port placement be rotated more laterally and superiorly for pADX (44). When comparing anterolateral and posterior minimally invasive approaches, the anterior or anterolateral approach provides for more working space than a posterior prone retroperitoneoscopic approach. This is an advantage when working around larger tumors. Conversely, the higher insufflation pressures used during retroperitoneoscopic approaches often result in less bleeding overall and potentially less bleeding during transection of the adrenal gland. Robotic assistance often overcomes access and space issues during posterior retroperitoneoscopic approaches.

Typically, in cases where tumors are larger than 7 cm, or in tandem with other intra-abdominal procedures, an anterior or anterolateral approach is preferred for any type of adrenalectomy (total or partial). At this size, it is doubtful an adequate remnant would be able to be created. If enough normal adrenal tissue is identified on preoperative imaging, an additional option for larger tumors is a hand-assisted

Table 2 Summary of surgical approaches, indications, contraindications, advantages, and disadvantages

Operative approach	Indications	Contraindications	Advantages	Disadvantages
Open	(I) Hostile abdomen; (II) second-line for benign tumors when amenable to MIV approach; (III) unable to tolerate insufflation; (IV) lack of resources for MIV approach; (V) concern for malignancy; (VI) total or partial adrenalectomy	(I) Benign tumor able to be approached in MIV manner with resources available and no patient comorbidities	(I) Access to entire abdomen and retroperitoneum; (II) able to combine with other procedures; (III) bilateral adrenalectomy without need for repositioning	(I) Greater pain; (II) greater blood loss; (III) higher risk of wound infection, hernias; (IV) longer hospital stay; (V) longer recovery
Laparoscopic transperitoneal	(I) Benign tumors; (II) total or partial adrenalectomy	(I) Hostile abdomen preventing access/ safe dissection; (II) comorbidities (pulmonary, cardiovascular) may limit ability to Insufflate abdomen	(I) Access to entire abdominal cavity; (II) tandem intra-abdominal procedures	(I) More difficult if multiple procedures required; (II) requires more mobilization (liver/spleen/ pancreas) than posterior approach
Posterior Retroperitoneoscopic	(I) Benign tumors (II) Anatomically amenable to posterior approach (III) Total or partial adrenalectomy	(I) Later stage renal disease not on dialysis (increased insufflation pressures may worsen kidney function) (II) Nerve stimulators in area	(I) More direct access to adrenal gland; (II) may be faster in some cases; (III) generally less blood loss; (IV) may have less blood pressure variability in pheochromocytoma cases	(I) More difficult to convert to open if necessary; (II) lack of access to peritoneal cavity; (III) limited ability to combine procedures (except kidney); (III) loss of working space and diminished blood loss if peritoneal cavity inadvertently entered; (IV) may lead to significantly increase CO_2 levels
LESS	(I) Minimally invasive approach desired; (II) small tumor/gland; (III) limited access for multiple ports; (IV) total or partial adrenalectomy	(I) Large tumors; (II) adrenocortical cancer or malignant pheochromocytoma suspected	(I) Cosmesis; (II) possibly less pain	(I) Need for increased surgeon experience; (II) increased operative time; (III) limited to smaller tumors in general; (IV) less ability to perform traction-countertraction maneuvers
Hand-assisted	(I) Less than open approach desired; (II) total or partial adrenalectomy	(I) Inability to tolerate insufflation	(I) Desire for less than standard open incision for large, benign tumors; (II) tactile sensation	(I) Greater pain; (II) greater blood loss; (III) higher risk of wound infection, hernias
Robot-assisted	(I) Minimally invasive approach desired; (II) total or partial adrenalectomy	(I) Open approach	(I) Improved visualization; (II) wristed motion; (III) ergonomics	(I) Increased cost; (II) increased time for robot docking; (III) lack of tactile sensation

LESS, laparoendoscopic single site; MIV, minimally invasive.

laparoscopic approach. Hand-assistance allows for easier dissection of the tumor, identification of the normal portion of the adrenal gland, and preservation of the remnant. In addition, an incision larger than a standard port site will be needed for extraction of a larger tumor as morcellation of the tumor is not advised due to the inability to perform proper and complete pathologic examination.

