Preoperative Setting-Up of Patients Undergoing Robotic Inferior Vena Cava Thrombectomy

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22.1 Introduction

Between 4 and 10% of renal cancers are associated with tumor thrombus in the inferior vena cava (IVC) [1]. Traditional open IVC thrombectomy remains a physically challenging and technically demanding surgery with significant perioperative morbidity and mortality [2]. However, as robotic techniques continue to evolve, carefully selected patients may have the opportunity to undergo robotic IVC thrombectomy (RIVCT). As a relatively new procedure, RIVCT techniques are growing and improving rapidly. Beginning in 2011, groups began reporting outcomes for level I or II RIVCTs [3]. The first series of robotic level III thrombectomy cases was reported by Gill et al. in 2015, demonstrating the safety

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and feasibility of the procedure [4]. Only a few years later, the first robotic IVC thrombectomy for a level IV thrombus with a mini-thoracotomy for cardiac control was successfully performed [5].

To date, there have not been any prospective randomized trials comparing outcomes of RIVCT to open surgery. However, several series have been published confirming the efficacy of RIVCT. While sample sizes are relatively small due to strict patient selection, the procedure has been generally standardized, creating a uniform and reproducible technique [6]. The approach hinges on minimizing manipulation of the IVC, dissecting tissue away from the great vessel [7]. This "IVC-first, kidney-last" approach has worked to minimize thrombus embolism and major hemorrhage.

For patients without metastatic disease, surgical excision of the tumor and thrombus is the first-line treatment. This provides a 5-year cancer-specific survival of up to 65% [4]. While surgical technique and skill is important, preoperative planning is paramount, and heavily influences RIVCT outcomes. Careful patient selection and evaluation must precede a surgical approach that is tailored to each patient. Preoperative considerations include a battery of testing, imaging, consultations, tumor staging, and preoperative procedures. Strict adhesion to standardized preoperative procedure minimizes complication rate and can drastically improve outcomes.

22.2 Patient Selection

22.2.1 Clinical Staging

Careful patient selection is the cornerstone of successful RIVCT. Perhaps the most important part of preoperative workup involves staging of the tumor thrombus, which should be performed less than a week before surgery. Staging may be performed either by computed tomography (CT) or magnetic resonance imaging (MRI), both of which have excellent sensitivity and specificity for assessing extent of tumor thrombus [8]. The most used staging system was developed by Neves and Zincke at the Mayo Clinic in 1987 [9, 10]. This system describes four levels of tumor thrombus based on cephalad extent within the IVC (Table 22.1). The staging system was modified by Ciancio et al. in 2002 to subdivide a level III thrombus into a further four categories [11].

This staging system may be used in conjunction with the American Joint Committee on Cancer (AJCC) system, which uses the familiar tumor-node-metastases (TNM) method. Regarding tumor thrombus, the AJCC TNM system is classified as follows [12]:

- T3a—Tumor extends into the renal vein, but not beyond Gerota's fascia
- T3b—Tumor extends into the IVC inferior to the diaphragm
- T3c—Tumor extends into the IVC superior to the diaphragm or invades the wall of the IVC.

Table 22.1 Mayo staging system of vena caval thrombectomy

Mayo staging system	Criteria
Level 0	Thrombus extending into the renal vein
Level I	Thrombus extending into the IVC no more than 2 cm superior the renal vein
Level II	Thrombus extending into the IVC more than 2 cm superior to the renal vein, but not to the hepatic vein
Level IIIa	Thrombus extending into the retrohepatic IVC, but inferior to the major hepatic veins
Level IIIb	Thrombus extending into the retrohepatic IVC, reaching the ostia of the major hepatic vessels
Level IIIc	Thrombus extending into the retrohepatic IVC superior to the major hepatic vessels, but inferior to the diaphragm
Level IIId	Supradiaphragmatic thrombus, but inferior to the right atrium
Level IV	Supradiaphragmatic thrombus that extends into the right atrium

Additionally, the degree of IVC lumenal occlusion may be described by the following system proposed by Blute et al. [13], which may be helpful with preoperative surgical planning:

- A—IVC with no occlusion
- B—IVC is partially occluded, distal bland thrombus limited to the pelvis
- C—IVC is partially occluded by tumor thrombus, associated bland thrombus
- D—IVC is completely occluded by tumor thrombus, associated bland thrombus.

22.3 Patient Evaluation

22.3.1 Imaging

Abdominopelvic imaging is vital to surgical approach and technique. Thrombus anatomy should be carefully studied including length, diameter, vessel involvement, arterialization, and bland thrombus presence/extent. Assessment of IVC anatomy should involve diameter, presence of blood flow, wall invasion, and the locations of bilateral renal vasculature. An assessment of hepatic anatomy should include the number and location of short and main hepatic veins, liver size, and involvement as suggested by congestion. Renal anatomy study should include number of renal arteries and veins, venous flow and collaterals, and renal tumor size/stage. Finally, the retroperitoneal anatomy should be carefully considered to assess adenopathy and venous collaterals [4].

