9 Management of Vascular Injuries (IVC)

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9.1 Introduction

Minimally invasive surgery has undergone revolutionary changes in the last decades, with more complex procedures being performed by means of different approaches. This revolution has been possible thanks to the existence of new surgical devices and better image capture devices. Complex and extended resections and reconstructions are now being performed safely and with good outcomes. Surgeons have increased their laparoscopic skills to such a high level that almost anything will be possible in a near future. From a diagnostic tool, laparoscopy has become a complex and sophisticated treatment method. As more and more studies have concluded regarding the safety, feasibility and successful outcomes of laparoscopic techniques, minimally invasive surgery has become the gold standard for the treatment of an increasingly large number of surgical diseases. Posterior retroperitoneoscopic adrenalectomy (PRA) is one of those innovative techniques. It is a product of the laparoscopic revolution, stemming from the need for being less aggressive and promoting faster recovery.

The consequence of this minimally invasive surgery revolution is the occurrence of more complex and severe complications than the ones seen when laparoscopy first started being used [1, 2]. Present-day surgeons need not only to have, but also explore and develop their skills so that they can deal with adversity laparoscopically. However, surgeons must not forget that the patients' well-being always comes first. Conversion to open surgery must not be seen as a failure but as an option to correctly treat a complex complication.

9.2 The Major Vascular Complication

Retroperitoneoscopic surgery (renal and adrenal) has several advantages over the laparoscopic approach. It has a low rate of complications, most of them minor [2, 3]. PRA has a lower complication rate than laparoscopic adrenalectomy. Additionally, PRA has less operation time, less postoperative pain, less blood loss, and faster recovery to normal activity [4].

Major vascular complications during minimally invasive procedures are rare but can be fatal. The global incidence of vascular injuries in minimally invasive surgery is 0.2/1000 procedures. These injuries are associated with a morbidity rate of 6–13% and mortality of 12–23% [5].

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Minimally invasive adrenalectomy (laparoscopic and retroperitoneoscopic) has an overall complication rate of 0–15% for unilateral surgery and up to 23% for bilateral [4]. In one of the largest published series on PRA, the complication rate goes up to 14.4% [3]. Even though the most common complications are vascular and visceral injuries during the transperitoneal laparoscopic approach (TLA), there are no data available on the rate of vascular complications during PRA [1]. In a 560 PRA analysis from Walz et al., no major vascular injury was reported [3]. As the retroperitoneoscopic approach (RA) is increasingly used, reports of complications will allow us to assess their frequency and severity [2]. Meraney et al. report a vascular complications rate of 1.7% during 404 retroperitoneoscopic procedures, including renal surgery and adrenal surgery [1]. These authors present a total of five vascular complications affecting renal veins and renal arteries during nephrectomies, and adrenal vein during adrenalectomy. They were able to laparoscopically control the bleeding with EndoGIA or vascular clips because all injured vessels could be ligated during the procedure. However, there may be an injury to a vessel which must be repaired and preserved. This not only increases difficulty but also demands vascular suture skills. In an analysis of 316 retroperitoneoscopic urologic procedures (renal and adrenal), Kumar et al. report seven major vascular complications. However, none of these complications (0%) occurred during adrenal surgery [2].

Vascular injuries during laparoscopic surgery can occur at entry (75%) or during dissection (25%) [2, 5]. Because the umbilicus is the preferred location for the Veress needle and first trocar placement in laparoscopy, bifurcation of aorta and the inferior vena cava (IVC) are the most common sites of injury at entry. Over 70% of injuries occur on the right-side iliac vessels, possibly because of trocar trajectory during placement, considering that the surgeon is standing on the patient's left side in many laparoscopic procedures [5]. In PRA, there is no risk for vascular injury at entry, since first trocar is placed with digital control and no Veress needle is used. Vascular injuries will only occur during dissection (blunt, sharp, or energy devices). During a PRA, major vascular complications may include injury to the IVC above the renal vessels, injury to the renal veins, and injury to the renal arteries. In all these scenarios, the surgeon must repair and preserve the vessel. Minor vascular bleeding can stop spontaneously due to the high pneumoretroperitoneum pressure [2, 4].

