Complications in Robot-Assisted Renal Surgery

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1 Introduction

Several authors have described the benefits of robotic surgery to approach renal tumors [1]. In this scenario, in the USA, robot-assisted partial nephrectomy has become the standard surgery for managing renal tumors smaller than 5 cm [2]. Some authors have described renal function preservation of up to 90% in favor of PN versus 70% of the radical nephrectomy group [3]. The finesse provided by robotic technology associates the intraoperative 3D digital image with highly precise instruments, maximizing renal parenchyma preservation and postoperative recovery. However, despite its advantages, robotic surgery is not devoid of complications. In this chapter we describe the management of the most common complications associated with the robotic approach to renal surgery.

2 Intraoperative Complications and Management

2.1 Patient Positioning

The first step to avoid complications in robotic surgery starts with patient positioning. All patients must have pad protection in all articulations and points of body contact with the operative table. In addition, head and face protection is crucial in this process to avoid trauma to the patient's eyes. In some reports, the chances of corneal abrasions in robotic surgery can reach up to 6.5-fold compared to open surgery [4].

In the current literature, several authors have described complications during this initial step of the surgery, being skin lesion, the most common issue reported, and operative time the most important risk factor for nerve injuries [5–7]. Common nerve injuries include brachial nerve plexus due to hyperabduction in kidney surgery, ulnar nerve injury due to elbow compression against the table corner, radial nerve injury due to hand and wrist compression, and femoral nerve injury due to the lithotomy position in radical prostatectomies and cystectomies. For each additional hour of surgery, it is estimated that the nerve injury increases up to 100-fold [8, 9].

Finally, the collision between the robotic arms and the patient's body is another source of skin complications. In these cases, the tableside assistant and anesthesia team must monitor these robotic movements during the surgery and provide an appropriate external arm angulation and trocar burp when required [10].

2.2 Trocar Placement and Bowel Lesion

Appropriate trocar placement is imperative for the success of the robot-assisted surgical procedure. The correct trocar triangulation associated with a standardized technique is crucial to avoid internal lesions and optimize robotic movements during the surgery. In renal surgeries, especially partial nephrectomies, the trocar placement is always adapted according to the type of robot used (S, Si, X, Xi, and SP), patient's size, body habitus, tumor location, and renal anatomy. In addition, the past surgical history is a determinant factor while placing the trocars due to the highest chances of intra-abdominal adhesions, which increases vascular and bowel lesions during the abdominal access. In these cases, the most appropriate trocar placement is performed with Hasson's technique or Palmer's point access [11, 12].

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P. Wiklund et al. (eds.), *Robotic Urologic Surgery*, https://doi.org/10.1007/978-3-031-00363-9_50

Recent studies reported the chances of vascular and bowel lesions in robot-assisted surgeries in up to 0.1% of the cases, being vascular injury the most common complication [13]. However, despite the small likelihood, an adverse and unrecognized injury can cause serious impacts on the patient's health. In this scenario, it is crucial to inspect the whole abdominal with the robotic or laparoscopic scope after placing the first trocar and before proceeding with the next trocars. In the case of any organ damage, the repair must be performed immediately.

Extra attention must be paid to patients with small body habitus and low BMI due to a smaller distance between the skin incision and the aortocaval space, which increases the chances of damaging these structures while placing the Veress needle or the robotic trocar.

Besides the trocar placement, bowel injury can happen while releasing the colon to access the kidney in both sides. Two different types of injury mechanisms are described: mechanical and thermal.

Mechanical injuries are usually associated with retraction and blunt dissection. Due to the lack of tactile feedback, some delicate organs and structures are damaged with inappropriate mechanical manipulation.

In general, robotic instruments provide two types of energy: monopolar and bipolar. Both have potential for thermal lesions of the bowel. Monopolar energy causes more lateral thermal spread and produces higher temperatures than bipolar electrocautery, the Harmonic scalpel, and LigaSure [14]. Thermal injury is usually more extensive than expected, and conservative management can result in acute perforation during the postoperative period. Intraoperative repair is usually the best management. If a bowel repair is required, all bowel edges must be refreshed, and all affected tissue removed before the primary repair [14]. The injured site should be drained, and the patient must be prescribed antibiotic treatment [15].

