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European Association of Urology



## Nightmares in Urology: Open Science

# Superior Mesenteric Artery Injury During Robot-assisted Laparoscopic Nephrectomy: A Robotic Nightmare

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### Article info

#### Article history:

Accepted February 3, 2022

#### Associate Editor:

Guillaume Ploussard

#### Keywords:

Kidney cancer  
Robotics  
Nightmares in urology

### Abstract

Major vascular injuries during robotic renal surgery are rare, but the close proximity of the superior mesenteric artery (SMA) to the left renal artery means that it is liable to iatrogenic injury with potentially catastrophic implications. In this review, we present a case of accidental SMA ligation during a robot-assisted laparoscopic nephrectomy for a 12-cm upper pole renal mass. Prompt recognition and early vascular surgical assistance with conversion to open surgery allowed a primary vascular anastomosis to be made. A computed tomography angiogram at 6 wk was normal. On review of the imaging, the left renal artery take-off was higher than the SMA, which represents an anatomical variant and may have contributed to the injury. The risk of accidental SMA ligation is highest in left-sided tumours and in larger medial tumours that lead to significant distortion of the anatomy. The anatomy of the renal artery can also vary greatly. Surgeons must be knowledgeable of common variations and meticulously review preoperative imaging for the number and course of renal vessels as well as the location of the SMA. In cases of significant bleeding, rapid conversion to open surgery and urgent vascular consultation are critical.

**Patient summary:** In this article, we describe an accidental injury to a major blood vessel (the superior mesenteric artery) during a left robotic radical nephrectomy (kidney removal) for a tumour. We discuss the anatomical relationships of the blood vessels of the small bowel and kidneys, and how to anticipate, recognise, and manage such accidental injuries.

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## 1. Introduction and context

Robotic-assisted surgery has revolutionised renal surgery in recent times and is now commonplace across Europe. In the UK, nearly two-thirds of all partial nephrectomies are now performed with robotic assistance [1]. Robotic assistance is also employed in radical and simple nephrectomy, pyeloplasty, adrenalectomy, ureteric reimplantation, and even renal transplant surgery [2].

There are a number of advantages to robotic-assisted renal surgery, such as the enhanced degree of freedom, three-dimensional visualisation, and elimination of tremor [2]. Significant complications for the experienced robotic surgeon are uncommon, but due to the close proximity of vital vascular structures (renal vessels, aorta, inferior vena cava, superior mesenteric artery [SMA], inferior mesenteric artery, lumbar vessels, as well as collateral branches), there is potential for catastrophic vascular complications in complex robotic renal surgery. A number of patient and operative factors mean that the SMA is liable to iatrogenic injury. While it remains rare, an unrecognised SMA injury can lead to rapid bowel ischaemia, haemodynamic instability, and death if left untreated. It is therefore imperative that surgeons are able to recognise and manage this potentially catastrophic complication.

In this review, we present a case of accidental SMA ligation during robotic-assisted radical nephrectomy with an accompanying video. We also explore the anatomy of the SMA, discuss the risk factors for SMA injury, and summarise the principles of its management.

## 2. Materials, patients, and methods

A 64-yr-old individual underwent a robot-assisted laparoscopic nephrectomy for a 12-cm upper pole, medially located, renal mass. After general anaesthesia, appropriate patient positioning, and port placement, the descending colon was mobilised. The ureter and gonadal vein were followed to the hilum. Significantly distorted anatomy was encountered due to the large tumour. The SMA, which was located just superior to the renal vein, was incorrectly identified as the renal artery, ligated with Hem-o-lok clips, and divided (see [supplementary video](#)). This was recognised immediately upon further hilar dissection, and vascular surgeon assistance was requested immediately. Nephrectomy was performed after ligation and division of the true renal arteries and vein. A subcostal incision was made, the specimen was delivered, and the distal SMA was dissected out further to allow primary anastomosis. After administration of 5000 IU heparin, clamps were applied to the proximal and distal SMA, laparoscopic Hem-o-lok clips were excised and margins trimmed, and the repair was performed via primary anastomosis with 6/0 Prolene. The time to reanastomosis was approximately 1 h. The bowel was inspected and remained healthy throughout the case. The patient was commenced on prophylactic dalteparin during the hospital stay and aspirin for 3 mo postoperatively. A computed tomography (CT) angiogram at 6 wk was normal.

