Chapter

The Surgical Approach in Adrenal Gland Pathology

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Abstract

The pathology of the adrenal gland and the clinical management of the adrenal clinical entities are particularly complex. The surgical approach to adrenal disorders, both in the classic way and especially in the minimally invasive way, is reserved for highly addressable centers and experienced surgeons. The surgical treatment is dedicated to both functional and nonfunctional adrenal tumors, closely following specific criteria. Regarding adrenal pathology, the surgical treatment is indicated for adrenal tumors that secret mineralocorticoid hormones (Conn syndrome), adrenal tumors secreting glucocorticoids (Cushing syndrome), pheochromocytomas, paragangliomas, neuroblastomas, adrenal carcinomas, and metastases. At the same time, non-secreting tumors should be removed as soon as imaging details are recorded an increasing dimensions of these tumors during a short time interval (up to one year). Although laparoscopic adrenal removal became a gold standard procedure in the late 90s, the classic open surgical adrenalectomy is reserved for bulky adrenal tumors and adrenal cancers, but it is overshadowed by possible multiple complications such as lung damage, wound infections, thrombosis, bleeding, etc. The minimally invasive approach, either laparoscopically or robotically, is dedicated to small tumors, with the advantage of rapid patient recovery, rapid socio-professional reintegration, and reduction of complications. Laparoscopic adrenalectomy is indicated in a wide range of pathologies, ranging from Conn adenoma, Cushing syndrome, and pheochromocytoma, to hormonal inactive tumors or other pathologies. The surgical sparing of the adrenal cortex is advised in cases of hereditary disorders affecting the adrenal gland (such as the MEN2 syndrome) in order to avoid primary adrenal insufficiency after the surgical excision. The postoperative evolution must be closely monitored by the anesthetic-surgical team, and the subsequent follow-up must not be neglected. We will discuss the primary surgical indications and contraindications of adrenal gland pathology in this chapter, as well as the perioperative management of specific tumors, surgical approach types, pluses and minuses of various adrenal surgery procedures, surgical technique and tactics, potential complications, and postoperative management.

Keywords: adrenal gland, adrenalectomy, sparing, minimal invasive surgery

1. Introduction

The pathology of the adrenal gland and the clinical management of the adrenal clinical entities are particularly complex. Surgery for adrenal diseases should only be

performed by skilled surgeons in highly addressable centers. The surgical treatment is dedicated to both functional and nonfunctional adrenal tumors.

Regarding adrenal pathology, the surgical treatment is indicated for adrenal tumors that secret mineralocorticoid hormones (Conn syndrome), adrenal tumors secreting glucocorticoids (Cushing syndrome), pheochromocytomas, adrenal metastases, paragangliomas, neuroblastomas, and adrenal carcinomas [1].

In adrenal gland surgery, a multidisciplinary approach involving surgeons, anesthesiologists, endocrinologists, and oncologists plays a key role in patient management. Adrenalectomy is a very frequent surgical intervention with minimal invasive approach in endocrinology surgery [2, 3].

Dr. Lamar Snow performed the first laparoscopic adrenalectomy in 1991, and Dr. Joseph Petelin presented the first description of the procedure in a video at the international symposium of laparoscopic surgery, Saskatoon, Saskatchewan, Canada in August 1992 [4]. In literature, Go H. performed his first laparoscopic adrenalectomy on January 17, 1992, and published it in 1993, after Gagner published his first laparoscopic adrenalectomy in March 1992. Laparoscopic adrenal surgery advanced significantly when Michel Gagner published the lateral trans peritoneal procedure in 1992 [2, 5]. This procedure went on to become the most popular laparoscopic adrenalectomy procedure. The video-assisted approach recognizes three forms, depending on the patient's location and access: first, anterior (trans-peritoneal), second lateral (transperitoneal or retroperitoneal), and third posterior (transperitoneal or retroperitoneal) (retroperitoneal). Soon after, laparoscopic adrenalectomy (after the cholecystectomy) was recognized as the second-best surgical treatment [1].

Transabdominal, transthoracic, and retroperitoneal surgery are the most common approaches to adrenal pathology. To provide a fair control of vascular pedicles' maneuvers therapy, these comprise huge incisions and thorough plan dissections. Postoperative morbidity may vary depending on the surgical technique used to remove the adrenal gland. The development of minimally invasive surgery (MIS) techniques has resulted in significant changes to the majority of surgical operations. The procedure of adrenalectomy is a good illustration of this. The advantages of laparoscopy are completely utilized in this form of approach [2–4].