Unrecognized bowel injuries usually present as sepsis and acute abdominal pain in the postoperative period. Other signs and symptoms are leukopenia or leukocytosis, fever, orifice pain trocar, ileus, nausea, or vomiting. In these scenarios, a CT scan usually supports the diagnosis. In cases of suspicion, a diagnostic laparoscopy should be performed.

Technical refinement is the best way of minimizing complications during trocar placement and bowel manipulation. When using bipolar or monopolar energy, the surgeon must ensure that the instruments are not touching each other and that the arm is not touching the bowel, vessels, or adjacent structures; only the tip of the instrument must be in contact with the bleeding tissue to be cauterized. In addition, the surgeon must avoid manipulating the bowel with tools with delicate tips such as scissors and Maryland.

2.3 Potential Issues with Pneumoperitoneum

Insufflation of CO_2 and pneumoperitoneum pressures during the surgical procedure are always potential factors of complications. In addition, extended operative time is associated with hypercapnia and metabolic acidosis, especially in smokers and patients with chronic obstructive pulmonary disease (COPD). In such cases, some authors have described pneumoperitoneum insufflation with helium gas as an alternative to CO_2 [16–18].

The CO_2 insufflation rate is also important due to the increased risk of embolic events, hypotension, and vagal response. Monitoring the rapid increase of intra-abdominal pressure is crucial, mainly when operating patients with cardiovascular diseases and morbid obesity due to the asystole and ventilation issues during the surgery [6].

2.4 Hepatic, Splenic, and Pancreatic Lesions

Hepatic, splenic, and pancreatic lesions are uncommon events in robot-assisted renal surgery. Some authors have reported up to 0.3% of splenic lesions in left upper urinary tract surgeries while mobilizing the spleen to access the upper pole of the kidney [19]. On the other hand, hepatic lesions are difficult to estimate because minor injuries are not usually reported. Bile duct injuries appear in the right adrenalectomy and partial nephrectomy. In these cases, the general surgery team must be contacted immediately to manage ductal lesions appropriately.

It is estimated that pancreatic injury rates reach up to 0.2% during left kidney surgery. Despite the uncommon event, it has substantial morbidity. The best advice to prevent this complication is a careful dissection of the upper renal pole, between the tail of the pancreas and Gerota's fascia [14]. It is also recommended to have an intraoperative evaluation of the general surgery team when suspecting or recognizing an inadvertent pancreatic lesion.

2.5 Vascular Injury and Management

Controlling the renal hilum and manipulation of large-caliber vessels are common steps of robot-assisted renal surgery. However, being direct branches of the aorta and vena cava, any lesion of the renal artery or vein has deadly potential. In this scenario, preoperative imaging studies, including 3D reconstructions, are crucial for avoiding accidental vascular lesions [20].

In our experience, after dissecting the renal artery and vein, a vessel loop is used to repair these branches and facilitate the manipulation while placing the bulldog clamp (Fig. 1). These repairs are important landmarks to identify the vessels in the case of any accidental vascular lesion and massive bleeding. Placing vessel loops is also an option to minimize the blood loss in large-caliber vessels such as aortic injuries, allowing an appropriate surgical view during the repair (Fig. 2).

The bedside assistant has a fundamental role during these episodes of vascular injuries. The assistant must associate an efficient suction with compression of the bleeding source

