FDCT-NSFC joint subsidy program detailed proposal

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Author contributions
TBG and CLY designed the article. YCW and XYG collected and evaluated the data and wrote the first draft of the manuscript. All authors reviewed the manuscript. All authors contributed to the interpretation of the results. YCW, XYG, and ZM wrote the final draft of the manuscript. YFS and LHG read and approved the final version of the manuscript.

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The authors declare no conflicts of interest.

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Abbreviations
MRI, Magnetic resonance imaging; CT, computed tomography.

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Abstract
The surgical removal of renal cancer, along with the thrombectomy of the inferior vena cava tumour thrombus, represents a remarkable milestone in urological surgery. This procedure is not only technically demanding but also requires a high level of surgical expertise. Managing renal cancer combined with a vena cava tumour thrombus poses significant challenges, especially when dealing with combined grade II-IV inferior vena cava tumour thrombus. The complexity of these cases is further exacerbated by the delicate anatomical structures involved and the need to preserve critical vessels while effectively removing the tumour. The Upper Urethral Tumour Treatment Centre of Weifang People’s Hospital successfully treated a challenging case of left renal tumour combined with grade II inferior vena cava tumour thrombus. The surgical team, led by experienced urological surgeons, meticulously planned and executed the procedure, ensuring minimal trauma to the patient and complete removal of the tumour. This achievement not only demonstrates the hospital’s commitment to providing state-of-the-art surgical care but also highlights the importance of continued research and training in urological oncology. The successful outcome of this case is a testament to the expertise and dedication of the medical team and offers hope to patients facing similar complex surgical challenges.

Keywords: renal carcinoma; vena cava tumour thrombus; renal artery embolism; transoesophageal echocardiography; three-dimensional reconstruction techniques
**Background**

Cancer is the second leading cause of death nationwide after heart disease [1]. Renal cancer has the third highest incidence among urological tumours, following bladder and prostate cancer. According to the American Cancer Centre, in 2021, the incidence of renal cancer accounts for approximately 2–3% of all new malignancies. The incidence of renal cancer is increasing every year, and its mortality rate is high [2]. Although traditional laparoscopic or robotic surgery is the standard procedure for radical surgery in renal cancer, open surgery remains the preferred procedure for cT3NxMx renal tumours with vena cava tumour thrombus, particularly inferior vena cava tumour thrombus (grade II or III tumour thrombus). The right renal vein is shorter than the left because of anatomical variations between the two, and it is more likely to develop grade I and II inferior vena cava tumour thrombus in suitable renal tumours compared with the left. Management of this condition is also relatively simple. A lower incidence is observed for left renal tumours in combination with inferior vena cava tumour thrombus, and the surgical procedure is relatively more complex. The risk of fatal complications, such as massive bleeding and pulmonary embolism caused by thrombus shedding during the surgery, is also higher [3]. Herein, we discuss the case of a left renal tumour combined with a grade II inferior vena cava tumour thrombus. Detailed preoperative imaging combined with 3D reconstruction techniques, hospital-wide consultation, and intraoperative transoesophageal echocardiography was performed to precisely locate the tumour thrombus. Finally, the tumour and tumour thrombus were removed in toto, followed by uneventful vascular reconstruction. Following surgery, the patient made a full recovery and was discharged from the hospital. This case is described below and further reviewed in the literature to discuss the several concerns and intraoperative surgical techniques currently performed for treating renal tumours combined with inferior vena cava tumour thrombus to improve the treatment of locally progressive renal cancer.

