The surgical evolution of radical nephrectomy and tumor thrombectomy: a narrative review

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Background and Objective: Renal cell carcinoma (RCC) accounts for 2–3% of all malignant disease in adults. RCC propagates into the renal vein and inferior vena cava (IVC) in up to 25% of patients with RCC. Despite advances in medical management such as immunotherapy, surgical resection remains the gold standard treatment of RCC with venous tumor thrombus (TT) extension. Surgical innovation has revolutionized the management of RCC with TT, reducing morbidity and mortality through advanced surgical techniques and minimally invasive approaches. The aim of this review is to summarize the evolving developments in the surgical treatment of RCC with venous TT.

Methods: We performed an advanced search on PubMed between the inception of the database and April 2022 to summarize the evolution of the surgical management of RCC with venous TT, focusing on the reports of key historical, current, and recent studies.

Key Content and Findings: Implementation of entirely intraabdominal liver transplant-based approaches have allowed for successful surgical excision of higher-level tumor thrombi, obviating the need for sternotomy or cardiopulmonary bypass (CPB). Recent advances in robotic surgery provide a promising approach for minimally invasive management of RCC with venous TT extension.

Conclusions: Surgical innovation has revolutionized the management of RCC with TT, reducing morbidity and mortality through minimally invasive techniques with preserved oncologic effectiveness.

Keywords: Renal cell carcinoma; tumor thrombus; nephrectomy; thrombectomy; surgical technique

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Introduction

Renal cell carcinoma (RCC) is one of the 10 most common cancers found in men and women, accounting for 2–3% of all malignant disease in adults with a lifetime risk for development of RCC in 1 in 62 (1.6%) (1,2). RCC extends into the renal vein and inferior vena cava (IVC) in up to 25% of patients with RCC, reaching the right atrium in 1% of cases (1-7). Despite advances in medical management like target-specific therapy, surgical resection remains the mainstay treatment for RCC with venous tumor thrombus (TT) extension and the only hope for a potential cure. Reports have demonstrated durable cancer-free survival following radical nephrectomy and tumor thrombectomy (5,8-12). Surgical innovation has revolutionized the management of RCC with TT, reducing morbidity and mortality through minimally invasive techniques with preserved oncologic effectiveness.

The aim of this review is to summarize the evolving developments in the surgical treatment of RCC with venous TT in efforts to provide the potential reader with comprehensive and enlightening knowledge on this particular field. We present the following article in accordance with the Narrative Review reporting checklist (available at https://atm.amegroups.com/article/view/10.21037/atm-22-2877/rc).

Methods

We conducted an advanced literature search in PubMed (from the inception of the database to April 24, 2022). Only papers in English were included. The following MeSH terms and their combinations using Boolean operators (AND, OR, NOT) were searched: "renal cell carcinoma", "renal cancer", "renal tumor", "kidney cancer", "kidney tumor", "tumor thrombus", "inferior vena cava involvement", "surgery", "surgical approach", "surgical technique". Our detailed search strategy is summarized in *Table 1*.

The surgical evolution

Historical view

The first report of RCC with TT extension date back to over a century ago. Successful excision of TT was futile, where it was described that macroscopic involvement of any vein portends a poor prognosis and that rarely would all involved tissue be removed with surgical resection (6). A system of staging was lacking until 1969 when Robson *et al.* defined RCC staging (13). However, until then, extension into the IVC was considered an incurable stage. As surgeons were continuously faced with cases of RCC with caval tumor extension, several surgical and therapeutic approaches have been developed in efforts of safe and curative resection.

In 1988, Marshall *et al.* (14) mention the need to solve the technical difficulties in controlling the vasculature and to decrease the risk of dissemination of tumor or pulmonary emboli. For cases of tumor at the level of or above the major hepatic veins, the authors describe a technique of combining cardiopulmonary bypass (CPB), hypothermia, and temporary exsanguination to permit for careful dissection in a bloodless field with less risk of embolization. They report 15 patients who underwent surgical treatment of RCC with intracaval tumor extension above the level of the most inferior hepatic vein. In six patients, mobilization of the IVC with division of the short hepatic veins to the caudate lobe allowed excision of the tumor without CPB. Nine patients (five with intracardiac TT, three with supradiaphragmatic TT, and one with infradiaphragmatic TT) required CPB under deep hypothermia. Survival of patients without and with CPB was 75% at two years and 25% at three years, respectively.