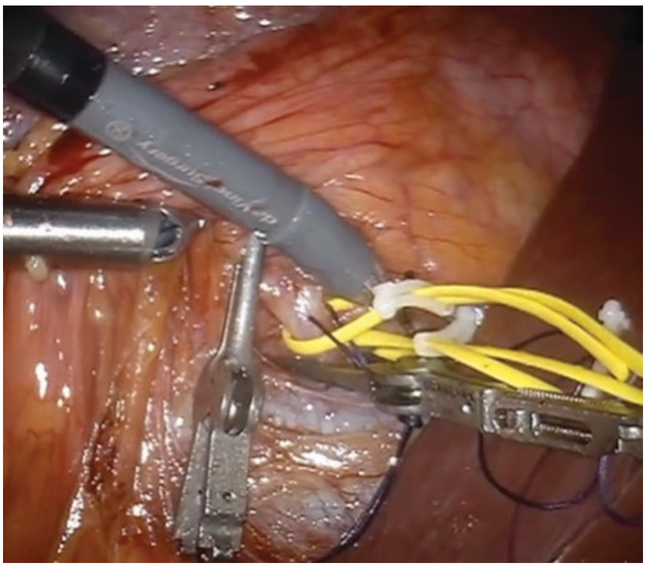

Fig. 1 Renal artery repaired by vessel loops

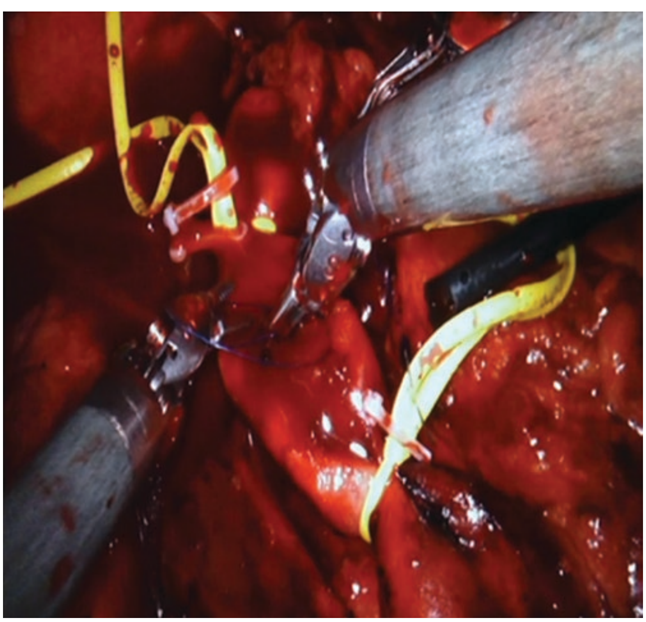

Fig. 2 Aorta injury. Vessel loops repairing the edges of the lesion to decrease blood loss and improve visualization

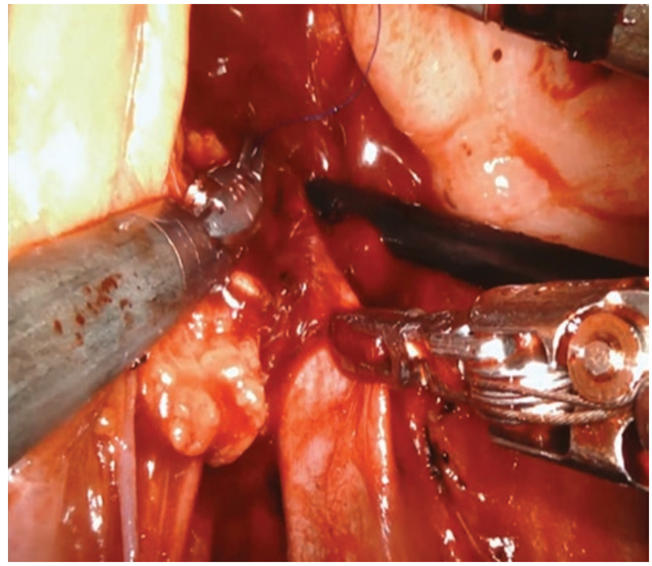

Fig. 3 Bedside assistant associating pressure and suction to improve the operative view while decreasing blood loss

(Fig. 3). Performing the blood suction without applying local compression increases the blood loss and, in the case of massive bleeding, will not properly clean the surgical site for identifying and repairing the lesion. The assistant can also use other resources to help the robotic surgeon, such as introducing a compress through the 12 mm port for improving the compression surface, placing a new trocar to work with both hands, or using additional bulldog clamps to decrease the active bleeding while the surgeon repairs the lesion.

Sliding Hem-o-Lok clips is another situation that usually leads to massive bleeding, especially when only one clip is placed in large-caliber vessels. For this reason, we usually apply two clips on the renal artery or direct branches of the aorta. In addition, the assistant must have extra caution when using the suction over a clamped artery because the tip of the suction device can displace or slide the clip, causing substantial bleeding.

Finally, some patients present a hemorrhagic state after unclamping the renal artery and vein due to a medullar or cortical vessel that was not controlled during the renorrhaphy. In our technique, all sutures used in the renorrhaphy have Hem-o-Lok clips on their tips. In these episodes of parenchymal bleeding after unclamping, the first step is the suture tightening by sliding the Hem-o-Lok of the suture. However, sometimes, the suture adjustment is not enough to stop the bleeding. In such cases, we usually release the suture and apply new stitches to the bleeding site.

