12 Robotic Surgery and Innovation

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12.1 Introduction

The emergence of robot-assisted surgery has brought some advantages to minimally invasive surgery. Compared to classical laparoscopic systems, robotic systems allow for three-dimensional visualization with more pleasing contrast and color resolution. In addition, they are equipped with sensitive instruments with high mobility that can work in smaller areas. However, this better technology comes at a higher overall cost. Another disadvantage is the need for a well-trained surgeon and supporting team to use the system, which can be complex. The first use of robotic technology in adrenal gland surgery was made in 1999 by Piazza et al. in Italy [1]. As the robotic system became widespread globally, publications with larger numbers of cases followed. In the current literature, transabdominal lateral robotic adrenalectomy (TL-RA) seems to be a more commonly used technique than robotic posterior retroperitoneal adrenalectomy (RPRA). A recently published EUROCRINE study compared robot-assisted and conventional laparoscopic adrenalectomy [2]. EUROCRINE is an online endocrine surgical quality registry that aims to decrease mortality in the surgical care of patients with endocrine tumors, with a special focus on rare tumors, by means of an international database based in Europe. In the aforementioned study, data from 46 centers registered in the system were examined. The authors excluded retroperitoneal cases because the number of RPRAs was only six. Vatansever et al. studied 1005 patients, 816 of whom were laparoscopic and 189 were robot-assisted adrenalectomy. The authors suggested that robotic adrenalectomy could be considered a preferred approach in more challenging and difficult cases, including large (>50 mm) and functioning (e.g., pheochromocytoma) tumors and obese patients. In conclusion, analysis of the EUROCRINE database supports that, beyond being safe and effective, robot-assisted adrenalectomies show lower complication rates and shorter postoperative durations of stay [2]. Although it is not very common in the EUROCRINE information system, RPRA has been performed in many centers in increasing numbers since 2010, when it was first described in the literature. In this section, the surgical technique of RPRA and the results of this technique will be discussed.

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12.2 Surgical Technique of Robotic Posterior Retroperitoneal Adrenalectomy

Many minimally invasive techniques are used for the surgical treatment of adrenal gland diseases. One of these techniques is RPRA, which many centers successfully apply, and is a safe, feasible, and effective method [3]. This approach ensures avoidance of the peritoneal cavity, which is the main advantage. Not entering the peritoneal cavity reduces complications associated with intraperitoneal access, such as visceral injury, intraperitoneal bleeding, and adhesion formation. Therefore, RPRA may be the preferred approach, especially in patients who require intervention on bilateral adrenal glands and in patients who have had more than one abdominal surgery—in these cases, intraperitoneal surgery may be more difficult due to previous adhesion formation. However, the most significant shortcoming of RPRA is the limitation in the working area, which increases the technical difficulties of the operation.

12.3 Preoperative Preparation and Setup of the Patient

The RPRA technique is slightly modified compared to the conventional approach. Robotic surgery can be performed with one of the DaVinci robotic surgery systems (Intuitive Surgical Sarl, Aubonne, Switzerland). The system consists of a 4-arm robotic manipulator and remote control surgical console. Surgery is performed under general anesthesia. Preoperative preparation and patient positioning are the same as posterior retroperitoneoscopic adrenalectomy (PRA). The robotic approach provides enough working space and facilitates orientation by providing readily identifiable anatomical landmarks and better visualization of surrounding anatomical structures.