In 1994, Swierzewski *et al.* (15) report certain principles for caval surgery for RCC thrombus regardless of the level of the thrombus. The authors report 100 cases of radical nephrectomy and thrombectomy for patients with RCC and venous tumor extension, with CPB used in 13 patients with tumor involving the right atrium. The authors describe an open, right-sided transabdominal approach even if the thrombus originated from a left renal tumor. Minimal manipulation of the IVC and renal vein was advised until a DeWeese clip was temporarily placed on the vena cava above the TT. When the tumor extended above the level of the hepatic veins or in the intrapericardial portion of the IVC, a Pringle maneuver was performed. However, contrary to the approach by Marshall *et al.*, CPB was only required in the case of tumor within the right atrium. The authors report an overall adjusted 5- and 10-year survival rate of 54% and 46%, respectively, with a median survival time of 5.1 years.

In 1998, Fitzgerald *et al.* (16) describe a minimally invasive approach for CPB during resection of a right atrial TT. Using a chevron incision, the kidney and tumor were mobilized and the IVC was dissected up to the diaphragm using the Langenbuch maneuver. After circulatory arrest was achieved, the right atrium was explored and the IVC

Table 1 Detailed search strategy summary

Items	Specification
Date of search	April 24, 2022
Databases and other sources searched	PubMed
Search terms used	Boolean operators (AND, OR, NOT)
	Key words: "renal cell carcinoma", "renal cancer", "renal tumor", "kidney cancer", "kidney tumor", "tumor thrombus", "inferior vena cava involvement", "surgery", "surgical approach", and "surgical technique"
Timeframe	From inception to April 24, 2022
Inclusion and exclusion criteria	English literatures including clinical trial, randomized clinical trial, meta-analysis, review, and systematic review were collected for reviewing
Selection process	JG collected the literatures and extracted the relevant information. All authors jointly discussed and selected the literature for the review

was opened below the diaphragm to the ostium of the renal vein and the thrombus was extracted.

A few years later, Belis *et al.* (17) describe a technique to minimize ischemic time. They believed that mobilizing the kidney before CPB increases the risk of tumor embolization before vascular control. They detail obtaining full vascular control before renal manipulation, showing no significant increase in circulatory arrest time or blood loss.

Shortly after, Ciancio *et al.* (18) set up the principles by which the transplant-based approach for RCC with vascular involvement is settled. This technique was tailored on a case-by-case basis depending on the anatomic level of the TT inside the IVC. The main objective of this approach is to increase the exposure at difficult access areas within the abdomen (i.e., particularly at the subdiaphragmatic space and large retroperitoneal vessels) through mobilization of the different visceral compartments. In this way, surgical safety is empowered, permitting the removal of these tumors exclusively from the abdominal cavity without the need for CPB in most instances.

Current trends

Preoperative assessment and planning

Effective surgical treatment of patients with RCC with venous TT requires meticulous preoperative planning. Cross-sectional imaging has facilitated precise delineation of primary tumors, predicting thrombus extent with 96% accuracy (5,19). Advancements in cross-sectional imaging have also facilitated the detection of lymphadenopathy and intra-abdominal metastasis (7). MRI can also be utilized to determine the extent of TT, the degree of IVC occlusion, and the presence of venous anomalies and bland thrombus (4,7). If the TT is shown to extend into the right atrium, further preoperative assessment with transesophageal echocardiogram (TEE) can be considered (7,20).

Hevia *et al.* (20) state that the most crucial element in preoperative workup is to determine the level of the TT. The Neves-Zinke classification (21) is one of the most common classification systems used to define the level of the thrombus. Ciancio *et al.* (22) routinely utilize a modified approach for level III thrombi (retrohepatic), as exposure and control of major hepatic veins are a key factor in surgical strategies. The authors categorized level III thrombi into four groups: IIIa (retrohepatic IVC below major hepatic veins), IIIb (retrohepatic IVC reaching the ostia of major hepatic veins), IIIc (retrohepatic IVC and extending above major hepatic veins, but below diaphragm), and IIId (suprahepatic and supradiaphragmatic IVC, reaching intrapericardial IVC, but infra-atrial) (*Figure 1*).

Preoperative renal artery embolization is another advancement that has been developed in the surgical management of RCC with TT as it facilitates the dissection the renal tumor, decreases the extent of the tumor, and minimizes intraoperative blood loss (4,7,23). However, intraoperative early ligation of the renal artery has been shown to be technically feasible and a good alternative to preoperative renal artery embolization avoiding post-embolization syndrome and other side-effects (20,24).