2.5.1 Hemostatic Agent's Role in Bleeding Episodes

Several groups have reported the role of hemostatic agents in robot-assisted renal surgery for the final hemostasis and for reducing the warm ischemia when performing tumor enucleation without clamping the renal artery [21–24]. A variety of brands and materials are available in the market, such as hemostatic patches, foam, and powder products. However, the current literature still lacks well-designed studies describing which hemostatic agent is the most appropriate for renal surgery.

In our experience, hemostatic patches such as TachoSil are effective for minimizing renal sutures in enucleations of small and peripheral tumors (Fig. 4). The patch is placed on the tumor bed, and the robotic arm performs a local pressure with a wet gauze over the patch. After 5 min of pressure, the gauze is removed, and the hemostasis is checked with low-pressure insufflation (Fig. 5). These patches can also be used in the hemostasis of hepatic and splenic inadvertent lesions.

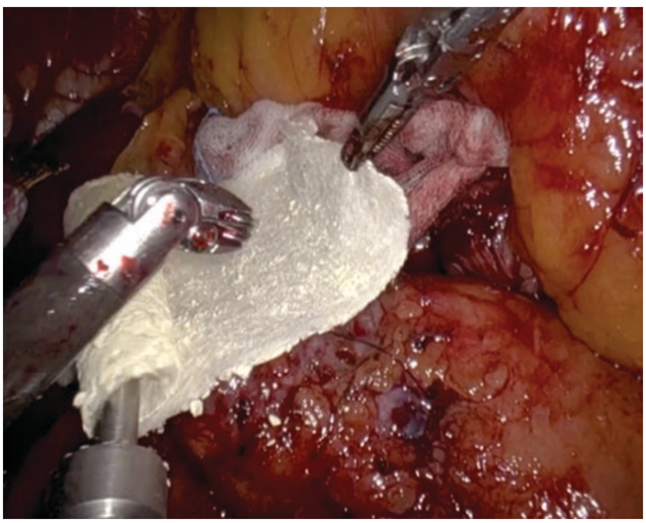

Fig. 4 Hemostatic patch before application

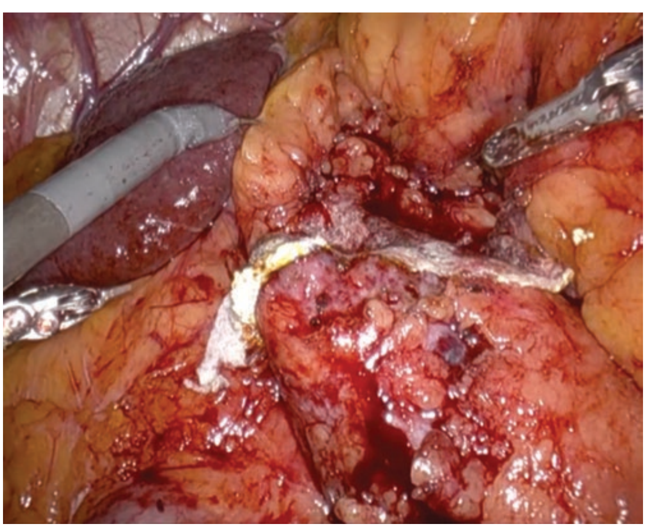

Fig. 5 Hemostatic patch after 5 min

2.6 Instrument Malfunction and Material Issues

Some studies in the literature described up to 4.6% of issues associated with the materials used in robot-assisted surgery, including software-related, mechanical, electric, and instrumental failures [25, 26]. Alemzadeh and colleagues reported up to 2.7% of conversion rates due to instrumental and robotic malfunction [27].

In our experience, all instruments are tested on the surgical back table. The robotic instruments have the tips, and the protective sheets checked before being inserted into the patient. Especial attention must be taken with the vascular bulldog clamps because the pressure applied by each clamp differs among the brands, sizes, and the number of times used [28]. Before using in the patient, the clamps and appliers must be checked by the surgeon and tableside assistant. Having a bulldog clamp with inappropriate pressure leads to two different types of complications. Clamps with a loose grip and decreased pressure lead to a hemorrhagic state during the tumor enucleation, while clamps with a strong grip or opening issues lead to a more extended ischemic state, which impacts the renal function (Fig. 6).