In a review of 31 cases of major vascular injuries during gynecologic laparoscopic surgery, all fatalities (22.6%) were due to venous damage on the right or left side [6]. This data supports the idea that it is easier to repair an artery than a vein. Arteries and veins are anatomically different. A major artery is composed of an endothelium, an internal elastic lamina, a thick layer of muscle and elastic fibers, an external elastic lamina, and an adventitia with vasa vasorum. In contrast, a major vein has a thin layer of muscle fibers, no elastic laminas, and the adventitia is the thickest layer. The vein has a thin wall compared to the large lumen. Additionally, the diameter of the arterial lumen is identical to the wall thickness [7]. Due to these anatomical characteristics, a vein ruptures easily during repair even if the surgeon's hand movement is smooth.

9.3 Surgical Team and Operation Room Staff Preparation

A retrospective analysis of 89 cases of retroperitoneal major vascular injuries (aorta and/or IVC) following blunt and penetrating trauma treated in a Level 1 Trauma Center concluded that factors for reducing mortality include spending less time from the admission to the operation stage, aggressive resuscitation method, as well as having human and material resources ready [8].

In elective surgery, the patient is already in the operation room, but it is crucial that the surgical team, anesthesiologist, scrub nurse as well as the remaining operation room staff know what to do if a major vascular injury happens. When confronted with this situation, immedi-

ately inform the anesthesiologist, the scrub nurse, and the remaining staff; inform the operating room coordinator; keep the operating room team updated; ask for help from another surgeon (vascular surgeon if available); inform the blood bank for crossmatching (at least 6 units); get fresh frozen plasma and platelets as required; get 0 Rh units; assure two large-bore cannulas for intravenous access; initiate antibiotic prophylaxis; keep the patient warm; prepare for open surgery (the scrub nurse is responsible for the vascular set) [5]. All these actions must be performed by nurses and runners, while both the surgeon and the anesthesiologist assess the vascular injury and the blood loss, apply pressure on the bleeding site while trying to control the hemorrhage, and decide what to do next. Victoria Asfour, from the Imperial College of London, recommends resorting to a major vascular injury protocol. This protocol summarizes the roles to be played by the runners, the nurses, the anesthesiologist, and the surgeon into three groups of actions [5]. During the entire repair process, it is mandatory to maintain coordination between the surgeon–anesthesiologist–nurse–blood department [9].

To anticipate this stressful situation, a preoperative briefing is paramount. Before beginning the operation, the entire team must know what is going to be done and why, the steps of the procedure, the main risks, and how to act in case of major complications. The surgeon must inform and anticipate any unusual findings or actions. Stress must be prevented, and a preoperative briefing is one way of doing it.

Knowing who to call for help, if necessary, is a question that must be addressed before the start of any surgery. The entire staff must know who the person is. If available, a vascular surgeon should be called, but a fellow general surgeon is also a very good alternative. The number of surgeons with a great deal of experience in managing major vascular injuries during minimally invasive procedures is scarce [5]. So, ideally within this setting, you should call someone who has experience in different procedures of general surgery and vascular surgery.

9.4 Vascular Injury Repair

From the very first stage of the procedure, both the surgeon and the assistant must remain calm. Two questions must be immediately addressed by the surgeon:

- Can I identify and control the bleeding site laparoscopically?
- Can I repair it myself or will I need help?

Although vascular repair can be performed laparoscopically, conversion to open surgery can be mandatory to assure fast and effective bleeding control and to promote appropriate and safe repair. Conversion to open surgery must not be viewed as a failure. Calling another surgeon or vascular surgeon for help is paramount. Even if the surgeon can repair the injury by himself, "a fresh mind" and "a new set of eyes" will help bring anxiety levels down. Do not ever be afraid or ashamed of calling for help. Sharing the decision process with another fellow is crucial for successfully treating a major complication.