Unfortunately, the patient developed lung metastases at 6 mo and passed away 2 yr after their surgery despite immunotherapy.

On review of the imaging, the left renal artery take-off was higher than the SMA, which represents an anatomical variant and may have contributed to the accidental ligation of the SMA.

## 3. Discussion

Injury to the SMA during abdominal surgery is rare but likely under-reported. The existing literature primarily consists of case reports and small case series [3–5]. It is of critical importance for robotic surgeons to identify SMA injury given the potential catastrophic consequences of inaction that may give rise to a mortality rate of 50%.

### 3.1. Anatomy

Understanding the complex anatomy and relations of the SMA is important in order to minimise iatrogenic injuries during renal surgery. The SMA arises directly from the abdominal aorta immediately inferior to the origin of the coeliac trunk, descending along the posterior aspect of the abdomen and passing over the left renal vein ([Fig. 1](#)). It is a major vessel, supplying the midgut, including the duodenum (from the major duodenal papilla), ileum, caecum, and ascending colon up to the proximal two-thirds of the transverse colon. It gives rise to several major branches including the jejunal and ileal arteries, middle and right colic, and ileocolic arteries. Given the extensive segments of large and small bowel supplied, accidental ligation or occlusion of the SMA imparts a high risk of mortality owing to widespread visceral ischaemia.

The location of injury determines the severity of ischaemia and is a strong predictor of mortality in models based on traumatic vascular injury; more proximal injuries lead to a greater degree of ischaemia and subsequent mortality [6]. The Fullen et al's [7] classification ([Table 1](#)) defines four anatomical zones of injury conferring different degrees of associated ischaemia. Maximal ischaemia occurs at zone 1 in comparison with zone 4, where there is minimal or possibly no ischaemia due to the presence of an effective collateral circulation [6].

In the classical anatomical relationship, the SMA passes anterior to the left renal vein, which traverses approximately 8.5 cm from the renal hilum, anterior to the aorta towards the medial aspect of the inferior vena cava. Most major arteries supplying the kidney, however, lie posterior to the left renal vein. The close proximity between the SMA and the left renal artery in the densely populated vascular region between the left renal hilum and the aorta plays a significant role in the mistaking of the SMA for the renal artery. Furthermore, larger left-sided tumours, especially medial upper pole masses, often distort these anatomical relationships, increasing the risk of vascular injury even for the experienced surgeon.

The SMA usually branches off more medially from the aorta compared with the renal artery and runs at a more horizontal angle on the horizon. It is also usually larger, with a greater diameter, and is more tortuous than the renal artery. We feel that if the purple (large) Hem-o-lok clips are not large enough when ligating the renal artery, the surgeon should reassess the anatomy to check whether it is the SMA. The SMA also usually has much more lymphatic tissue on it than the renal artery, which should be considered by the operating surgeon.