2.7 Considerations for Vena Cava Thrombus Surgery

Renal surgery in patients with vena cava thrombus is one of the most challenging procedures in urology due to the increased intra- and postoperative complication rates compared to the standard partial nephrectomy [1]. Despite the potential blood loss during the surgery, these cases, depending on the thrombus level, must be faced by a high-volume

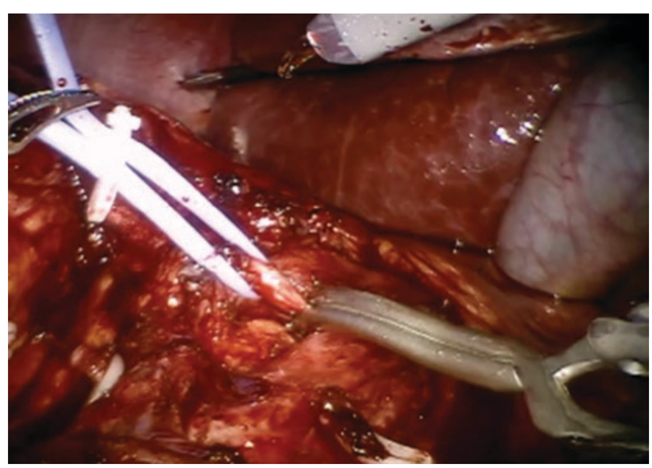

Fig. 6 Laparoscopic bulldog with opening issues during renal artery clamping

center with a multidisciplinary surgical team including vascular and cardiac surgery.

Our consideration for this type of surgery regard the IVC thrombectomy. Before opening the vena cava, the thrombus must have its limits identified with intraoperative ultrasound, and an appropriate IVC clamping with vessel loops must be performed to avoid embolism of any fragment. After the thrombus removal, the IVC interior walls are checked for tumoral infiltration. In these cases, the infiltration is removed, and a bovine patch is placed to repair the IVC wall. Finally, before releasing the tourniquet, the IVC is filled with saline solution to avoid gas embolism.

3 Postoperative Complications Related with the Robotic Approach

Some of the complications related with robotic approach may be experienced during the postoperative period, and they should be properly identified in order to optimize their management.

3.1 Acute Kidney Injury

Acute Kidney Injury (AKI) is a common occurrence after partial nephrectomy and is a significant risk factor for chronic kidney disease. RAPN have been demonstrated to reduce the risk of AKI [29], but this finding may be related to the shorter ischemia time of robotic surgery or to the selective clamping of only arteries in RAPN [30]. Therefore, prospective evidence is needed to confirm these findings from retrospective analyses. Within the context of patients treated with robot-assisted approach, age, gender, BMI, diabetes, nephrometric scores, and baseline estimated glomerular filtration have been demonstrated to be strongly associated with the risk of experiencing AKI in the postoperative time [31]. The data corroborate the importance of patient selection to reduce the risk of AKI. Moreover, when considering ischemia time, this preoperative information can aid in the early identification of patients who would potentially benefit from an early multidisciplinary consultation.

3.2 Venous Thromboembolism (VTE) Complications

Deep venous thrombosis (DVT) and pulmonary embolism are postoperative complications strongly related to oncological surgeries. Although there are many risk factors inherent to the patients, positioning and prolonged operative time can remarkably influence thromboembolic events [32, 33]. Surgical features, such as lymph node dissection, can increase the incidence of DVT/pulmonary embolism up to sevenfold, while minimally invasive surgery seems to have lower risk of thromboembolism than open approaches [34].

While comorbidities and most of the surgical features related to VTE are not modifiable, VTE prophylaxis management is of utmost relevance. Early ambulation, sequential compression devices, and chemoprophylaxis are helpful measures in patients at risk of VTE without contraindications [32]. A randomized study showed that 4-week anticoagulation prophylaxis has advantages in relation to 1-week administration after major abdominal surgeries [35]. Single preoperative chemoprophylaxis has also shown benefits without increasing the risk of bleeding in patients [36].