**Patients**

A 54-year-old married male patient was hospitalised for a month because of increased pain in the left lumbar region. The pain occurred without apparent cause or reason a month ago, and the patient had no difficulty in urination and no symptoms such as urinary tract irritation. The patient developed carnal haematuria in the last week, along with general symptoms, such as loss of appetite, weakness and, wasting, etc. After undergoing a double renal ultrasound at our outpatient clinic, a possible diagnosis of a left kidney tumour was established, following which the patient was admitted to our upper urinary tract tumour treatment centre. The patient had a history of hypertension and diabetes mellitus, which were well under control. Physical examination revealed the following findings: body temperature, 36.6 °C; pulse, 85 beats/min; respiratory rate, 20 breaths/min; blood pressure, 130/70 mmHg; chronic disease appearance; grey-coloured skin. No swelling was observed in the face, and both lower limbs, and no pressure or percussion pain was reported in the right renal area. The following examinations were performed after hospital admission: (1) Enhanced computed tomography (CT) of the abdomen (left renal occupancy, renal cell carcinoma with tumour thrombus in the left renal vein and inferior vena cava (Figure 1)). (2) 3D CT medical reconstruction determining the length and height of the inferior vena cava and renal vein tumour thrombus (Figure 2). (3) Magnetic resonance imaging (MRI) of the upper abdomen to consider grade II inferior vena cava tumour thrombus (at the level of the short hepatic vein). The inferior vena cava tumour thrombus had an approximate cross-sectional diameter of 6.2 × 2.3 cm, excluding the inferior vena cava wall invasion. Laboratory tests revealed a haemoglobin level of 103 g/l. A hospital-wide consultation was organized before surgery to determine the timing of the surgery and an alternative surgical plan considering the complexity of the condition and the need for surgery. The liver turning technique was performed via a multidisciplinary approach (the Pringle technique to block the second hepatic portal and the extracorporeal veno-venous transfer technique). Written informed consent has been obtained from the patient or publication of this case report and any accompanying images. A copy of the written consent is available for review by the Editor-in-Chief of this journal.

![Figure 1 Preoperative enhanced computed tomography](https://doi.org/10.53388/BMEC2024006)
Preliminary diagnoses of malignant tumour of the left kidney (cT3bN0Mx), hypertension (grade 2, high-risk group), and type 2 diabetes mellitus were established.

The posterior laparoscopic approach combined with open surgery was performed. The left renal artery and all collateral veins of the renal vein were dissected using a Hem-lock clamp under posterior laparoscopy. The periphery of the kidney was freed, during which we observed that the left kidney was enlarged and the renal surface sore and congested. Severe adhesions were observed between the fatty capsule around the left kidney and the perirenal tissue. After completely freeing the lower left kidney, the peritoneum was opened along the "Toldt line" in the left paracolic sulcus. After the patient was placed in the supine position, an inverted L incision was made under the rib cage. The inferior vena cava was completely freed until the left renal vein was exposed after entering the abdominal cavity. The left renal vein was significantly thickened and had a hard texture, with an approximate diameter of 3 cm. A solid, palpable mass was observed in the cavity. This mass extended into the inferior vena cava, with the mass in the inferior vena cava measuring approximately 6 cm in length. The connection between the inferior vena cava and the renal vein was interrupted using Endo GIA, while the thrombus was detected in real-time using transoesophageal echocardiography (Figure 3) to determine the length and height of the tumour thrombus in the inferior vena cava and exclude the problem of new thrombus. A Rummel tube was used to block the right renal vein and the inferior vena cava on both sides of the tumour thrombus, starting with the distal end of the inferior vena cava, the beginning of the right renal vein, and the proximal end of the inferior vena cava. The blocked section of the vena cava was incised to an approximate length of 5 cm, the tumour thrombus was removed from the inferior vena cava, and the inferior vena cava was repeatedly irrigated with heparin dissolved in water. Sutures were given using 4-0 Prolene to close the wall of the inferior vena cava after confirming that the wall of the inferior vena cava was free of cancerous thrombus and the distal end of the inferior vena cava was free of the red thrombus. After satisfactory anastomosis of the inferior vena cava wall was achieved using heparin dissolved in water, the inferior vena cava was opened sequentially in the proximal, renal, and distal ends to restore circulation. After adequate haemostasis, layer-by-layer incision closure was performed using sutures, and the procedure was completed.