Surgical management

For locally advanced RCC with TT, various surgical

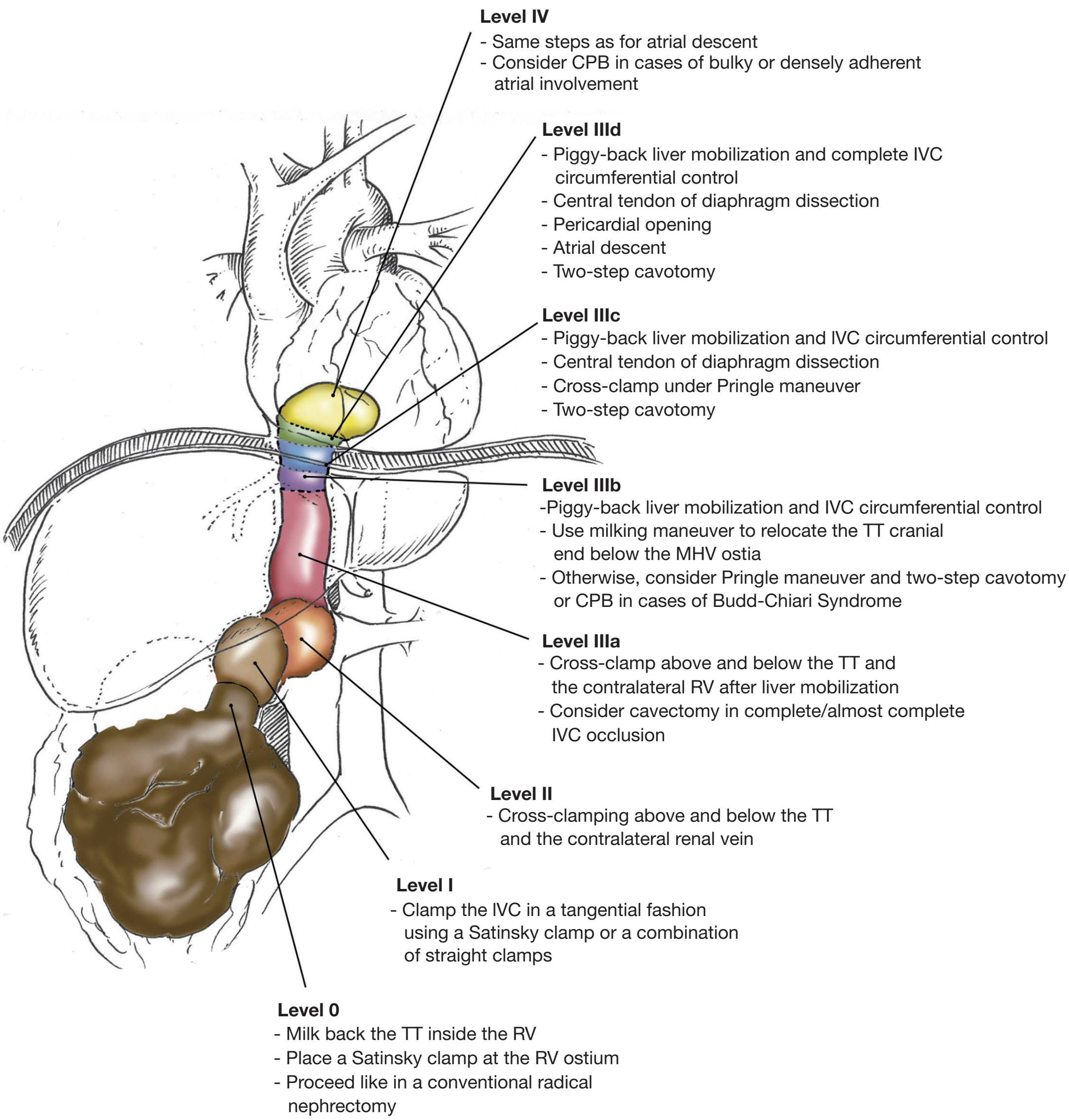

Figure 1 A diagram showing the surgical maneuvers recommended in various scenarios of RCC with IVC TT according to the University of Miami thrombus level classification system. CPB, cardiopulmonary bypass; IVC, inferior vena cava; TT, tumor thrombus; MHV, middle hepatic vein; RV, renal vein; RCC, renal cell carcinoma.