3.3 Rhabdomyolysis

Clinically relevant rhabdomyolysis can occur in patients exposed to prolonged robotic procedures, particularly at the beginning of the procedure learning curve. Serum creatine kinase (CK) increases after surgery peak at 18 h after the procedure, but CK elevation in isolation should not be used to predict positioning injury [37]. Prolonged Trendelenburg position, high body mass index, peripheral vascular disease, and comorbidities increase the risk of muscle injuries [38, 39]. Serum CK dosage is indicated for these patients and for those with pain in the back, thigh, or gluteals after surgery. Serum CK levels of >1000 IU/L or myoglobinuria confirms a rhabdomyolysis diagnosis, which increases the postoperative renal failure risk. Hypervolemic diuretic therapy and management of metabolic acidosis are required in such situations [37].

3.4 Ocular Complications

A steep Trendelenburg position combined with pneumoperitoneum can cause increased intraocular pressure, reduced ocular perfusion, and possibly visual impairment caused by ischemic optic neuropathy. Permanent vision loss is a rare but important complication [40, 41]. In the context of renal surgery, the risk of ocular complications is reduced due to the limited use of steep Trendelenburg, while pneumoperitoneum still remains a notable risk factor. Therefore, limiting operative time, adequate intraoperative blood pressure monitoring, and transparent occlusive dressing as opposed to standard eye tape may play a role in minimizing the risk of postoperative ocular complications [40].

3.5 Port-Site Hernias

Port-site hernias are a late access-related complication, which occur in <1% of robot-assisted procedures. There is a higher incidence with >10 mm port sites, although 8 mm robotic and even 5 mm port-site hernias have been described. Cutting trocars have been associated with larger fascial defects; thus, blunt-tipped obturators have been preferred. Port-site with >10 mm closure is the best way to avoid hernias, although some studies have shown low incidence of hernia in non-midline port-sites of <12 mm [42].

3.6 Skin Lesions

Most skin lesions are positioning related. The combination of general anesthesia and prolonged immobilization is a combination of known risk factors which increase the risk of decubitus pressure lesions. Moreover, inadequate fixation and patient slippage might potentiate it and lead to severe decubitus and trocar-site lesions. Therefore, fixation of the patient on the table with a gel mattress, restraints, and body and shoulder straps may prevent such complications [43].

3.7 Postoperative Complication Assessment: Is there a Quality Control?

During the past decade, it has been proposed to introduce standardized systems for reporting complications [44–47]. Although these recommendations, few studies demonstrated a weakness in the literature for grading and reporting of complications following partial nephrectomy [48]. For instance, it was found that only six studies (2.9%) fulfilled all the criteria proposed by the European Association of Urology (EAU) for reporting complications. Therefore, the EAU recommended to use a 14-criteria template to collect and report complications after urological surgery [49]. A recent systematic review described that, after publication of the EAU guideline recommendations on outcome reporting, there was mainly better adherence to all the criteria [50]. Overall, there was underreporting (<50%) for 6 of the 14 criteria after publication of the EAU guidelines. Moreover, they found statistically significant improvements in the inclusion of mortality rates and causes of death, definitions of complications, severity grade, postoperative complications tabulated either by grade or complication type, and inclusion of risk factors in analyses. As previously reported, the vast majority of studies did not investigate who collected the data and the percentage of patients lost to follow-up. Despite a causal link between the introduction of EAU guidelines for reporting complications and the improvement of quality assessment after renal surgery cannot be proven (particularly in non-European center), the introduction of standardized guideless may have influenced the methodology of researchers for collecting and reporting complications after robotic renal surgery.

Of note, most complications may happen at the beginning of a surgeon learning curve; therefore, console and team training outside the OR represent a crucial step to reduce the risk of experiencing complications related to robotic approach. Indeed, it has been agreed during international multi-specialty consensus meeting that basic device training and basic skills training are fundaments steps to be achieved when starting with a robotic surgery program [51].

4 Conclusion

Patients' selection, adequate positioning, mentorship training during the learning curve, and avoiding last-longing procedures are key steps to prevent robot-assisted-related complications.

Considering the importance of team training and communication, the assistant has a fundamental role and should undergo a similar pattern of basic training. This said, we believe that team training and standardization of the surgical technique is crucial to minimize the risk of complications. From a clinical point of view, complex renal surgery should be always performed in a high-volume center where urological department is supported by other highly experienced specialties, such as vascular and general surgery, which can help in managing intra- and postoperative complications.

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