1.1 Anatomy landmarks

The kidneys and the adrenal glands are in close proximity. The right adrenal is predominantly suprarenal, while the left adrenal is mostly prerenal and medial to the left upper pole of the kidney. An adrenal gland, which is crescent-shaped on the left and triangular on the right, sits above the superior medial pole of each kidney. While the right adrenal gland is frequently supra-renally positioned, the left adrenal gland is typically pre-renally positioned. On the left, between the 11th and 12th ribs, and on the right, between the 12th rib, the adrenal glands are situated in front of the ribs in both regions [2]. The adrenal glands are encased in a capsule that creates septa that convey capillaries into the gland's core [4]. The renal fascia surrounds the adrenal glands, which are surrounded by a significant amount of renal fat (Gerota fascia). The renal fascia's ventral and dorsal layers stretch upward, covering the adrenal glands and attaching to the diaphragm. The renal fascia, which attaches to the diaphragm, as well as big renal veins and arteries, keep them in place. Despite their mobility, the adrenal glands are anchored to the abdominal wall due to their attachment to the diaphragm. That is why hemostasis is challenging because they move in concert with the diaphragm during breathing [5].

For radiological anatomy and also for adrenalectomy, topographic anatomy is crucial. The adrenal glands have a close architecture with several significant anatomical structures, in addition to their intimate association with the kidney. The anterior, posterior, and medial edges of the adrenals are inspected topographically [5].

The renal fat and renal fascia are in contact with the superior portion of the dorsal abdominal wall, which includes the adrenal glands. The 11th and 12th ribs, subcostals muscles, latissimus dorsi muscles, and sacrospinalis muscles are all located adjacent to each adrenal gland, as well as the diaphragmatic crus and lateral arcuate ligament that divide the adrenal glands from the pleura [6].

The right adrenal gland is located 3 mm behind the inferior vena cava and near the celiac ganglion. The gland is not proximal to the renal arteries because of its suprarenal position. It is separated from the pancreas head and duodenal loop on the inferior side by the vena cava, and by the Winslow foramen on the superior side. In contact with the lateral upper region of the anterior face is the inferior medial bare portion of the liver [6, 7].

The inferolateral portion of the anterior side is covered by the peritoneum, which is situated between the liver, kidney, and hepatic flexure. In either a laparoscopic or open adrenalectomy, the peritoneum is open after the movement of the organs, and the right lobes of the liver and gallbladder are brought up while the colon is taken down [8].

The peritoneum of the omental bursa covers the anterior portion of the left adrenal gland superiorly. The peritoneum does not cover the inferior part of the anterior face, despite being close to the medial border of the spleen, the pancreatic body, and the splenic vein and artery behind it. It is connected to the transverse mesocolon on the pancreatic inferior side. The omental bursa and stomach are separated from the adrenal by the pancreatic body. About 7 mm from the aorta, the medial side of the adrenal gland is situated in front of the celiac truncus. The left adrenal gland is near the left renal vein and renal sinus because of its prerenal location [9].

The retroperitoneal region can be reached by separating the splenic flexure and splenic lateral connections, migrating the left adrenal laterally and separating the splenic lateral connections. During the avascular dissection, the veins in front of the adrenal gland, the pancreatic body, and the spleen are mobilized and dragged to the right side. The pancreatic body can also be shifted by opening the peritoneum at the inferior and superior sides of the organ in the bursa omentalis region, especially when the adrenal glands are small. After releasing the gastrocolic ligament, this step is done [8, 9].

The middle and superior adrenal arteries are derived from the aorta, the renal artery, and the inferior phrenic artery, respectively. The lower adrenal arteries come from the renal artery. In addition to other blood vessels, the intercostal and gonadal vessels may also feed the adrenals. These arteries divide into around 50 arterioles under the glandular capsule, creating a rich plexus that needs to be carefully dissected and managed for homeostasis during the adrenalectomy [7–9].

Each adrenal is normally emptied by a single adrenal vein, as opposed to the arterial supply. Controlling this main vein is crucial for physiopathology, especially in malignancies that release excessive hormones. Normally, the left adrenal vein is longer (30mm) and connects the inferior phrenic vein, highlighting the left renal vein after emptying into it. Small (5mm), the right adrenal vein usually drains into the inferior vena cava. Approximately 5% to 10% of persons have accessory veins. These auxiliary veins could directly drain into the left hepatic vein, the right renal vein, or the left renal vein on the left [10].

One lymphatic plexus is located deep inside the capsule, whereas the other is located in the medulla. The adrenal gland produces a vast number of lymphatic channels that run alongside bigger vessels. These lymphatic channels terminate at the lateral aortic lymph nodes surrounding the places where the renal vein drains into the vena cava, as well as the para-aortic lymph nodes close to the diaphragmatic cruris and the renal artery exit. The fact that some lymphatic veins can cross the diaphragm and leak into the posterior mediastinum or the ductus toracicus helps to explain how adrenocortical cancers can spread both locally and regionally. The sympathetic visceral nervous system gives rise to the nerves. The sympathetic celiac ganglia supply the visceral afferent fibers. Nerves and vessels are ligated concurrently during adrenalectomy [9, 10].

2. Indications and contraindications

The majority of adrenal masses are now identified as incidentalomas as a result of the extensive use of ultrasonography and cross-sectional radiological imaging.