approaches have been applied depending on the surgeon's experience, patient-specific anatomy, and extent of the TT (5). For patients with RCC with level I thrombi, the principles of traditional radical nephrectomy, first described by Robson *et al.* (13) can be applied. Through a thoracoabdominal incision, the affected kidney and the great vessels can be exposed, mobilized, and controlled. After ligation of the renal artery, dissection of IVC 2 cm above and below the renal vein should be done and the thrombus can be milked back into the renal vein, thus permitting cross-clamping at the level of the renal vein ostium. If circumstances do not allow milking of the tumor into the renal vein, proximal, distal and contralateral cross-clamping are commonly necessary to proceed with cavotomy and thrombectomy (20). After clamping of the contralateral renal vein and IVC above and below the thrombus, circumferential incision is made at this level. Sometimes, the venous upstream flow through the IVC may be preserved during TT removal. In these cases, TT should be free-floating inside the lumen to allow its complete control with a Satinsky clamp or a combination of straight vascular clamps. Once the TT is completely removed, the caval defect can then be sutured closed with caution to avoid constricting the diameter of the IVC (25). As a general rule, IVC diameter can be compromised in up to 50% of the lumen. Under these circumstances, a simple or double running suture is often sufficient to close the defect. However, if *en bloc* wall excision compromises more than 50% of the IVC lumen and enough collateralization is presumed incompletely developed, then caval reconstruction by means of autologous/heterologous patching is recommended (in efforts to avoid the development of postoperative lower-limb edema). In cases of complete/almost complete IVC occlusion, collateral circulation is guaranteed. In these cases, circumferential resection of the IVC *en bloc* with the TT can be considered. This approach requires IVC stapling at a level below the ostia of the major hepatic veins and below the TT. This maneuver provides better surgical margins and prevents embolization from dislodged fragments of bland thrombus located distally (i.e., below the TT) without putting contralateral kidney function at risk in the long term (26,27).

An open approach for radical nephrectomy with tumor thrombectomy has been performed using a midline, chevron, or subcostal incision, which provide excellent exposure of bilateral renal hila (5,28). Following entry into the peritoneum, the affected kidney, anterior surface of the IVC, and abdominal aorta are exposed. Hevia *et al.* (20) describe mobilizing the kidney medially until reaching the renal artery outside the Zuckerkandl fascia, where the artery is ligated and divided. Early ligation of the renal artery allows for collapse of collateral circulation, reducing bleeding and facilitating further dissection (22). In right sided-tumors, approaching the right renal artery in the space between the aorta and IVC can decrease early manipulation of the IVC and right renal vein (8). However, this maneuver may be difficult to perform in cases of masses crossing the midline or bulky lymph node spreading at the aorto-caval space. A posterior approach to the renal artery may facilitate vascular control in such situations. Conversely, many authors advocate for arterial embolization that should be best performed within the 48 hours prior to the intervention.

For level II thrombi, it is important to achieve adequate exposure and control of the infrahepatic and retrohepatic IVC (in case of TT stopping at the edge of the liver) before cavotomy and thrombectomy (20,25). This can be achieved through a less complex mobilization of the posterior surface of the liver, which exposes the anterior and lateral surface of the IVC. Some small hepatic and lumbar veins should then be ligated and divided. Vascular clamps can then be placed on the contralateral renal vein, as well as on the IVC below and above the thrombus, and a cavotomy and thrombectomy can be performed. Clamping below the hepatic venous confluence obviates the need for bypass due to collateral venous return via the lumbar, azygos-hemiazygos, and portal venous systems (5).

Level III thrombi necessitate precise characterization of the tumor level on preoperative imaging and intraoperative transesophageal echocardiography (TEE) is strongly advised (8). Level III thrombi have been successfully resected with the use of CPB with circulatory arrest (25), however their complete intraabdominal surgical excision can be performed without the use of CPB by utilizing hepatic mobilization maneuvers (8,18,29,30). A transplant-based approach for gaining access to the retrohepatic IVC has been described at length by Ciancio *et al.* (18). The liver is mobilized and surgical control of the hepatic hilum is performed, which allows for isolation and control of the porta hepatis (in the case where the thrombus extends above the hepatic veins and the Pringle maneuver is needed) (31,32). A piggyback maneuver is then performed (33). Circumferential control of the IVC is obtained via anterior and posterior dissection.