The patient is carefully placed in a prone jack-knife position (Fig. 12.1). Attention should be paid to pressure points, and necessary places (especially the axilla) should be supported appropriately with pillows and gels. The retroperitoneal space is entered through a 1.5–2 cm transverse incision, placed just beneath the lowest tip of the 12th rib. Then, the trocar is replaced with a dissecting balloon under direct view to generate an adequate working space. After that, a medial 12-mm-long trocar is placed along the lateral border of the paraspinous muscles. Next, two 8-mm robotic trocars are applied, one lateral to the 12th rib port site and one medial approximately 3 cm below the junction of the 12th rib and the spine. A 5-mm inferior port is often placed 3–5 cm (as far away as possible from each other, attempting to prevent instrument collision) caudad to the central port site and used for the assistant port (retractor, suction, or irrigator device). The role of the assistant at the surgical table is to change the robotic instruments when necessary, assist in dissection from the assistant's port, attach the clip to the adrenal vein, seal with the vessel

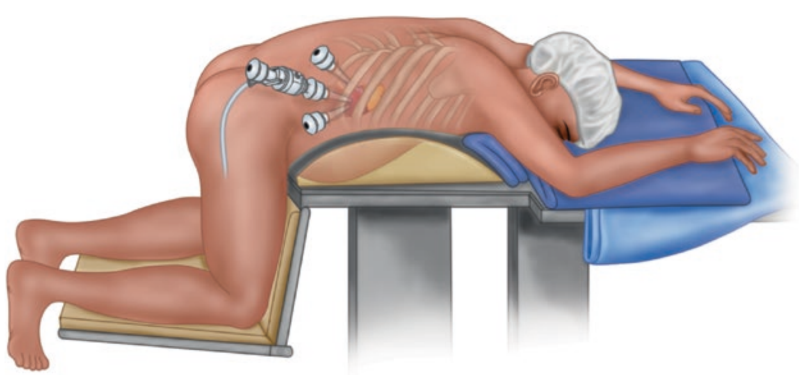

Fig. 12.1 Patient positioning for RPRA

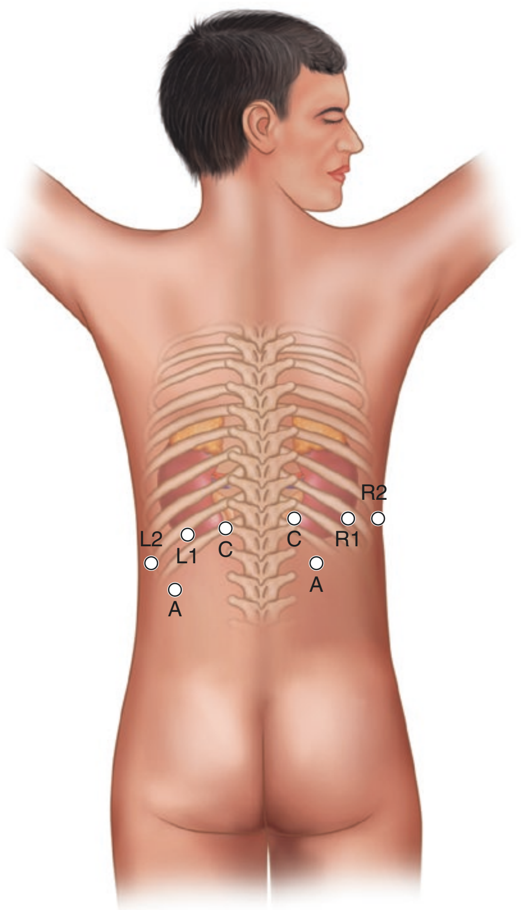

Fig. 12.2 Port placement for RPRA. A—assistant port, C—camera, L1, L2—robotic trocars (left side), R1, R2—robotic trocars (right side)

sealing device, and perform the wash-aspiration process (Fig. 12.2). Pneumoretroperitoneum is established with CO_2 insufflation, maintained at 15–20 mmHg throughout the procedure. A 30-degree non-robotic endoscope is introduced looking up. Gerota's retroperitoneal fascia is then taken down without injuring surrounding structures or violating the peritoneal layer laterally using a blunt laparoscopic grasper. After the port application, a 30-degree robotic endoscope is inserted, and the cavity is carefully inspected to exclude any iatrogenic injuries or to check for other retroperitoneal masses. At this point, the robotic unit is docked, and the primary surgeon moves to the operating console (Fig. 12.3).