Congruent with ESE/ENSAT guideline**s,** adrenalectomy indications are as follows: functional adrenal tumors, adrenocortical carcinoma, pheochromocytoma, and metastatic tumors. Similarly, patients with unilateral adrenal masses that seem benign on imaging or with adrenal masses that have radiological characteristics that are suggestive of malignancy and have a diameter of less than 6 cm but no imaging signs of local invasion should consider laparoscopic adrenalectomy. For unilateral adrenal tumors with radiological features indicative of cancer and imaging evidence of local invasion, open adrenalectomy is typically performed. The guidelines also suggest surgical removal if the lesion grows by more than 20% over the course of six to twelve months of monitoring of adrenal incidentalomas, combined with at least a 5-mm rise in maximum diameter. Furthermore, surgical treatment should be taken into consideration in a customized manner for individuals with autonomic cortisol secretion who also have comorbidities that may be connected to cortisol excess [11].

Moreover, several studies have reported the outcome of surgical intervention in the potential reversal of autonomic cortisol secretion. Weight reduction, reduced blood pressure, improved glucose tolerance, decreased cholesterol levels, and favorable effects on bone architecture have all been linked to improved metabolic function following adrenalectomy. Cardiovascular benefits in patients with autonomic cortisol secretion were the subject of a recent systematic analysis with adrenalectomy improving cardiovascular outcome and death [12].

An adrenocortical carcinoma poses the biggest risk to a unilateral adrenal lesion with ambiguous imaging features. Surgery is the most crucial therapeutic intervention for adrenocortical carcinoma without metastases. According to recommendations in the guidelines, only referral institutions and surgeons with experience in open and laparoscopic adrenal surgery and who execute more than 15 benign and malignant adrenalectomies annually should perform surgery on patients with this pathology [13].

Hormone-producing tumors have surgical indications regardless of their size. The following are hormone-secreting adrenal tumors for which adrenalectomy is recommended: Cushing's syndrome is caused by an overproduction of glucocorticoids in the fasciculate adrenal cortex, Conn's syndrome is caused by an overproduction of aldosterone in the glomerulosa adrenal cortex, and Pheochromocytomas are caused by an overproduction of catecholamine in the adrenal medulla [11]. Due to pituitary

or ectopic ACTH synthesis, adenomas that originate from the reticularis layer of the adrenal cortex and produce excessive levels of androgens and estrogens may infrequently require a bilateral adrenalectomy in Cushing's disease [7].

Nonfunctioning adrenocortical malignancies account for around a half of adrenocortical cancers. Thus, 50% is composed of tumors that secrete 15% cortisol, 10% androgens, 5% estrogens, and only 1% aldosterone, and the remaining 18% of tumors may secrete other hormonal varieties [7]. Malignant pheochromocytomas account for about 12% to 29% of all pheochromocytomas. Lung and breast malignancies, melanoma, renal cell carcinoma, and lymphoma frequently metastasize to the adrenal gland. Adrenalectomy may be required in these patients. The risk of malignancy associated with the size of a nonfunctional adrenal tumor is an indication for surgery. The risk of cancer is roughly 2% if the lesions are less than 4 cm in diameter. Malignancy is 6% more likely in lesions that are 4–6 cm long, and 25% more likely in lesions that are 6 cm long [11]. At the time of diagnosis, 90 percent of adrenocortical tumors have a diameter of more than 4 cm. Most adrenal masses discovered by chance are less than 4 cm in diameter and nonfunctional. Patients who have benign imaging results are not candidates for surgery, although clinical and radiological follow-up is suggested at 6–12 months. Even if that case where the imaging findings are benign, surgical therapy should be considered for each tumor separately since the risk of malignancy increases with the size of the mass [14, 15]. Some disorders, such as asymptomatic myelolipoma or a simple cyst with a diameter of more than 4 cm, may not require surgery [1, 12, 16].

3. Preoperative preparation

Surgical treatment is an option in the management of adrenal masses, respecting the indications mentioned above. In the case of adrenalectomy, the preoperative preparation is determined by the pathology for which the procedure is conducted. The preoperative preparation for an adrenalectomy for a benign nonsecretory or malignant nonsecretory disease is no different than for any other surgery. The condition in which we are dealing with pheochromocytoma, the patient necessitates specific preparation, as outlined in a previously published chapter.

Patients with pheochromocytoma are treated with alpha-blockers, intravascular volume expansion, and beta-blockers (especially if concerns regarding tachyarrhythmia are present) prior to adrenal surgery. Patients may develop substantial hypotension when the tumor is free of vascularization, particularly after dividing the adrenal vein intraoperatively. This necessitates fluid optimization and inotropic support, which may need to be continued in the immediate postoperative period. In addition, mineralocorticoid receptor antagonists, such as spironolactone or eplerenone, are frequently recommended to patients with adrenal incidentalomas and primary hyperaldosteronism. This specific medication should be stopped after adrenalectomy for primary aldosteronism in order to avoid hyperkalemia. Depending on the patient's postoperative blood pressure, other antihypertensives may be discontinued or lowered. Despite successful surgery, older patients and those with long-standing hypertension are more likely to suffer permanent vascular damage and need antihypertensive medication for a long period of time [14]. Furthermore, current endocrine guidelines support perioperative glucocorticoid medication at major surgical stress dosages for patients with autonomic cortisol secretion as part of preoperative care.