As mentioned prior, MRI or CT imaging should be performed less than a week before surgery [8]. If the patient has acceptable renal function, CT is commonly

performed. A multi-phasic CT is generally preferred, providing imaging at multiple different times following contrast administration. This method has a high sensitivity (93%) and specificity (97%) for detecting tumor thrombus [14, 15]. Patients with contrast allergies or borderline renal function may receive an MRI with contrast allowing for multi-planar reformatting. CT and MRI imaging is preferred as it describes the extent of the renal tumor into the peri-renal fat, adrenal involvement, intra-abdominal adenopathy, caval flow characteristics, and vascularity of the kidney, including any collateral vessels [16]. A multiplanar review of the multiphase images on a workstation by an experienced abdominal radiologist often leads to a more detailed nuanced mapping of the vasculature. Multiplanar review is important as a single plane review may miss crucial details such as focal IVC wall involvement and variant anatomy. A direct consultation between the urological team and radiologist is critical for surgical planning. Additionally, for patients with level IIId or IV thrombi, a transesophageal echocardiogram is generally warranted to assess involvement of the right atrium.

Occasionally, neither CT nor MRI may be possible, either due to availability or patient intolerance. In such cases, inferior vena cavography may be used for assessment and staging. However, this imaging modality is limited due to its invasive nature, high contrast load, and risk of complications [10, 17]. Abdominal ultrasound may also be used, but results are highly dependent on the position of the thrombus and skill of the ultrasonographer [18]. Studies have shown that ultrasonography has a sensitivity of 68% when detecting thrombi below the level of insertion of the hepatic vein. Additionally, in more than 40% of cases, the IVC is not fully visualized by ultrasound imaging [19].

22.3.2 Additional Pertinent Testing

All patients should receive metastatic workup within 30 days prior to surgery. This should include pertinent laboratory testing such as a complete blood count, comprehensive metabolic panel, serum calcium, liver function tests, and urinalysis [20]. If urothelial carcinoma is within the differential diagnosis or if urinalysis reveals gross or microscopic hematuria, urine cytology or cystoscopy should be considered. Additionally, patients should have a chest CT, bone scan, and brain MRI if possible. If necessary, a pet-CT should be ordered to assess potentially metastatic lesions [16].

Renal function should be assessed prior to surgery. Radionuclide mercaptoacetyltriglycine-3 renal scan and 24-hour urine collection for creatinine clearance, protein excretion, and estimated glomerular filtration rate may be considered as needed [16]. Cardio-pulmonary clearance and lower extremity duplex Doppler ultrasonography should be ordered prior to surgery.

22.4 Preoperative Procedures

22.4.1 Angioembolization

Reliable preoperative renal artery angioembolization (RAE) is immensely helpful for RIVCT, particularly for left-sided thrombi. This is because intraoperatively the left renal vein is ligated well before control of the left renal artery is achieved. Therefore, RAE helps to minimize blood control and allows for early ligation of the renal vein [4].

Studies have shown that the efficacy of RAE varies by the tumor size, tumor vascularity, and the completeness of embolization [21, 22]. In patients with large, high level tumor thrombi, RAE may help downsize or partially regress the tumor thrombus prior to surgery, which can optimize surgical approach and outcomes [2, 23]. Additionally, preoperative RAE can induce local edema that can improve cleavage between the infarcted kidney and other surrounding tissues [24]. This may help with plane dissection, and the effect appears to be most pronounced at 72 hours following RAE [25]. However, this improved dissection must be weighted against the risk of collateral vessel development. As a result, the recommended time between RAE and surgery is less than 24 hours to 2 days [1, 26–29].

It has also been suggested that delaying the time between RAE and surgery may stimulate the production of tumor antibodies as a result of extensive tumor necrosis [24, 30]. This delay is suggested to act as a kind of autovaccination to provide specific active immunotherapy that may be protective against metastases. Though studies have shown mixed results, this hypothesis is far from proven [31–33].

22.4.2 Placement of IVC Filter

An additional consideration involves consulting interventional radiology to place a preoperative IVC Greenfield filter. Preoperative placement may be useful in patients who present with pulmonary emboli despite administration of anticoagulation or in patients for whom anticoagulation is contraindicated. Additionally, if the IVC is completely and chronically occluded prior to surgery, placement of a filter may be indicated. Due to the risk of decreased flow caused by collateral vessels, the IVC should be placed inferior to the contralateral vessel [34]. If an IVC filter must be placed, it should be done less than 48 hours before surgery [17, 35]. It should also be placed suprarenal through a superior approach [35].It should be noted that if a patient presents with an IVC thrombus presents following a pulmonary embolism, the appropriate treatment is often urgent nephrectomy rather than placement of an IVC filter. Filters are often avoided because the thrombus often incorporates the filter into itself as it grows [13, 34]. This can unnecessarily complicate surgical complexity and adversely affect outcomes. Intraoperatively, placement of a filter may be considered if distal bland thrombus exists that is not

associated with tumor thrombus. This may be indicated to prevent the propagation of bland thrombus, achieve negative surgical margins, or clear vena cava wall invasion [13].