Globally, there are three principals to perform a vascular repair:

- Proximal and distal vascular control (bleeding control).
- Exposure of the vessel and the injury (dissect the vessel if necessary).
- Repair with a non-absorbable suture.

It is very important to have good exposure before attempting to repair a vascular injury [5]. Placing a suture or a clamp with poor exposure can cause more damage or additional injuries to other structures. However, additional dissection of large vessels should be avoided if good injury exposure is already present [10].

9.4.1 How to Do It?

In the presence of a vascular injury during a PRA, there are a few procedures that must be followed to promote safe and efficient repair [1]. The steps

outlined below overlap during the decision-making process.

1. The available working space is very limited and makes it difficult to perform a laparoscopic suture.

   This must be considered when deciding whether to convert or not to open surgery. Trocar positioning in a PRA is associated with limited freedom of the instruments and increases "sword fighting," making it difficult to perform a vascular suture [4].
2. Assess severity and nature of the injury.

   Although good injury exposure is mandatory, large vessel dissection should be avoided when not necessary [10]. It is very important to resist the temptation to blindly place clips or clamps. Doing this without good visualization of the injured vessel can result in more damage (vascular and collateral). Always take into account that a vein is harder to repair than an artery, and also that the "hemostatic suture" is not appropriate to repair a major vessel [5].
3. Can you repair it yourself?

   Even if you can repair it, asking for help is mandatory. If possible, call a vascular surgeon or ask for assistance from a fellow general surgeon [5].
4. Decide if immediate conversion is the best option for safe and efficient vascular repair.

   A surgeon's expertise and skills in laparoscopic suturing and vascular repair are crucial to decision-making. All surgeons must be able to perform a vascular repair during an inadvertent vascular accident.
5. Laparoscopically apply pressure with a gauze.

   Immediately place a gauze through the balloon trocar and apply pressure on the bleeding site. This is the fastest, simplest, and easiest way to control bleeding [5]. This action will give the surgical team and operating room staff time to think and prepare for repair.
6. Keep pneumoretroperitoneum pressure high.

   PRA allows for the use of high pressures of CO_2. This will help tamponade venous hemorrhage and give us a dry working space [1–3]. Retroperitoneoscopic adrenalectomy is performed with pressures up to 25 mmHg, which can help stop bleeding. Some authors recommend increasing the pressure up to 30 mmHg to obtain temporary hemostasis [4]. High pressure can cause gas embolism and cardiac instability. However, several studies have not reported a single case of pulmonary embolism or deep vein thrombosis (iliac or femoral) [3–11].
7. Place the patient in a Trendelenburg position.

   Some authors recommend the Trendelenburg as the preferred position in the presence of a major vascular injury. It decreases the venous pressure in the lower extremities and will keep brain cells irrigated in case of hypovolemia [5–12].
8. Use a fourth trocar.

   This extra port can be used for better tissue retraction and bleeding vessel exposure. It can also be used to place a laparoscopic vascular clamp if necessary [1].
9. Laparoscopic suture for vascular repair.

   Use a nonabsorbable polypropylene 000/0000 suture. Vessel stenosis must be avoided and therefore, separate stitches are to be preferred to continuous suture. Manipulate the vessel wall carefully. Smooth movements using a good needle holder are crucial for good repair. Pass the needle through the vessel wall and open the needle holder. Next, grab the needle tip and pull it carefully. This will help avoid vessel wall laceration.
10. Reduce pressure and inspect for hemostasis.

    High pneumoretroperitoneum pressure can give a false sense of security after a vascular repair. Bleeding recurrence can occur after deflation. Decrease pressure to 5 mmHg and inspect for hemostasis [2]. If there is no bleeding, the repair is finished.
11. Local hemostatic.