Once the robotic unit is docked, the 8-mm robotic cadiere forceps are used on the left-sided port and the 8-mm robotic cautery hook is used on the right-side port. This may change according to the surgeon's preference. The 30-degree camera is looking down from this point, and dissection is carried out from lateral to medial, detaching the tissue above the kidney. Next, the assistant retracts the kidney caudally. The surgeon subsequently dissects the adrenal gland and the tissue surrounding it from the superior aspect of the kidney. First, the right or left adrenal vein is identified medially, extending from the adrenal gland to the vena cava or renal vein, respectively. Then, the adrenal vein is carefully dissected and clipped (using the robotic clip applier or standard laparoscopic clips) or ligated with a vessel sealer—placed by the bedside assistant through the 5-mm assistant port. The adrenal gland is then removed from its retroperitoneal attachments. For hemostasis control, before the mass is removed from the retroperitoneal area, it is advised to wait 3–4 minutes after the retroperitoneal gas is evacuated and recheck the operation site. After the adrenalectomy is complete, the robotic unit is undocked. The gland is removed using a specimen retrieval bag and delivered via the 12-mm middle port by extending the port site incision at the skin and fascia, as necessary. After the operative site is irrigated and suctioned, the trocars are removed. The trocar sites are closed appropriately. The patient is then placed supine, extubated, and taken to the recovery room in a stable condition.