Adrenal surgery can be done either laparoscopically or openly. Transabdominal or retroperitoneal approaches can be used for both techniques. The gland can be reached transabdominal or retroperitoneal in either technique [7]. Laparoscopic surgery can be performed in a traditional or robotic manner. With a single port, both ways can be used [13]. The surgical procedure is influenced by the size and also by the kind of the lesion, the patient's general features, and the surgeon's level of experience. Laparoscopic adrenalectomy is really regarded as the best course of therapy for some people [14]. Laparoscopic transabdominal or retroperitoneoscopic surgery has benefits over open surgery in terms of shorter hospital stays, postoperative discomfort, intraoperative blood loss, total 30-day postoperative sequelae, and mortality. Over the past ten years, mortality following adrenalectomy has decreased, with a fatality rate of < 2% [1].

3.1 Adrenalectomy – surgical technique

Furthermore, the surgical strategy is determined by the surgeon's preference, expertise, and knowledge with the procedures. Aspects to take into account include the patient's unique pathological history of abdominal or retroperitoneal surgical procedures, body mass index, tumor size, and location. However, the surgical approach may be impacted by these factors [14].

Normal anatomy is included in the laparoscopic method, and if open surgery is required for special circumstances, it may be done easily [15]. Although the retroperitoneal method allows for direct access to the adrenal gland and requires less dissection and mobilization of other visceral organs, general surgeons find it difficult to master because of a lack of experience. The retroperitoneal surgical approach is also contraindicated in patients with a high body mass index and excessive retroperitoneal fat, as well as those with tumors larger than seven to eight centimeters in diameter. In addition, a tumor near the inferior vena cava on the right side or the aorta on the left may require a difficult retroperitoneal excision. In terms of operating times, blood loss volumes, intraoperative hemodynamic events, rates of morbidity and death, and rates of switching from a minimally invasive to an open surgery approach, retrospective reviews of the literature have shown that laparoscopic and robotic excision of pheochromocytomas are equivalent [9]. The advantages of robotic adrenalectomy also include three-dimensional access, increased wrist mobility for the surgeon, and a stable camera port. Robotic adrenal surgery has certain drawbacks, including rising costs, a slow learning curve, and a lack of tactile input [3].

Patients should be positioned supine on the operating table for laparoscopic transabdominal lateral adrenalectomy. A nasogastric tube and Foley catheter are normally put in after general anesthesia is administered. The patient is positioned in a lateral decubitus position with the afflicted side facing up. A raised arm board is employed, and an axillary cushion is used to support the elevated arm. The superior iliac spine should be the breakpoint for the operating table, and the bed should be bent to expand the working area. The table is bent by around 100–120 degrees in reference to the ground plane to widen the space between the iliac crest and the costal edge. The surgeon and assistant stand side by side and face the patient's front while the monitor is placed at the patient's head side [15].

CO2 insufflation is conducted after gaining peritoneal access 2 cm inferior to the right/left costal border in the midclavicular line, using either the blind (Verres Needle) or optical (Hasson) trocar. An open approach to the first trocar site can also cause pneumoperitoneum. CO2 insufflation is usually done with low/medium flow

rate of inflation until a pressure of 12–14 mmHg [15]. Between the midclavicular line medially and the anterior axillary line laterally, four 10-mm trocars are inserted 2 cm below the costal margin. Additional ports may be placed if necessary [7], often one 10-mm trocar in the upper epigastric area (to be utilized for retraction - liver for the right side or spleen for the left side).

The first port is often accessed by the midclavicular line. Adrenalectomy is frequently performed through four ports on the right and three to four ports on the left. The inferior vena cava image will remain straight and parallel throughout the procedure as long as the midclavicular line trocar is employed as a camera port on the right side of the procedure (30-degree laparoscope). The two medial ports, together with the anterior axillary line port, can all be used as functional ports. The instruments and ports, on the other hand, can be replaced as needed to give optimal exposure. A liver retractor is normally inserted through the port below the xiphoid process, parallel to inferior margin of the liver. It is strongly advisable to use only a 10-mm trocar in order to facilitate the use of different laparoscopic devices (including suction devices, seal and cut devices, and special clamps). More than 5 cm between the ports should be left to allow laparoscopic instruments to move freely [17–19].

A fourth port is typically positioned laterally on the middle axillary line or medially on the midclavicular line, although adrenalectomy can be performed with three ports on the left side, spaced 5 centimeters apart from the anterior axillary line. The abdomen is examined once the surgeon has entered the peritoneal area to look for any disease and injuries caused by the installation of the port, but because the patient is positioned on his lateral side, little information can be gathered (consequently, it is mandatory for a surgeon to investigate the patient in order not to have any intraoperative findings that can lead to a conversion to open surgery) [19, 20].