    Topical agents like fibrin, synthetic glues, and adhesives have proved their value as hemostatic and sealants [5]. Following a major vascular repair, these agents can be used to reinforce the repair [12].

12. Place a drain.

    The retroperitoneal space is a virtual one, and tamponade will occur after deflation. Placing a drain will not avoid recurrence but will eventually help in its early diagnosis.

9.5 Vascular Injuries and Learning Curve

The learning curve is a key point of all surgical procedures. Knowing how many procedures surgeons should perform until they properly master it is a matter of constant debate. In our point of view, the learning curve is influenced by surgeons' experience in different procedures and the skills they have gained while performing different surgical techniques. The learning curve will be influenced by the surgeons themselves and similarly, they also represent a factor with an impact on the complication rate.

Rassweiller et al. demonstrate the importance of the learning curve. In the first 50 retroperitoneoscopic procedures (renal and adrenal), there was a 14% rate of complications, contrasting with a 2% complication rate in procedures 150-200. Additionally, conversion to open surgery decreased from 10% in the first 50 procedures to 4% in the procedures 150–200 [13]. Kumar et al. report a decrease in minor complications as more retroperitoneoscopic surgical procedures (renal and adrenal) are performed, although the number of major complications remains stable [2]. In the Meraney et al., analysis of 404 retroperitoneoscopic procedures (renal and adrenal) conversion to open surgery was not necessary for the last 200 procedures. This data reflects the impact of the learning curve [1]. In Essen, Alesina et al. report an operation time of 117 minutes during the learning phase for PRA. After performing 2310 PRA, they reduced operation time to 45 minutes and complication rate to less than 1% [4]. With increased experience, comes a decrease in the complication rate [2].

Gaining experience in the management of major vascular injuries during retroperitoneoscopic adrenalectomy is not easy because they are rare [2]. In 2006, Walz presented his results of 560 PRA performed on 520 patients. There was not a single case of major vascular injury. In fact, there were no cases of major bleeding in 11 conversions (2.0%). Walz only reports one case of reoperation due to bleeding from the gland remnant after partial adrenalectomy [3]. In 2019, Alesina reported no major vascular injuries after 2310 procedures [4]. In a case series analysis of the first 20 procedures performed by the author, one IVC injury was reported. Conversion to posterior open for a safe and effective vascular repair was necessary (see case report below) [14].

The rarity of major vascular injuries during PRA supports its safety. Moreover, there is no solid experience on how to manage these life-threatening complications. Injury to the IVC (including retro hepatic) is a possibility when dissecting the right gland and the right adrenal vein. An injury at this site is difficult to approach. Gaining experience in such a rare situation is not easy but performing other different surgical procedures can give you the skills you need. A surgeon should have experience in vascular surgery in order to know the principles of a vascular repair and be able to perform it. In a stressful situation like an IVC bleeding, a vascular surgeon may not be available. Additionally, many of them will also not have experience in managing a retro hepatic IVC injury. It is even more difficult to find someone with experience in laparoscopic vascular repair.

How can surgeons gain experience in the management of a retroperitoneal IVC injury? Trauma patients can be a learning site. However, retroperitoneal vascular injuries are rare. A Level 1 Trauma Center in the United States treated 65 IVC injuries and 39 abdominal aorta injuries due to blunt and penetrating trauma over a 10-year period [8]. Some of the patients had both aortic and IVC injuries. Suture was the most frequently used technique. Of course, all patients were treated by an open approach. In that analysis, the authors concluded that suprarenal located injury has a 15 times higher risk of mortality [8]. This is a common location of IVC injury during a PRA.

It is difficult for surgeons to learn how to deal with IVC injury just from severe trauma patients with a retroperitoneal vascular injury. Firstly,

they are rare situations. Secondly, a surgeon must know what to do before facing a major vascular trauma in the emergency department. Active learning from books and videos can help doctors prepare for dealing with a major vascular injury. Periodic hands-on courses in animal models will also help surgeons to learn how to approach and repair these difficult located injuries [9]. Simulation and eventually digital/virtual constructed scenarios will be the future of a surgeon's learning process, like in airplane pilot training.