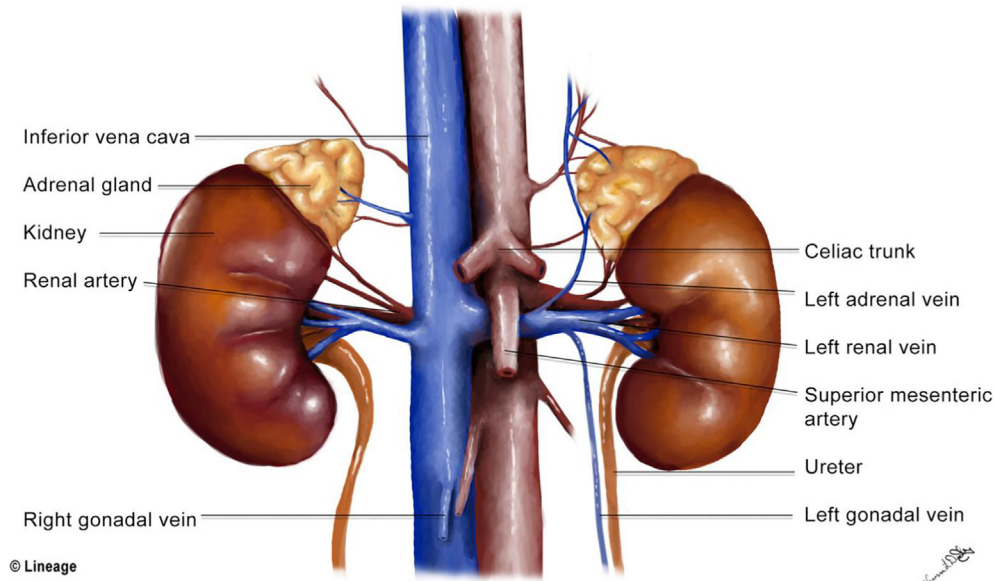


Fig. 1 – Depiction of renal vascular anatomy (permission for use granted by Derek Moore, MedBullets).

Table 1 – Fullen et al's [7] classification of superior mesenteric artery injury.

Zone	Segment of superior mesenteric artery	Grade	Ischaemic category	Bowel segments affected
I	Trunk proximal to first major branch (inferior pancreaticoduodenal artery)	I	Maximal	Jejunum, ileum, right colon
II	Trunk between inferior pancreaticoduodenal and middle colic arteries	II	Moderate	Major segment, small bowel, and/or right colon
III	Trunk distal to middle colic arteries	III	Minimal	Minor segment(s), small bowel, or right colon
IV	Segmental branches, and jejunal, ileal, or colic arteries	IV	None	No ischaemic bowel

The table was adapted from [24].

### 3.2. Anatomical variation

Given the relationship between the SMA and the renal artery, and the location of the kidneys in relation to the aorta, it is the proximal portion or main trunk of the SMA that may be mistaken for the renal artery. While there is little anatomical variation in this section of the SMA [8], the anatomy of the renal artery can vary greatly. The classical description of a single renal artery arising from the aorta is present only in 25% of cases. Common variations include multiple arteries including polar arteries, early branching resulting in multiple hilar arterial branches, aberrant course of the renal artery, retroaortic renal vein resulting in the left renal artery lying anterior to the renal vein, and aberrant origin of the main renal artery including from the lower aspect of aorta and iliac arteries [9].

In this case, the left renal artery take-off was higher than the SMA, which represents an anatomical variant and was an important factor contributing to accidental ligation of the SMA. Surgeons must be knowledgeable of the common variations in renal vascular supply and should meticulously review the imaging for the number and course of renal vessels as well as the location of the SMA [10].

### 3.3. Risk factors for injury

#### 3.3.1. Patient factors

Morbid obesity is a risk factor for perioperative complications in renal surgery, and long-term outcomes were historically poor for this group [11]. However, the advent of minimally invasive laparoscopic and robotic-assisted surgery has reduced the length of hospital stay, blood loss, and postoperative complications [12]. The greater degree of freedom and better views mean that operating with robotic assistance on patients with morbid obesity now carries less risk than with previous techniques. In obese patients, however, there remains a risk of access injury when inserting a trocar [11]. The umbilicus can be displaced significantly in the obese patient and special care must be taken to avoid vascular trocar injury in such cases. Nevertheless, with increasing experience in minimally invasive surgical techniques, these complications are now rare [13].

Patients undergoing renal surgery for nononcological indications such as recurrent pyelonephritis can also present a challenge. Multiple previous infections and instrumentation to the perinephric region (eg, nephrostomy insertions and antegrade stents) may lead to chronic

inflammatory changes, formation of fibrotic adhesions, and distorted anatomy. Mobilisation and resection must therefore be undertaken with extreme caution, and adequate preoperative imaging is mandatory in such cases, which carry a high risk of vascular complications.

### 3.3.2. Tumour factors

Tumour size and location are the main tumour factors that predispose to SMA injury. Left-sided, large, upper pole, medial/hilar tumours are the main predictors of SMA injury during renal surgery [5,10,14]. Large tumours are likely to lead to significant distortion of the vasculature; therefore, meticulous dissection and mobilisation of the kidney and hilum can minimise the risk of injury. In such cases, it is important to mobilise the descending colon completely to rotate the SMA medially in the mesentery, identify the aorta, and dissect on the left lateral aspect of the aorta superiorly towards the renal hilum. The renal artery can also be approached from a posterior direction after mobilisation of posterior renal attachments, allowing identification and isolation of the major renal vessels from the posterior location. Careful attention must also be paid to the multiple arterial collaterals commonly found in larger, vascular tumours.