For the right adrenalectomy, two working ports are used to insert an atraumatic grasper and an L-hook cautery. If mobilization of the visceral surface of the liver is not successfully achieved by simple upward retraction of liver segments V and VI, a retractor is inserted under the liver, the liver is retracted and the right triangular ligament of the liver is first detached. Thus, the inferior vena cava is reached medially after opening the posterior peritoneum with the cautery, starting from the right triangular ligament of the liver and removing 1 cm from the edge of the liver, thus exposing and dissecting the fascia of Gerota. While the surgeon applies inferior lateral counter-traction on the superior pole of the kidney, avoiding any pressure over the adrenal tissue, the assistant must provide appropriate retraction of the liver in a superior medial way so as not to drain it and to avoid the release of any hormone product into the systemic blood circulation [9, 21, 22].

Normally, the upper medial part of the adrenal is dissected first by the surgical team, unless the adrenal tumor does not invade the lateral wall of the inferior vena cava or if the adrenal tumor is located posterior to the vein. During this dissection, we may use a Harmonic® scalpel (Ethicon Endo-Surgery INC- Johnson & Johnson Medical SPA, NJ, USA), LigaSureTM (Medtronic, Minneapolis, MN, USA), or any other medical sealing and cutting device, preferably 10 mm in diameter, so that enough connective tissue can be trapped to be sealed along with the dedicated vessels.

Using a little piece of fabric, the surgeon can gently move the adrenal gland laterally without damaging it. The adrenal vein is exposed by continuing the dissection from the medial side of the adrenal to the lateral side of the vena cava and is usually a short vein, no longer than 10–15 mm. As it approaches the liver, the right adrenal vein is often visible laterally and slightly below the inferior vena cava. Two clamps are used to transect the lateral side of the wall of the vena cava after circumferential dissection

of the adrenal vein. One clip is used to clip the adrenal side, and endoscopic scissors are used to separate it [7, 9, 21]. Sealing and cutting (without clipping) the adrenal vein is also to be performed, if the diameter of this vein is less than 7 mm, according to the technical recommendations of the dedicated laparoscopic instrument.

An auxiliary adrenal vein can be found 2–3 cm above the primary adrenal vein in around 20% of cases and should be dissected, clipped, and divided if present [6]. Alternatively, vascular staples can be used to divide the adrenal vein. The gland's inferior medial side is then dissected. Right adrenal gland's superior medial pole needs special care since there is an artery that has to be ligated or shut off because it supplies the parenchyma. Between it and the upper pole of the kidney is the periadrenal adipose layer of the adrenal gland. It is vital to locate and protect any renal arteries in the higher pole, just like on the left side [13].

The adrenal gland is then pushed up and the dissection is completed on the posterior and lateral sides of the gland as well as superiorly, and during this period of dissection, a particular concern of the surgeon should be not to accidentally injure the adrenal tissue. Otherwise bleeding will occur and it is very difficult to achieve adequate hemostasis with the electrocautery, so it is advisable to use a gauze pad for gentle compression over the adrenal tissue. The gland is removed from the 12-mm port location and placed always in a retrieval bag. If necessary, trocar incisions can be expanded. Incisional hernias should be avoided by closing the port side with a resorbable suture [6, 13, 15]. Many publications propose ligation of the adrenal vein as the first step in adrenalectomy, especially for pheochromocytoma. However, with big adrenal masses, the suitable dissection area for identifying the adrenal vein at the first stage may not be available. As a result, the adrenal vein should be dissected only when it is safe to do so (clearly visualization, good exposure, and no intense traction from the cava wall).

The mobilization of the spleen, which is performed by dissecting the splenic-parietal ligament, is the first stage in the left adrenalectomy surgery unless the division of the left colonic flexure with its proper mobilization is necessary and the first gesture after intraperitoneal video inspection. In the lateral decubitus posture, the splenic-parietal ligament is plainly visible. In order to successfully retract the spleen and expose its posterior aspect, it is recommended to dissect the splenic-parietal ligament starting at the inferior and posterior edge of the spleen, leaving a margin of roughly 2 cm of peritoneum. When the splenic-parietal ligament is separated until it reaches the diaphragm, the fundus of the stomach and the left crus of the organ are visible. Thus, the splenic-parietal ligament is completely dissected, allowing the spleen to be fully mobilized [7, 10].

The splenorenal ligament is then dissected, starting from the posterior portion of the spleen and going to the tail of the pancreas, taking care not to damage this parenchyma. Between the tail of the pancreas and the fascia Gerota, a groove is delineated and an avascular plane is dissected [6]. With the help of gravity, the splenopancreatic block is moved medially out of the operative field, exposing the upper pole of the kidney and the adrenal area, which is brownish in color, not as yellow as the pancreas in the perirenal adipose tissue. The pancreatic tail and spleen are retracted if necessary, using a retractor inserted through a port positioned medially or laterally [16].