9.6 Case Report

In 2018, we had to treat a major vascular complication while performing a right PRA. It was an IVC injury. This report aims to share that experience and the difficulties a surgeon must deal with while managing a major vascular injury by posterior RA.

Firstly, stay calm. This is of paramount importance for a successful repair. Secondly, ask for immediate help from another surgeon. A "fresh mind" is crucial for a good repair. Thirdly, inform the anesthesiologist of what is happening and what you are about to do. Fourth, the scrub nurse and remaining operation room staff must immediately provide the required instruments to perform the repair. Fifth, do not hesitate to convert to open surgery if necessary. When the goal is fast bleeding control and vascular repair, conversion must not be seen as a failure but as a way to achieve that goal.

A male patient complaining of right lumbar pain was diagnosed with a giant (11 cm) nonfunctioning adrenal cyst. Abdominal Computed Tomography (CT) and Magnetic Resonance Imaging (MRI) were both performed to obtain detailed anatomical information (Figs. 9.1 and 9.2). He had no comorbidities. Despite the large size of the lesion, the surgical team decided to use the posterior RA. The plan was to dissect the cyst as much as possible without rupture, aspirate its liquid content, ligate the adrenal vein, and retrieve it in a bag. This was not the first time this approach was performed on a lesion this size.

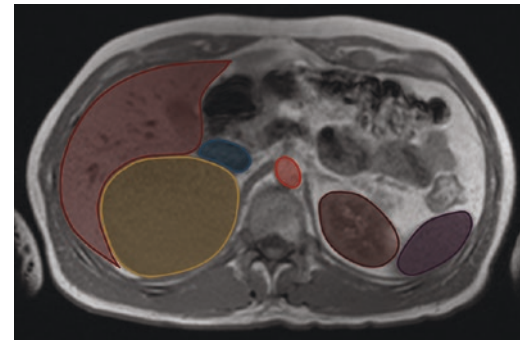

Fig. 9.1 MRI—axial plane. An 11-cm giant cyst of the right adrenal gland (*yellow*) is pushing the right lobe of the liver (*light brown*). The cyst pushes and flattens the IVC (*blue*). Aorta (*red*). Left kidney (*dark brown*). Spleen (*purple*)

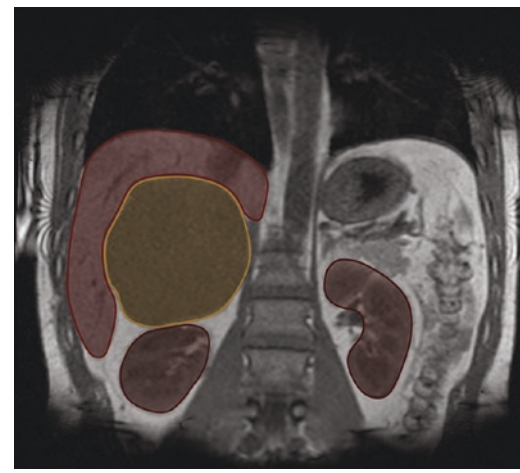

Fig. 9.2 MRI—coronal plane. The giant cyst of the right adrenal (*yellow*) is pushing the right kidney (*dark brown*) down. The liver (*light brown*) is also pushed and compressed by the huge lesion

Although minimally invasive surgery has several advantages over open surgery, it has a possible negative impact on R0 resection and a higher risk of cystic rupture. This is the rationality for advising open surgery for lesions larger than 6 cm or suspected of harboring cancer (see Chap. 5) [14, 15]. However, minimally invasive surgery has been used for large lesions. In 2016, we successfully resected a 14-cm cystic pheochromocytoma by posterior RA [15].