22.5 Preoperative Considerations

22.5.1 Preoperative Medical Therapy

Generally, RIVCT patients are referred for surgical therapy without prior medical therapy [8]. There has been little success with systemic immunotherapy trials [36]. Recently however, there has been growing interest in the use of systemic kinase inhibitors to downsize tumor thrombus level prior to surgery [8, 28]. Several retrospective studies have produced variable results, showing decreased thrombus levels in between 7 and 19% of cases [37–39].

It should be noted that—though it is possible to decrease tumor level with targeted medical therapy—this does not always change surgical approach. Additionally, some tumor thrombi may continue to grow despite medical therapy. Therefore, if a tumor thrombus is resectable at presentation, it may be prudent to refer for surgery rather than administer systemic medical therapy.

22.5.2 Anti-coagulation

In the setting of RIVTC, anti-coagulation is sometimes given as treatment/prophylaxis for pulmonary embolism. Tumor thrombi generally consist of non-friable tumor tissue that is unlikely to cause a pulmonary embolism [8]. However, when a pulmonary embolism occurs mortality is immensely high. An assessment of eight series of a total of 803 IVC thrombectomy patients showed that despite an incidence of 1.49%, overall mortality from preoperative pulmonary embolism was 75% [40–45]. Therefore, in cases of preoperative pulmonary embolism, anti-coagulation may be administered. Anti-coagulation may also be appropriate if preoperative imaging reveals significant bland thrombus.

22.5.3 Consultations

Prior to surgery various consultations may be appropriate based on patient circumstances and characteristics. Anesthesia and cardiothoracic surgical consultations are recommended for patients older than 50 years of age as well as patients who will receive cardiopulmonary bypass [20, 35]. An anesthesiologist familiar with rapid fluid shift, cardiopulmonary bypass, and transesophageal echocardiogram is preferred [10]. Particularly for level II to IV thrombi, transesophageal echocardiogram (TEE) monitoring can be immensely helpful. It is recommended that such patients receive TEE preoperatively following induction of anesthesia [46]. The

TEE may be performed as a continuous intraoperative monitoring measure at the discretion of the surgeon and the anesthesiologist. This can be helpful to assist in dissection, monitor patient volume responsiveness and cardiac performance, assess intraoperative complications (such as intraoperative embolism) in real-time, and ensure complete resection of tumor thrombus.

Hepatobiliary consultation is warranted for tumor thrombi particularly of level III and IV. A skilled hepatobiliary team typically assists with mobilization of the liver intraoperatively. This involves disconnection of the perihepatic ligaments, including the falciform ligaments, the right and left triangular ligaments, and the coronary ligaments [47]. This allows for the vessel tourniquet to be placed in the suprahepatic and infradiaphragmatic IVC, superior to the proximal IVC thrombus.

Cardiology should be consulted if the patient has two or more risk factors for coronary artery disease [35]. Consultation with vascular surgery may also be warranted if the surgeon does not have expertise with complex vascular reconstruction. An experienced hospitalist or intensivist should be consulted for perioperative management. Finally, a skilled surgical oncologist should be consulted and prepared in the case of conversion to open surgery.

Given the potential medical complexity of renal tumors with caval involvement, the involvement of medical hospitalists or intensivists teams in the coordination of multi-disciplinary care is recommended. Patients with high level tumor thrombi are at risk for sudden conversion to a variety of medical maladies, including sudden onset hepatopathy and Budd-Chiari Syndrome, with resultant coagulopathy and a classical clinical triad of pain, ascites, and hepatomegaly. Such medical sequelae are often poor prognostic harbingers, and a vigilant eye for the development of these must be maintained. The post-operative recovery of these patients is also often challenging, and intensivist care in the acute post-operative setting, followed by hospitalist involvement as the patient transitions to the ward, remains critical.

Bland thrombus distal to the tumor thrombus may develop from the venous stasis secondary to chronic luminal occlusion of the IVC and the hypercoagulability of malignancy. As such, and evaluation of the extent of bland thrombus burden in the lower extremities using duplex ultrasonography of the bilateral lower extremities starting from the groin and extending distally may guide pre-operative, intra-operative, and post-operative strategies. For instance, the utilization and extent of pre-operative anticoagulation may be in part guided by the extent of distal bland thrombus. Intraoperatively, both tumor involvement within the wall of the IVC firstly, and extent of distal bland thrombus, secondly, may guide the decision to perform inferior vena cavectomy. Lastly, extent of bland thrombus will certainly play a role in the anticoagulation approach in the post-operative setting. One study recommended intraoperative placement of a IVC filter in patients with evidence of distal tumor thrombus that is not associated with tumor thrombus. The same study stated that IVC filters must never be placed superior to tumor thrombus due to the possibility of tumor incorporating into the filter [13]. In such a case, it may be worth consulting with an experienced vascular surgeon or interventional radiologist.

Lastly, even within the urologic team in charge of the patient's care, the active participation of specialists with both minimally invasive and open surgical skills is a must. The potential for catastrophic intraoperative complications such as tumor embolism increases with the extent of IVC involvement and the risk of conversion to open surgery has a similar correlation. As such, we recommend that surgical teams discuss the possibility of open conversion well in advance, and have a practiced, set plan for rapid undocking and open conversion should the need arise.

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