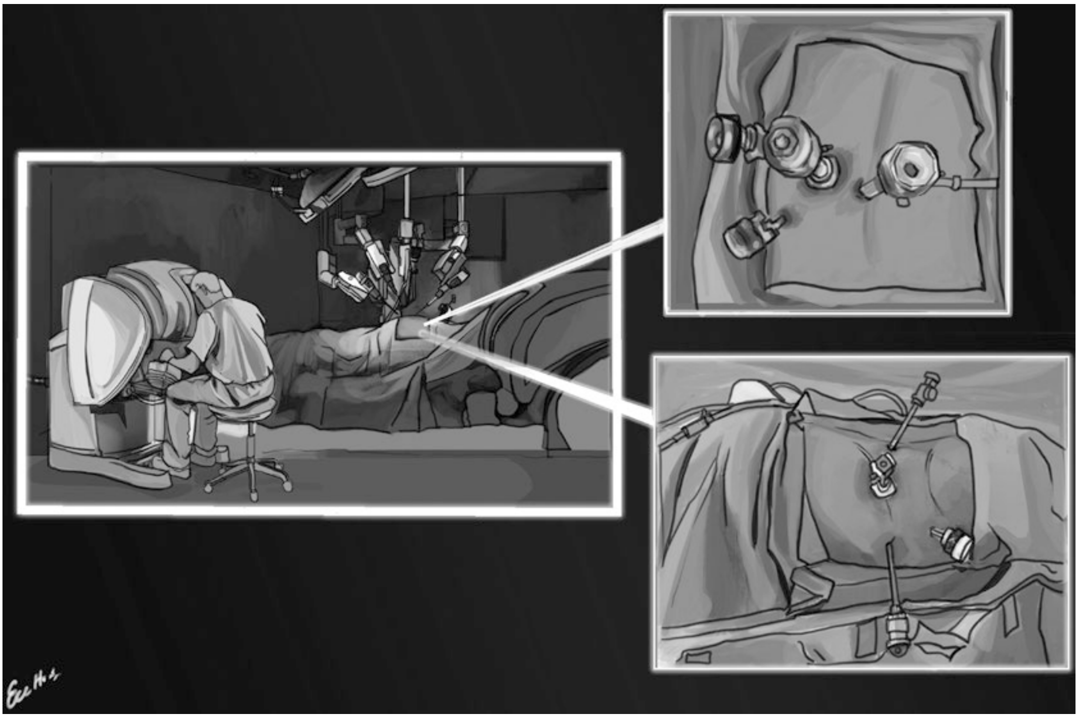

Fig. 12.3 Ports in place for RPRA

12.4 Evidence Regarding Robotic Posterior Retroperitoneal Adrenalectomy

12.4.1 Case Series

The surgical technique of RPRA was first described by Berber et al. in 2010 in a series of 8 patients [4]. The mean operative time in these first series was 214.8 min, docking time was 21.7 min, and console time was 97.1 min. In the first few cases, the docking time lasted 60 minutes, but later on, this time could be reduced to 7 min. The mean blood loss was 24 ml, and the patients were discharged from the hospital within 24 h. The highlight in this first series was the length of the operation time, which was quite long compared to the conventional retroperitoneoscopic adrenalectomy data.

Also in 2010, a 6-patient study (one of the first RPRA series) was published by Ludwing et al. [5]. In this study, the mean operation time was 121 min, the console time was 57 minutes, the docking time was 14 minutes, the blood loss was <60 ml, and the hospital stay was 1.3 days. There was no morbidity in either study [4, 5].

After these initial reports, Dickson et al. published a series of 30 RPRA procedures performed on 28 consecutive patients (26 unilateral and 2 bilateral) [6]. Indications for adrenalectomy included pheochromocytoma, hyperaldosteronism, hypercortisolism, oligometastases, and nonfunctional tumors. The mean tumor size in the study was 3.8 ± 1.6 cm, and the mean body mass index was 30.7 ± 6.5 kg/m^2. The mean operative time for unilateral total adrenalectomy was 154 ± 43 minutes, the estimated blood loss (EBL) was 28.3 ± 50.9 ml, and the conversion rate to the open procedure was zero. Three patients had perioperative complications. These complications were reported as pneumothorax, urinary retention, and retroperitoneal hematoma requiring postoperative blood transfusion. In addition, cortex-sparing RPRA was performed for pheochromocytoma in four patients with MEN2A in this series. One of these patients underwent right adrenalectomy and left cortex-sparing adrenalectomy. No recurrent pheochromocytoma was observed in any patient during follow-up longer than 6 months. In addition, average serum cortisol values were found in the patient who underwent the bilateral procedure. Based on their early experience, the authors commented that robotic surgery might better preserve the vascularized residue during minimally invasive cortical sparing adrenalectomy thanks to its three-dimensional visualization capabilities, ergonomic design, enhanced visualization tools compared to those in standard endoscopic operations, and a more flexible approach to dissection. In addition, the fluorescence imaging ability of the robotic system may help visualize the integrity of the blood supply of the remnant adrenal tissue in such cases [7].

12.4.2 Laparoscopic Versus Robotic Posterior Retroperitoneal Adrenalectomy

In their 2012 study, Ağcaoğlu et al. compared 31 laparoscopic posterior retroperitoneal adrenalectomy (LPRA) and 31 RPRA cases [8]. Tumor size, blood loss, hospital stay, and skin-to-skin surgery times were similar between the two groups. However, after an initial learning curve of 10 cases, operative times were significantly shorter in the robotic group (139 vs. 167 min, $p = 0.046$), including robotic insertion times ranging from 5 to 30 min. In addition, pain scores on the postoperative first day were lower in the robotic group than in the laparoscopic retroperitoneal group ($p = 0.008$). The authors attributed this to the shorter operative time and less pressure on the incisions due to their articulating instruments.

In 2019, in a study published by Kim et al., LPRA was performed on 169 patients and RPRA on 61 patients [9]. There was no difference between the two groups regarding tumor size, BMI, EBL, or hospital stay. However, a significant difference between the two groups was found in the mean operation time (117 minutes for the LPRA group vs. 142 min for the RPRA group, $p = 0.006$). Furthermore, in the LPRA group, there was a positive correlation between operative time and male gender, tumor size, and pheochromocytoma. In RPRA, tumor size and pheochromocytoma affected the operation time. When the adrenal tumor size was ≤5.5 cm, a shorter operative time was registered in LPRA than RPRA ($p = 0.001$). There was no significant difference between LPRA and RPRA operation times when the tumor size was >5.5 cm ($p = 0.102$).