Starting on the lateral part of the gland, dissect from the upper to lower adrenal poles, remaining close to the posterior muscle plane. Energy devices are used to separate small arteries encountered during this dissection. The left renal vein is present on the inferior border of the operational field, thus care must be taken to avoid damaging it while the dissection is carried out along the inferior border of the adrenal gland at

the same time as the posterior plane, up to the level of the quadratus lumbaris muscle. The left adrenal vein is uncovered by continuing the dissection on the anteromedial side of the adrenal [9, 22].

On the medial side of the gland during this dissection, the left inferior diaphragmatic vein is frequently seen. The left adrenal vein should be exposed by following the left inferior diaphragmatic vein until it reaches it. The medial side of the gland is where it descends. Recognized and isolated is the left adrenal vein. It is longer than the right adrenal vein and empties into the left renal vein (at least 20–30 mm). Contrary to the side of the adrenal gland, which can either be snipped and divided with one clip or divided with an energy device, the side of the renal vein can be cut and split with two clips. Another vein that could need to be cut is the left inferior phrenic vein. If this vein's diameter is less than 7 mm, it can be sealed and severed using a sealing-cutting device, much like on the right side [6, 15].

It is typical to have a tissue tail that extends from the left adrenal gland to the hilum of the kidney. Dissecting the gland from the superior pole of the kidney, right adjacent to the kidney capsule, and all peri-adrenal fat in the specimen are required for an oncologically sound resection. At this point, attention should be paid to locating and safeguarding any superior renal arteries. The last adrenal dissection allows for the "hanging procedure." Pancreas injury should always be considered during dissection using a hook, coagulating scissors, or energy devices in order to avoid a postoperative pancreatic fistula. The adrenal is removed from the retrieval bag using a 10–12 mm trocar [13]. Installing a drain in the adrenal lodge is a solution; however, it is not frequently required. Some authors advise installing a drain there [1, 6, 7, 23, 24].

3.2 Laparoscopic transabdominal anterior adrenalectomy

For adrenalectomy, the anterior laparoscopic route is the least preferable method. The patient is positioned supine, the first trocar is implanted in the umbilicus, and three other trocars are placed in different configurations in the abdominal cavity. However, although it allows different abdominal conditions to be treated at the same time and can be performed bilaterally without changing the patient's posture, the submesocolic technique requires a longer surgical time and more port placements and therefore should be thought about beforehand. It seems to be easier to change the lateral side position of the patient for a bilateral adrenalectomy in the same surgical time [11, 24, 25].

3.3 Posterior retroperitoneal laparoscopic adrenalectomy

Supine positioning of the patient is used to provide vascular access and, if required, place a Foley catheter. The patient is placed in the jackknife position with the table bent to increase the space between the posterior rib edge and the pelvis. The surgeon is on one side of the adrenal gland, while the assistant is on the side that will not be removed. By creating a 1.5-cm incision, 2 cm inferior and parallel to the twelfth rib, cutting through the subcutaneous and posterior muscle layers, and finally reaching the retroperitoneal area, the surgeon can dissect the Gerota fascia posteriorly with his finger [11, 20, 26].

After that, a 12-mm trocar is reinserted into the area, and CO_2 is insufflated at a pressure of 12 to 15 mmHg. A 45 laparoscope is used in place of the 0 laparoscope. On either side of the initial port, two additional 5- or 10-mm trocars are inserted. The adrenal gland and arteries are then located using laparoscopic ultrasonography. The

lateral and inferior portions of the adrenal gland are then dissected after the superior pole. The medial dissection is usually done last, after which the veins are identified and separated, as detailed in the previous section on the "lateral transabdominal approach." Feeling the smooth interior surface of the twelfth rib confirms that you are at the right place [7, 13, 15, 26].

Using the Hasson trocar and a direct laparoscopic view, the retroperitoneal region can be reached. Retroperitoneum can be inserted using a finger or a balloon dissector. A 12-mm trocar is then reinserted into this space and the CO_2 is insufflated to 12 to 15 mmHg [7] or 20 to 25 mmHg CO_2. [16] One 5 or 10 mm working port is inserted medially from the lateral side of the para-spinal muscle to the camera port, and one port is introduced laterally from the middle axillary line to the camera port. A camera with a 30° or 45° angle is utilized [13, 15, 26].

The main markers for this procedure are the para-spinous muscle medially, the peritoneal margin laterally, the peri-renal area, which contains the kidney, adrenal gland, peri-renal fat anteriorly, and the ribs posteriorly. A strong insufflation pressure allows for clear visibility while also compressing any minor bleeding arteries. Hypercarbia and crepitus may occur, necessitating short periods of deflation or reduced insufflation pressures [13, 15, 24, 26].