**Postoperative pathological diagnosis**

A naked eye examination revealed a left-sided renal carcinoma, with perinephric fat measuring 18 × 14 × 9 cm. The renal fat capsule could not be detached easily. A mass measuring 12 × 10 × 9 cm, with a greyish-red to greyish-yellow appearance and a colourful and brittle cut surface, was observed at one renal pole adjacent to the renal pelvis and renal peritumour. An 8 cm long segment with a diameter of 0.5 cm along with the ureter was obtained. A greyish-yellow mass measuring 4 × 4 × 3 cm was observed in the renal vein. Three lymph nodes with diameters ranging from 0.5 cm to 2 cm in diameter were observed in the renal hilum (left renal vein tumour thrombus + inferior vena cava tumour thrombus). One greyish-yellow irregular, colourful, and brittle tissue, measuring 8 × 5 × 2 cm, was observed. Pathological diagnosis: (Left renal carcinoma) clear cell renal cell carcinoma, with a volume of 12 × 10 × 9 cm, World Health Organisation/International Society of Urological Pathology grade II, partly grade III, no involvement of the renal pelvis, and involvement of the renal peritumour. A carcinoma thrombus was observed in the vasculature, with no apparent nerve invasion. The ureteral and vascular margins were negative for tumour cells, and the carcinoma did not metastasise to the lymph nodes (renal hilar 0/6) (left renal vein tumour thrombus + inferior vena cava tumour thrombus). Clear cell renal cell carcinoma components were observed in the vasculature.

**Discussion**

Renal cancer is the third most prevalent urinary tract tumour and is the 12th most common cancer worldwide. The incidence of locally advanced renal cancer accounts for approximately 4–10% of all renal cancer cases [4]. Its incidence and mortality rates vary globally, with developed regions such as North America and Europe having the
highest rates and Asia and Africa having the lowest rates. According to the American Cancer Centre, in 2017, approximately 63,990 new cases and nearly 14,400 deaths from renal cancer occurred, with the incidence being twice as high in men as in women [5]. In addition to established risk factors, such as family history, smoking, obesity, high blood pressure, and antihypertensive drugs, some other contributing factors include environmental influences, lack of exercise, excessive alcohol consumption, and poor diet [6]. Locally progressive renal cancer is significantly vascular, with tumour vascular invasion and tumour thrombus observed in the renal veins and inferior vena cava in up to 10–25% of the patients [7]. For renal cancer with inferior vena cava tumour thrombus (particularly stage III cT3bNxMx), radical nephrectomy and complete thrombus removal is the most effective treatment if there is no local lymph node involvement or distant metastases preoperatively, with a 5-year survival rate of approximately 34–64% [8]. Such patients have a median untreated life expectancy of 5 months, with a 1-year disease-specific survival rate of 29% [7].

Many patients with right renal cancer combined with grade I-II inferior vena cava tumour thrombus have been operated on with satisfactory results since the establishment of the upper urinary tract tumour treatment centre at our hospital. Left renal cancer combined with grade II and inferior vena cava tumour thrombus has a lesser incidence owing to the anatomical differences. Combined with the recent perioperative situation of a patient with left renal cancer combined with grade II inferior vena cava tumour thrombus, we summarised the perioperative management and surgical techniques for renal cancer combined with inferior vena cava tumour thrombus. By doing this, we hope to contribute towards developing methods for improving the diagnosis and treatment of renal cancer with inferior vena cava tumour thrombus, thereby improving its prognosis.

**Grading and staging of inferior vena cava tumour thrombus**

The height of the tumour thrombus and the degree of vena cava wall invasion determine the surgical strategy for managing inferior vena cava tumour thrombus. The current inferior vena cava tumour thrombus classification is based on the thrombus invasion level of the inferior vena cava, including the Neves classification, the Novick classification, the Hinman classification, and the Mayo classification [7]. In 1987, the Mayo Clinic proposed the Neves classification, which was as follows: Grade I: a tumour extending from the renal vein into the inferior vena cava with the tip ≤ 2 cm from the renal vein opening. Grade II: a tumour with the tip > 2 cm from the renal vein opening but below the hepatic vein. Grade III: a tumour extending into the intrahepatic inferior vena cava with the tip below the level of the diaphragm. Grade IV, a tumour extending into the inferior vena cava above the level of the diaphragm [9]. A five-stage grading system for tumour thrombi was proposed by the Mayo Clinic in 2004. The addition of grade 0, i.e., tumour thrombi confined to the renal vein, to the Neves grading system is currently the most widely used and recommended grading method in the recent Chinese urological guideline editions for managing renal cancer.