After placing the trocars as usual (see Chap. 7) and setting the pneumoretroperitoneum to 25 mmHg, the cystic lesion was immediately

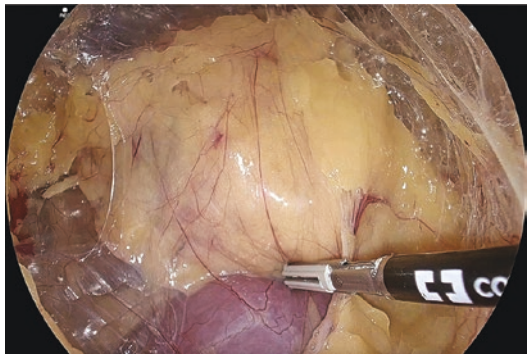

Fig. 9.3 Cyst with 11 cm over the upper pole of the right kidney. It occupies the entire operation field and pushes the kidney down

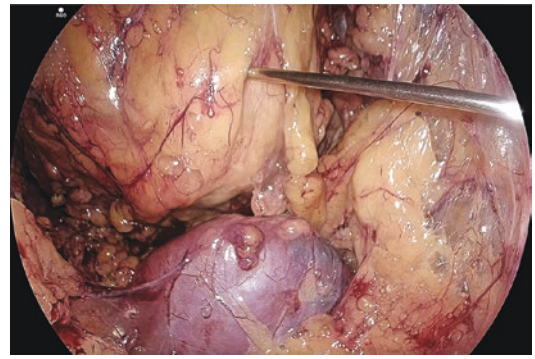

Fig. 9.4 Aspiration of the cystic content with a Veress needle. This was crucial to give the surgeon working space to go on with dissection

identified due to its large size (Fig. 9.3). Dissection started with LigaSure® from lateral to medial, separating the cyst from the upper pole of the kidney. Identification of the IVC was the next step and it was done uneventfully. At this time, dissection could not go further due to the large size of the cyst. Aspiration of its liquid content was performed using a Veress needle and a laparoscopic aspirator (Fig. 9.4). Clear serous fluid was aspirated. Dissection resumed even though the cyst was not fully empty. The cystic lesion was separated from the IVC with blunt dissection, but the adrenal vein was not immediately found. The surgical team decided to proceed with dissection all around the lesion, freeing the cyst as much as possible from the surrounding structures. An accidental opening of the cyst occurred, which completely emptied the lesion but also facilitated the procedure. A short adrenal vein was finally found and ligated with the LigaSure®. At this point, the cyst was only fixed to the IVC by a dense adhesion.

During the final dissection, a small injury to the IVC occurred when using the LigaSure®. It was a small hole with a size of approximately 2 mm (Fig. 9.5). No significant bleeding occurred due to the high pressure of the pneumoretroperitoneum (25 mmHg). A gauze was immediately introduced through the balloon trocar and pressure was applied on the injury site for fast bleeding control (Fig. 9.6). This gave the entire team time to prepare for vascular repair, as well as time for another surgeon to arrive.

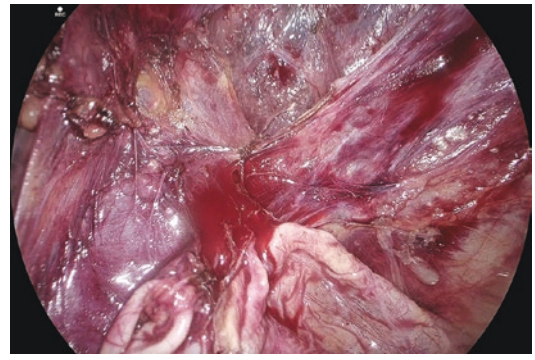

Fig. 9.5 A small IVC injury. No significant bleeding due to the 25-mmHg pneumoretroperitoneum