By pressing down on the kidney and mobilizing the gland inferiorly, the superior attachments of the adrenal might elevate the gland superiorly. Next, the detached, free adrenal vein needs to be located. Utilizing energy-based technology, the remaining adrenal linkages are subsequently removed [15, 26].

3.4 Lateral retroperitoneal laparoscopic adrenalectomy

The patient is positioned the same way as in the lateral transabdominal approach for this type of operation. Similar port placements are used in the posterior retroperitoneal laparoscopic approach as in the posterior retroperitoneal laparoscopic technique. Instead of being on the middle axillary line, the camera port on the anterior side might be placed on the anterior axillary line. The fourth port can potentially be implanted 5–7 cm lower than the anterior port on the anterior axillary line. Important anatomical markers can be used to help with orienting once the pneumo-retroperitoneum has been formed. The fact that the psoas muscle establishes longitudinal alignment and is commonly visible is taken into account by the surgeon. Additionally, the major veins that run parallel to the psoas muscle are visible upon retraction of the kidney anteriorly and upward following medial dissection. Although complete mobilization of the renal hilar arteries is not required following adrenalectomy, the renal artery can be detected by pulse identification. The left adrenal vein needs to be dissected and located via a posterior approach, as opposed to transperitoneal laparoscopy [26, 27].

3.5 Single-incision or single-port laparoscopic adrenalectomy

The single-port approach of laparoscopic adrenalectomy can be done transabdominally or retroperitoneally. Some investigations compared the traditional laparoscopic method to single-port adrenalectomy, finding no significant changes in patient length of stay or morbidity, as well as a minor benefit in cosmetic and postoperative discomfort. There is a lack of data on this strategy, and more research is needed [11, 17, 18, 22, 23].

3.6 Robot-assisted adrenalectomy

Although laparoscopic adrenalectomy has fewer drawbacks than open adrenalectomy in terms of blood loss, pain, hospital stay, and cosmesis, it does have certain drawbacks, such as the need for dexterity, two-dimensional vision, and reliance on a camera assistant. By giving surgeons a three-dimensional magnified view, superior ergonomics, camera control, and multi-articulated instruments, robotic adrenalectomy overcomes the constraints of laparoscopic surgery. Robotic adrenalectomy has yet to achieve general acceptance because of its higher cost and lengthier operating periods. Robotic adrenalectomy can be performed successfully using either the transperitoneal or retroperitoneal technique, depending on the patient's body habitus and the surgeon's skill. It has also been reported to be a viable approach for partial adrenalectomy [19, 24].

3.7 Partial adrenalectomy

In 1983, Irvin et al. [20] suggested cortex-preserving adrenalectomy or partial (or sub-total) adrenalectomy for the treatment of hereditary, bilateral pheochromocytoma in order to retain adrenocortical function and prevent lifetime steroid replacement therapy. The results of partial adrenalectomy utilizing the retroperitoneoscopic laparoscopic approach were published in 1996 [21, 27].

In order to treat minor adrenal masses, partial adrenalectomy is increasingly being used. Therefore, the suggested standard therapy for small benign and hormonally active adrenal tumors may change to minimally invasive partial adrenalectomy [27, 28].

In addition to genetic diseases with a risk of developing numerous adrenal tumors, solitary adrenal masses are now one of the criteria for partial adrenalectomy in bilateral adrenal masses. Particularly in patients with small hormone-active tumors, partial adrenalectomy should be carried out to lower the risk of malignancy. Partial adrenalectomy should not be performed when there are nonfunctional cortical tumors. The surgical reasoning in these cases is determined by the tumor's size and rate of growth at the time of diagnosis, as well as any indication of malignancy. In these patients, a complete adrenalectomy should be necessary [27, 28].

An important consideration in adrenal-sparing surgery is the preservation of the circulatory supply to the adrenal stump. Partial adrenalectomy necessitates the least amount of tissue manipulation and dissection. Studies have shown that patients treated for adrenocortical carcinomas with minimally invasive procedures experience disease recurrence earlier and more frequently due to a greater risk of intraoperative tumor leaking and positive margins. Patients who received laparoscopic resection in Stage 1 and Stage 2 were likewise shown to have worse overall survival rates [24]. In individuals who require lymphatic dissection and adrenalectomy, open surgery should be chosen. For locally advanced malignancies that have invaded surrounding organs or major arteries, the open approach is the best option [9, 13, 24, 26, 27].

Open adrenalectomy is still an option if there are any general or specific contraindications to laparoscopy (a patient cannot undergo laparoscopy if they are unable to undergo pneumoperitoneum, for example), or if there are any specific features of the adrenal tumor that call for a safer procedure, such as the presence of large lesions (12–16 cm in diameter) or the presence of malignant tumor with invasion of nearby structures [27, 28].