In a 51-patient study published by Fu et al. in 2020 comparing LPRA ($n = 32$) and RPRA ($n = 19$) only in patients with pheochromocytoma, the incidence of hemodynamic instability was lower in the RPRA group (26.3% vs. 56.2%, $p = 0.038$) [10]. In addition, in the RPRA group, the EBL (100 ml vs. 200 ml, $p = 0.042$) and hospital stay (5 days vs. 6 days, $p = 0.02$) were significantly lower than in the LPRA group.

In a study published by Ma et al. in 2021 comparing 86 RPRA and 315 LPRA patients, no difference was found regarding demographic and tumor characteristics between the two groups [11]. However, the mean postoperative stay (3 vs. 4 days, $p = 0.001$) was significantly shorter in the RPRA group. In addition, there was no difference between the two groups regarding the median operative time (100 vs. 110 min, $p = 0.554$), the median EBL (50 ml vs. 50 ml, $p = 0.730$), transfusion rate ($p = 0.497$), and incidence of postoperative complications ($p = 0.428$).

In 2013, Park et al. carried out "single-port" RPRA on five patients with adrenal cortical adenoma. The series had a mean operative time of 159.4 ± 57.6 (103–245) minutes and a mean EBL of 46.0 ± 56.8 (5–120) ml. Neither conversion to open surgery nor postoperative complications were reported in any patient [12].

12.4.3 Robotic Posterior Retroperitoneal Adrenalectomy Versus Transabdominal Lateral Robotic Adrenalectomy

In 2017, Kahramangil et al. compared RPRA and TL-RA cases [13]. As a result, there were 188 robotic adrenalectomy patients, 12 of whom underwent bilateral surgeries. In addition, 110 patients were operated on using the transabdominal lateral approach and 78 using the posterior retroperitoneal approach. When both groups were compared, in patients of similar age and gender, the tumor size was larger (4.2 ± 2.5 vs. 3.3 ± 2.0 cm, p = 0.01) and BMI was higher (29.2 ± 4.7 vs. 32.3 ± 8.1) in the TL-RA group. Furthermore, the operation time was significantly shorter in the RPRA group (136.3 ± 38.7 vs. 154.6 ± 48.4 min, p = 0.005). The authors stated that this difference was due to the shorter exposure time (32.8 ± 17.3 vs. 43.3 ± 14.9 minutes, p = 0.001). There was no difference in the EBL, conversion to open surgery, and length of hospital stay between the two approaches. Complications were observed in nine patients (the most common was urinary tract infection), similar in both groups. The authors reported no mortality. The pain score was higher in the TL-RA group on the postoperative first day (p = 0.001) and similar between the two groups on day 14. As a result of the study, the authors emphasized that the postoperative outcomes of both approaches were excellent and recommended that suitable patients should undergo RPRA in experienced centers because of the shorter operation time and lower postoperative pain.

12.4.4 Cost Analysis

Cost has been shown to be one of the most critical disadvantages of robotic surgery in general. However, studies have demonstrated that the multidisciplinary use of a robotic system and the increase in the number of surgeries performed to reduce costs. In a cost analysis report by Barbash et al., the additional cost of using a robot for unilateral adrenalectomies was estimated to range between 1400 and 2900 USD, or about 10–20% of the cost of the entire procedure [14].

Ma et al. also performed a detailed cost analysis of LPRA and RPRA. While the total cost of hospitalization was 8122 USD in the RPRA group, this cost was reported as 4108 USD in the LPRA group (p = 0.001) [11]. On the other hand, despite the fact that Ağcaoğlu et al. did not perform a detailed cost analysis in their study, the authors stated that the cost was approximately 900–950 USD per robotic procedure. They also argued that anesthesia costs for various general surgical procedures are 16–21 USD per minute and that RPRA can reduce the cost by shortening the operation time [8].

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Conflict of Interest The authors have no conflicts of interest to declare.

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