Laparoendoscopic single site (LESS) approaches utilize a single skin incision with specially designed ports via a transperitoneal or retroperitoneal approach (48). LESS has been successfully applied in various operations and has been demonstrated to be a feasible technique for adrenalectomy (49). In 2010, pADX using LESS was first reported by Yuge *et al.* (50). While an advantage of LESS is improved cosmesis, there are technical challenges which may be compounded during pADX by the need for additional mobility around the gland, including a limited ability to separate instruments from one another, poor triangulation, and inadequate countertraction. Operative time is longer, and LESS requires greater surgeon experience (50).

Postoperative management, complications and outcomes

Most patients do well after adrenal surgery, including those having undergone pADX (51). Standard postoperative care for adrenalectomy patients should be provided. Bleeding and infection are the two most common complications and are rare. Morbidity related to partial *vs.* total adrenalectomy has not been shown to differ related to significant postoperative bleeding requiring intervention. Postoperative testing of the hypothalamic-pituitary-adrenal axis the morning after surgery is usually pursued in patients undergoing surgery for hypercortisolism (except in those with overt Cushing syndrome as steroid supplementation is already known to be required) or in those who have undergone unilateral adrenalectomy with contralateral pADX. Methods of testing are variable, including obtaining a single morning cortisol level between 7:00 and 8:00 a.m. to formal stimulation testing with cosyntropin on postoperative day one. Some centers test several days after surgery (52-54). Multidisciplinary involvement of an endocrinologist is helpful in the immediate postoperative period and for long-term management. Patients should be warned about the potential for adrenal insufficiency and Addisonian crisis.

Follow-up in patients undergoing surgery for PCC or other functional tumors should have repeat biochemical testing within 1–3 weeks after surgery to document resolution or establish a new baseline (13,14). The term 'cortical sparing' is often used when pADX is performed to remove a PCC. While some of the cortex is spared because medullary cells cannot be selectively removed from normal adrenal tissue (a common misconception), patients with germline mutation-driven tumors will still need to undergo lifelong surveillance of the remnant (and the contralateral gland) to assess for recurrent PCCs. Patients should undergo repeat biochemical testing at least annually, and this is especially important in those with disease driven by a germline genetic mutation as these patients will be expected to develop a recurrence in the remnant in many cases since all adrenal tissue is affected by the same mutation. In a series including 26 patients with hereditary PCC who underwent pADX, 17 patients (65%) were steroid independent after a median follow-up of 71 months. Of 30 patients undergoing unilateral total adrenalectomy or pADX, 10% developed additional disease during this short period of follow-up (55). The role of follow-up imaging is controversial, especially in those operated on for functional tumors. Biochemical testing usually indicates recurrence of functional tumors, but some small tumors may autonomously secrete hormone without being outside the 'normal' range. Imaging can sometimes identify early recurrence of tumor, and this is important to facilitate the ability to perform pADX before the tumor involves too much of the gland (12).

Summary

Partial adrenalectomy is a safe and effective operation in patients who otherwise would be relegated to bilateral adrenalectomy, permanent postoperative adrenal insufficiency and the need for lifelong steroid supplementation. Partial adrenalectomy provides an opportunity for independence from chronic steroid replacement. Preoperative planning and intraoperative conduct of the operation are key to selecting appropriate patients and managing patients over the long-term, especially for those expected to have disease recurrence due to genetic mutations. Advancements in understanding the underlying disease processes, indications and contraindications to pADX and minimally invasive surgery, including robotic assistance and other intraoperative adjuncts, have allowed for more widespread offering of pADX to select patients.

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