The approach used will be determined by the patient's size, location, the likelihood of malignancy, and the surgeon's skill with the various approaches. In addition, the results and morbidity of open adrenalectomy differ depending on the pathophysiology of the disease and the technique used. All peritoneal techniques reduce the risk of postoperative ileus; however, extraperitoneal approaches are associated with significant rates of neuromuscular morbidities, such as persistent discomfort (14%), laxity in the flank muscles (30%), and flank numbness (30%) [2, 29, 30].

4. Postoperative complications

4.1 Postoperative outcomes

Untreated pheochromocytoma has a high rate of morbidity, which is difficult to determine. Cardiovascular reasons can be the cause of death for 71 % of patients, including myocardial infarction, hypertensive heart failure, or hemodynamic instability [18].

The goal of favorable postoperative results with cortical-sparing adrenalectomy is to avoid steroid reliance. The benefit of not using steroids must be weighed against the possibility of recurrence over time. The need for a complete adrenalectomy is determined by a genetic or familial propensity. Cortical sparing adrenalectomies are a suitable option for patients with familial illnesses including MEN 2B, VHL, and/or MEN 2A. Patients with MEN 2A or 2B syndromes who underwent cortical sparing adrenalectomy have a 51.8 percent incidence of recurrence at the age of ten. Moreover, 43 percent of patients who underwent the unilateral or bilateral cortex sparing technique became dependent on steroids. Cortical sparing adrenalectomy is another option for people with VHL syndrome [19].

To prevent recurrence or the development of metastatic illness, which can happen up to 40 years after the tumor was removed, patients with various forms of pheochromocytomas should be monitored for the rest of their lives [17].

There are some relative contraindications to laparoscopic surgery. Many patients can undergo laparoscopic surgery, despite the fact that maybe they had abdominal surgery in the past or they have obesity.

4.2 Contraindication of laparoscopic surgery

In people at high operative risk with cardiopulmonary disease and/or hematological disease, open surgery may be required. Even though previous abdominal surgery and obesity have been cited as relative contraindications for this procedure, many patients in these categories may still benefit from laparoscopic surgery. Therefore, personalized patient management by the surgical team is recommended [24].

4.3 Conversion to open surgery in laparoscopic surgery

There is a small risk when switching to open surgery from laparoscopic surgery, described in some of the studies as about 5 percent [29]. Laparoscopic adrenalectomy should be switched to classic open surgery if there is a macroscopic appearance suggestive of cancer such as invasion into surrounding structures or the

presence of suggestive regional lymphadenopathy. Also, intraoperative problems, such as uncontrolled bleeding that cannot be controlled laparoscopically, should be resolved by switching to the classic method if the surgeon fears he cannot control the situation [25].

4.4 Complications of right adrenalectomy

Bowel and vascular injuries, gas embolism, operating difficulties due to adhesions, and obesity are some of the common risks associated with the laparoscopic method. Difficulties may emerge as a result of an incorrect port placement or insufficient mobilization, as well as an incorrect surgical perspective. The right adrenalectomy has a number of particular adverse effects, including damage to the kidneys, liver, duodenum, gallbladder, common bile duct, inferior vena cava, portal vein, right adrenal vein, rupture of the adrenal capsule, and diaphragm injury [1, 6, 13].

4.5 Complications of left adrenalectomy

During port replacement, intra-abdominal organ damage is possible. When a port is inserted, there is a risk of intraabdominal organ harm. Inappropriate port placement, insufficient mobilization, and an incorrect surgical perspective can all lead to difficulties. Some possible adverse effects of left adrenalectomy include splenic artery and vein injury, spleen and pancreatic injury, and stomach injury. Bleeding may occur from poor plane dissection. It is possible to sustain injuries to the left adrenal or inferior phrenic veins. The left renal vein may be divided by mistake, assuming it to be a broad adrenal vein, especially in big tumors. There may be an injury to the left kidney's upper lateral artery, kidney parenchymal injury, gland capsular rupture, and diaphragm rupture [1, 6, 13].

5. Conclusions

In the case of adrenal gland surgery, it is critical to remember that a multidisciplinary approach involving surgeons, anesthesiologists, endocrinologists, radiologists, and oncologists plays a key role in patient management and that surgeon experience and hospital experience both have an impact on the procedure's success. Open adrenalectomy, laparoscopic adrenalectomy, robotic-assisted, and single-incision approaches are only a few of the operations on the adrenal glands that have been recorded in the literature. Surgeons should select the technique with which they are most familiar.

When compared to open surgery, several studies have shown that laparoscopic adrenalectomy is safe, effective, reduces hospital stays, operative blood loss, and wound complications, and has equal long-term outcomes; in fact, it is regarded as the gold standard for adrenal disorders that require surgery. Due to the scarcity of these cases in general practice, the learning curve for laparoscopic adrenalectomy may be difficult. For large tumors and morbidly obese patients, robotic adrenalectomy may offer advantages over laparoscopic adrenalectomy.

In the same way, single port adrenalectomy is technically viable and safe in the hands of an experienced surgeon, but it offers little, if any benefit over other typical laparoscopic adrenalectomy techniques.

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