### 3.4. Lymph node dissection

Iatrogenic injury of aortic branches during renal surgery appears to occur more frequently in patients with large renal tumours requiring extended lymphadenectomy [4]. Bulky adenopathy can distort anatomy and also conceal bleeding, meaning that injury to vascular structures might not be apparent immediately. Lymph nodes can be a useful identifying tool to distinguish renal artery from the SMA, which, however, is usually surrounded by thick neural and lymphatic tissues, much more so than the renal artery.

### 3.5. Surgical factors

Surgeon experience is also likely to be linked to SMA and other vascular injuries. Regularly “zooming out” to appreciate vessels bleeding in the entire surgical field, using delicate and controlled manoeuvres, ensuring that the instruments are kept within the field of vision, and being aware of a perceived distortion of the surgical field from “twisting/rotating” of the camera are critical to avoid inadvertent vascular injuries. Avoiding unintentional contact of energy-based instruments with vessels to reduce the risk of arcing injury to the vessel is also extremely important [15].

The unique features of the robotic platform allow for improved dexterity, tremor filtration, and motion scaling—benefits not afforded by laparoscopic surgery. As such, surgeons having adopted this technique are able to take on more difficult cases involving larger or more complex tumours, or cases traditionally performed via the open approach such as inferior vena cava thrombectomy. Nevertheless, the rate of major complications appears to be similar [16]. The emergence of image-guided surgery is likely to play an increasing role in avoiding vascular injury by delineating the renal vascular anatomy intraoperatively in

real time. Indocyanine green, a fluorescent contrast agent, is currently the most widely used tracer [17].

## 4. Management of SMA injury

Management depends on the type of injury. In cases of accidental ligation, a trial of removal of sutures or clips should be attempted. Sutures can be cut and Hem-o-lok clips can be removed with clip removal devices.

In cases of injury resulting in bleeding, general surgical principles apply as for all bleeding complications. Controlling obvious bleeding by compression or grasping the bleeding, increasing pneumoperitoneum, sparing the use of suction in absence of airseal, clear communication with the surgical team, rapid conversion to open surgery, and urgent vascular consultation are critical [18].

The technique used for repair should be chosen according to the nature and severity of injury. For superficial injuries, a simple suture can be performed, but more extensive injuries require more significant vascular repair [19]. With more extensive injury, immediate end-to-end anastomosis is the preferred approach and reasonable short- and long-term outcomes have been described for this method [3,4].

A number of other techniques have been described for use when end-to-end anastomosis is not viable [5,20]. Vein patches can help alleviate the risk of stenosis after repair, which is more common when vessels are sutured directly [21]. Saphenous or renal vein patches have reportedly been used successfully in SMA injury [22]. Aortomesenteric bypass can be used with venous or PTFE grafts. Alternatively, retrograde grafting from the common iliac artery is an option, but both of these techniques are technically demanding. Few cases of splenectomy have been described in order to revascularise ligated aortic vessels using the splenic artery, but the splenomesenteric bypass approach should be used only on a case-by-case basis, with consideration of patient and surgical factors [5]. The collateral circulation of the SMA is poor [23] and the consequences of proximal SMA injury can be devastating, so whichever approach is employed, speed of repair remains the key factor.

After repair, viability of the bowel should be assessed intraoperatively by palpation of an arterial pulse in the SMA as well as complete inspection of affected bowel segments. Postoperative imaging with CT angiography is advised.

## 5. Conclusions

Despite advances in robotic renal surgery, iatrogenic injury to the SMA can occur and presents a serious surgical emergency that often warrants open conversion. It is important for urologists to be aware of the patient-, disease-, and surgeon-related risk factors for SMA injury. Early recognition and prompt discussion with vascular surgeons can improve the outcomes for what is a highly morbid injury if left untreated.

**Conflicts of interest:** The authors have nothing to disclose.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.euros.2022.02.002>.

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