A new minimally invasive laparoscopic and robotic surgery classification based on anatomical landmarks and experience with tumour embolism surgery, namely the “301 classifications” standard, was proposed by the urology team at PLA General Hospital in 2017. Depending on whether the tumour thrombus exceeded the superior mesenteric artery, grade 0 for right renal vein tumour thrombus and grades 0a and 0b for left renal vein thrombus were established. Inferior vena cava tumour thrombus is classified into four grades, which are as follows: Grade I, thrombus below the first hepatic portal. Grade II, thrombus above the first hepatic portal to the second hepatic portal. Grade III, thrombus from the second hepatic portal to the level of the diaphragm. Grade IV, thrombus above the diaphragm. The surgical strategy for each grade is based on a combination of factors, such as tumour height, degree of inferior vena cava obstruction, the establishment of collateral circulation, inferior vena cava wall invasion, and proximal/distal thrombus [10]. The surgical strategy for each category has been proposed.

**Preoperative imaging assessment of inferior vena cava tumour thrombus**

MRI remains the standard method for assessing inferior vena cava tumour thrombus in renal cancer, although the diagnostic accuracy of MRI is comparable to that of CT for staging renal cancer. MRI can assess the extent of the inferior vena cava tumour thrombus and predict the invasion of the inferior vena cava wall by the thrombus. If the tumour did not invade the inferior vena cava wall, complete surgical removal of the tumour is sufficient. If the tumour invades the inferior vena cava wall, segmental resection and revascularisation of the inferior vena cava need to be performed. This makes the surgical procedure complex and the prognosis poor, with a poor 5-year survival rate [11].

Combined with the MRI characteristics of previous inferior vena cava tumour thrombus cases, we summarise several features that make MRI superior to CT for diagnosing inferior vena cava tumour thrombus: (1) MRI reveals the upper edge of the inferior vena cava tumour thrombus more distinctly than CT. (2) MRI has better sensitivity and specificity than CT while diagnosing inferior vein wall invasion (the inferior vena cava is filled with the thrombus, and the inferior vena cava wall is breached). The likelihood of wall invasion increases with an increase in the inferior vena cava diameter; some scholars have suggested that a lumen diameter of ≥ 24 mm at the renal vein opening might indicate inferior vena cava wall involvement [12]. (3) On identifying tumour thrombosis from new thrombosis, contrast-enhanced MRI reveals enhancement within the inferior vena cava or enhancement of the vein wall, suggesting a tumour thrombus; MRI weighting will not enhance a new thrombus without neointimal vessels [13].

In the modeling of 3D modeling diagram, we reconstructed around the location of kidney tumor and tumor thrombolus, with the purpose of defining the location of tumor and tumor thrombolus, so as to

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reduce the intraoperative collateral damage. 3D reconstruction techniques dependent on CT or MRI applied for evaluating renal cancer not only allow extreme visual discrimination of the arteries supplying the tumour, guiding the identification of the exclusive tumour blood vessels during surgery for precise operation but also clearly demonstrate the tumour’s size and morphology and its position in relation to the renal and large blood vessels. In terms of perioperative management, a solid awareness of the tumour and preparation for a successful ambulatory battle are of great help in guiding the surgery.

Perioperative management of inferior vena cava tumour thrombus

Preoperative renal artery embolisation. The surgical grade of renal cancer with a vena cava tumour thrombus is large, with a prolonged operative time and an increased risk of intraoperative bleeding. Whether preoperative renal artery embolisation interventions should be performed is debatable. Some scholars support renal artery embolisation within 1 week preoperatively, thereby significantly lowering the risk of intraoperative bleeding, making it relatively easy to the free renal vein. This is because the affected kidney will experience a period of acute oedema within 2 weeks after renal artery embolisation. The tumour's blood supply will decrease, and the tumour will shrink in size. In addition, preoperative intervention with renal artery embolisation will also reduce the height of the tumour thrombus intraoperatively to facilitate better fixation of the proximal end of the tumour embolus in patients with tumour emboli extending into the inferior vena cava [14]. Reportedly, no clear evidence exists on whether preoperative renal artery embolisation reduces total blood loss and the need for blood transfusion [15]. We do not routinely perform preoperative renal artery embolisation at our upper urinary tract tumour treatment centre. However, we choose to perform this when patients have moderate to severe anaemia or severe haematuria as a conservative treatment.