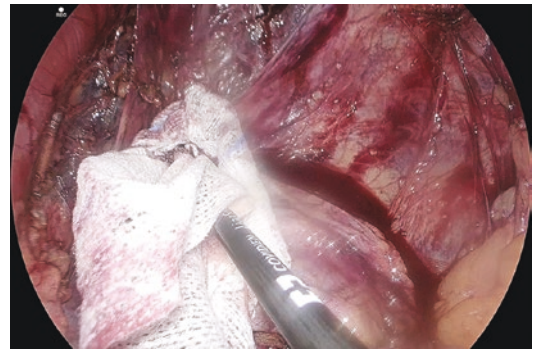

Fig. 9.6 Applying pressure with a gauze on the injury site is the fastest and easiest way to achieve temporary bleeding control. It gives the surgical team time to prepare for definitive repair

Since the IVC injury was easily identified and visualization was good, we decided to perform a laparoscopic vascular repair with a Prolene®

0000 (Fig. 9.7). No fourth trocar was placed. However, due to the positioning of the trocars, we struggled with "sword fighting." After several attempts, no-stitch was performed. The camera was changed to the balloon trocar and the medial trocar was used as a working port to try to increase the angle of the instruments and overtake the "sword fighting." We managed to get the first stitch, but when an attempt was made on the second knot, the vein tore even more (Fig. 9.8). At this point, the surgical team decided to convert to open posterior surgery.

While keeping the patient in the same position, a lumbar incision below the 12th rib was made. After entering the retroperitoneum, the assistant had to strongly pull the patient's ribs with a retractor to give the surgeon enough working space. Blood was now covering the entire operation field. Pressure on the bleeding site was applied with gauze, and the blood was then aspirated to give the surgeon a dry operation field. By gently retrieving the gauze, the IVC injury was identified. It was not in an easy-to-access position. The surgeon managed to repair the injury with a noncontinuous suture of Prolene 0000 (two stitches). No vascular clamp was used, nor was additional IVC dissection necessary since injury boundaries were readily visible. A hemostatic sponge (TachoSil®) was placed covering the suture and a drain was left in the retroperitoneum. The incision was sutured.

The patient spent 1 day in the Intensive Care Unit (ICU) and was then transferred to the surgery ward. The first oral intake was on postoperative day two. The drain was removed on day three (<50 ml). The patient was discharged home on the fifth postoperative day. Three months after surgery, the patient was recovering successfully, without pain and only complained of mild hypoesthesia on the lateral abdominal wall. He returned to his normal activity without impairments.

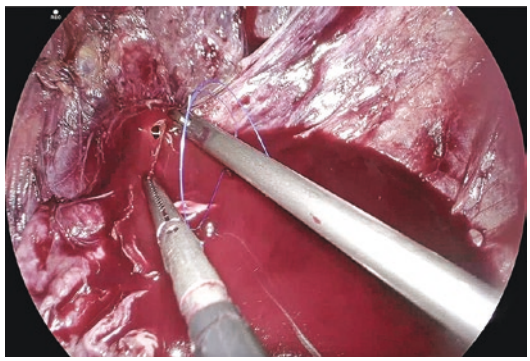

Fig. 9.7 Suturing the IVC injury by posterior RA

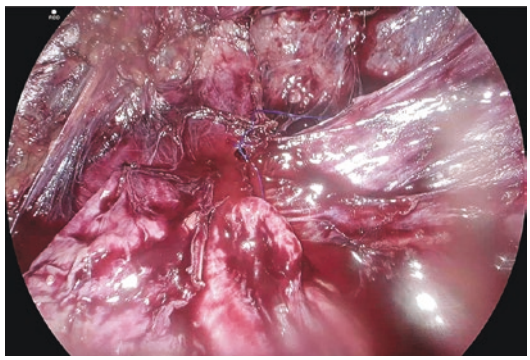

Fig. 9.8 IVC tore even more while performing retroperitoneoscopic vascular repair. The vein wall is fragile, and "sword fighting" makes it very difficult to suture

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