Perioperative anticoagulation and heparinisation. Preoperative anticoagulation is not routinely performed at our treatment centre because a tumour thrombus differs from a new thrombus. An aggregate of viable tumour cells and the corresponding trophoblastic blood supply mainly form a tumour thrombus, which is not easily dislodged to form thromboembolism. A preoperative pulmonary embolism incidence of 4.4% was reported in patients undergoing radical renal cancer surgery. The prognosis of patients with renal cancer and venous tumour thrombus cannot be predicted by means of a preoperative pulmonary embolism [16]. According to the 301 classifications, thrombosis in combination with renal cancer accounts for approximately 19.2% of cases. This percentage comprised patients with inferior vena cava tumour thrombus, while no thrombosis was observed in patients with renal vein tumour thrombus. The study centre also found that the thrombus in all cases occurred on the right side. The distal end of the thrombus can reach the bifurcation of the iliac vessels, mainly distal to the tumour thrombus, for which preoperative anticoagulation and regular monitoring of coagulation routine and international normalised ratio are recommended [10]. Anticoagulation management is required in the event of acute cerebral infarction and pulmonary embolism after surgery. There was only one case of right renal cancer combined with grade I inferior vena cava tumour thrombus at our treatment centre, wherein on postoperative day 1, an acute cerebral infarction occurred. The condition regressed during emergency thrombolytic therapy was administered. This concern has been reported only by a few studies, and no clear treatment guidelines have been established. Generally, anticoagulants are administered but only in case of pulmonary embolism, combined cerebral infarction and other complications as a life-saving treatment. Increasing albumin reserve and appropriate volume expansion are advised after surgery. Low-molecular anticoagulation should be administered as early as possible if there are no obvious contraindications to anticoagulation.

Intraoperative techniques for inferior vena cava tumour thrombus

Operation mode. The various surgical approaches include robotic surgery, laparoscopic surgery, laparoscopy combined with open surgery, open surgery, etc. The appropriate surgical approach should be chosen based on the local hospital's level of healthcare. An adequate amount of blood (self + allogeneic blood) should be kept ready before the surgery. During surgery, the surgical field should be completely exposed, and the lateral branch veins and all lumbar veins should be disconnected to lower the risk of unnecessary bleeding during the extraction of the inferior vena cava tumour thrombus embolus. Surgical manipulation should be delicate to minimise compression of the inferior vena cava tumour thrombus to prevent dislodgement of the tumour thrombus while dealing with an inferior vena cava tumour thrombus.

Intraoperative transoesophageal echocardiography. We performed intraoperative transoesophageal echocardiography (GE Corporation). We observed thin strips of substantial echogenic lesions in the inferior vena cava on oesophageal ultrasound, which floated slightly with blood pressure flow or respiration. Oesophageal ultrasound was performed after administering anaesthesia to confirm the height and location of the inferior vena cava. For grade II-III inferior vena cava tumour thrombus emboli, oesophageal ultrasound can be used to guide the Fogarty balloon in the proximal release of the tumour thrombus to prevent dislodgement of the tumour thrombus and the development of lethal complications such as pulmonary embolism.

Multidisciplinary assistance. Liver rotation and venous-venous diversion are generally not required owing to the advantages of multidisciplinary assistance for grade II inferior vena cava tumour thrombus emboli. However, our treatment centre usually invites the hepatobiliary and pancreatic medicine team to perform liver reversal at the same stage to dissect and expose the second hepatic hilar to obtain maximum spatial exposure. This is done to ensure that the Rummel duct blocking clip can be kept as far as possible from the head of the tumour thrombus embolus and to leave a certain operating space to prevent the dislodgement of the tumour thrombus embolus.

Coeliac ascites and preventing lymphatic leakage. Coeliac ascites are mainly caused by intraoperative destruction of the coeliac pond, resulting in lymphatic vessel destruction within the coeliac pond. Due to the presence of the coeliac pond in the retroperitoneum, particularly in left-sided renal surgery, the chances of developing coeliac ascites are high if the surgery is not performed with caution. Anatomically, the left renal hilum is more likely to be close to the abdominal aorta. Several lymphatic vessels and the main lymphatic trunk are found along the parietal aortic area. These vessels receive lymph from the left and right lumbar trunk and the intestinal trunk, i.e., most lymph from the lower body converges into the coeliac pond and then flows back into the veins via the thoracic duct. Reportedly, a coeliac pond is observed in approximately 45.45% of our population [17]. If left renal cancer is combined with an inferior vena cava tumour thrombus, the coeliac pool (chyle pool) should be protected when dealing with the posterior aspect of the left renal vein. The lymphatic tissue should be minimally stripped, and the coeliac pool should be protected, thereby lowering the chances of developing coeliac ascites. Premature removal of the laparoscopic drain should be avoided, albumin reserves should be boosted, and parenteral intravenous nutrition should be enhanced to prevent postoperative lymphocele and lymphocele drainage.

Vascular preservation and disconnection issues. The renal veins comprise seven lateral veins, which are as follows: the subphrenic vein, the central adrenal vein, the second and third lumbar veins, the lumbar ascending vein, the genital vein, the ureteral vein, and the subdorsal renal vein. In contrast, the left side has a venous complex, with more collateral circulation and better blood circulation than the right side.

Ligating and dissecting the renal vein at the opening of the inferior vena cava of the affected kidney without special treatment for other vessels is sufficient for Mayo grade 0 tumour thrombi. Ligating and dissecting all the collateral veins of the affected kidney is necessary for
combined grade I, II, and III inferior vena cava tumour thrombi.

All collateral veins of the renal vein can be definitively cut off in right renal cancer combined with an inferior vena cava tumour thrombus. In the case of left renal carcinoma combined with inferior vena cava tumour thrombus, all the collateral veins of the left renal vein need to be cut off (as in Figure 4). The right central adrenal vein needs to be preserved to prevent adrenal crisis in the short term. In the case of renal cancer combined with grade II inferior vena cava tumour thrombus, interrupting the tumour thrombus segment of the renal vein with Endo GIA is advisable, given the safety of the procedure and the ease with which the affected kidney can be removed and the inferior vena cava can be extracted (Figure 5).

Figure 4 Intraoperative dissection of all lateral branches of the left renal vein to protect the coeliac pool on the posterior side of the left renal vein and prevent coeliac ascites

Intraoperative embolisation techniques. (A) Oesophageal ultrasound is performed to monitor the inferior vena cava tumour embolus in real time to clarify the real-time height and location of the embolus and detect whether it is combined with new thrombotic problems before blocking the collateral circulation for embolus removal. (B) All collateral veins should be blocked with Rummel tubes during surgery to control the bleeding during embolisation for grade II tumour emboli. The surgical procedure should be performed delicately and with caution to maintain a clear surgical field. (C) After the cancer embolus is removed, the inferior vena cava lumen should be repeatedly irrigated with heparin water to ensure no residual cancer emboli persist.

Prognosis of locally progressive renal cancer

The prognosis of patients with locally progressive renal cancer who receive a non-surgical intervention is poor, and the median survival is approximately 5 months. For patients undergoing radical renal surgery and cancer embolism removal surgery without distant metastases, the specific survival rate at 5 years is approximately 60% [18]. The 3-year tumor recurrence rate after radical tumor resection in patients with non-metastatic renal cancer with inferior vena cava cancerous thrombus is about 50% [19]. A thorough preoperative communication and comprehensive assessment are required for such high-risk procedures. Distant metastases are a significant predictor of reduced survival [20]. Reportedly, the height and location of the tumour embolus have no significant impact on survival. With advances in medical technology and high-level perioperative care, surgery does not additionally impact patient mortality [21].
patients without distant metastases, radical surgery is recommended because it improves the overall survival rate and quality of life. Additionally, new targeted therapies with genetic testing can be employed as adjuvant therapy to improve the treatment options for locally progressive renal cancer.

Conclusions

The survival rate is low in patients with locally progressive renal cancer who do not receive surgical intervention. Radical resection of renal cancer combined with inferior vena cava cancer embolism removal surgery in a multidisciplinary setting is beneficial for patients without distant metastases, particularly those with renal cancer combined with an inferior vena cava tumour thrombus. The need for high-risk surgery and the indications for the procedure are well understood. During the perioperative period, the height and location of the tumour emboli are adequately assessed. The surgical procedure is refined, and all collateral veins of the affected kidney are adequately dissected to reduce bleeding and prevent dislodgement of the tumour emboli. Immediate postoperative care and high-protein energy and nutritional support are provided to ensure the patient’s recovery.

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