If the TT can be milked down below the hepatic venous confluence, a clamp can be placed on the IVC below the hepatic venous outflow to avoid liver congestion (34). TEE monitoring should be used to assess potential dislodgement of the thrombus. In the case of level IIId thrombi and where the milking maneuver cannot be performed, the surgeon should continue dissecting until there is exposure of the supradiaphragmatic and intrapericardial IVC (35). Sequential vascular clamping occurs in the following order under TEE monitoring: (I) IVC below the thrombus; (II) contralateral renal vein (and right adrenal vein in case of left-sided renal tumor); (III) Pringle maneuver; and (IV) IVC above the TT (below the major hepatic veins if milking maneuver was successful or supradiaphragmatic IVC if not) (20,32). Rapid infusion of blood products through a central line or veno-venous or CPB is recommended in the case of significant hypotension (5). Although higher-level thrombi exhibit larger TT diameters and invasion of the IVC wall, collateralization favors tolerance of the combination IVC cross-clamping and Pringle maneuver.

In the case of higher level TT, such as IV thrombi, CPB with or without hypothermic circulatory arrest has been generally accepted in management (25). However, due to the risk of coagulopathy and central nervous system complications, there remains controversy over its use (20,30). The principles of the transplant-based approach already mentioned may be used in controlling the right atrium in cases of non-massive atrial involvement, avoiding the need for CPB in most instances (35).

Neoadjuvant systemic therapy and radiation therapy

Immunotherapy and radiotherapy in the management of advanced RCC has expanded rapidly over the last decade, as combinations of immune checkpoints inhibitors (ICIs) and anti-angiogenic tyrosine kinase inhibits (TKIs) become the new cornerstone for treatment (36). Historically, preoperative systemic and radiation therapy have shown limited usefulness for treatment of IVC thrombi in RCC (37). However, advances in neoadjuvant therapy offers several benefits, such as downsizing/downstaging an otherwise unresectable tumor, reducing surgical morbidity by reducing tumor complexity, and allowing early and prompt oncological control, which can reduce post-operative recurrence risk (38-41). Few reports in the literature have described complete response to antiangiogenic neoadjuvant therapy in the surgical management of RCC with IVC TT (42,43). Shuch *et al.* (44) report reduction in primary tumor, vena cava thrombus and lymph node metastasis after neoadjuvant sunitinib therapy. Karakiewicz *et al.* (45) report a case of decrease in renal tumor size from 11 to 8 cm and TT downstage from the right atria to the renal vein after sunitinib neoadjuvant therapy.

Radiation therapy has historically been considered ineffective in treating RCC due to the adverse effects on healthy tissue and radio-resistance of RCC cells. However, advances in radiotherapy, such as hypo-fractionated stereotactic ablative radiotherapy (SAbR), have shown success in patients with RCC metastasis in several trials (41,46,47).

Margulis *et al.* report a prospective trial investigating the use of 40 Gy in 5 fractions to patients with RCC and IVC TT. Six patients were included in the final analysis, of those three had M1 disease (48). They describe minimal adverse events and no intraoperative complications or technical difficulties. Although a small cohort, this study highlights that neoadjuvant SAbR is feasible and safe.

The use of adjuvant systemic therapy in RCC with IVC TT is another development in treatment, however, this topic is out of scope of this review on the evolution in surgical management of advanced RCC.

Recent developments

Minimally invasive kidney cancer surgery for the treatment of radical nephrectomy and IVC tumor thrombectomy is growing in recent years (49-54). Over the last two decades, laparoscopic excision of locally invasive RCC have been described, however its use for level II and III thrombi is still considered very challenging (51). Robotic surgery and techniques are currently being applied to IVC thrombectomy.

Laparoscopic RN and tumor thrombectomy

In 2002, Sundaram *et al.* (55) reported the first transperitoneal hand-assisted laparoscopic procedure for a right-sided RCC and level I TT. After caval control, the TT was milked back into the renal vein using a Gelport® and a Satinsky clamp placed through a flexible port. This maneuver allowed the performance of a cavotomy for TT withdrawal. The cavotomy was sutured closed by means of a hand-assisted intracorporal knotting technique. Conversely, Varkarakis *et al.* (56) preferred the performance of a hybrid laparoscopic-open technique by creating an 8–12 cm open incision to facilitate the placement of the Satinsky clamp.

A year later, the first retroperitoneal hybrid approach for RN and thrombectomy was reported (57) and Romero *et al.* (58) published the first case of pure laparoscopic approach for radical nephrectomy and tumor thrombectomy. In 2010, Hoang *et al.* (59) report a hybrid transperitoneal approach in a level III TT. Duplicating the principles of the transplant-based technique, they encircled the hepatic pedicle to perform a Pringle maneuver and achieved complete mobilization of the liver to permit control of the entire IVC before attempting the cavotomy.

Wang *et al.* (60) also attempted to follow the surgical principles of the open approach. However, a Satinsky clamp was only placed distally on the IVC, while proximal control was not undertaken until the entire TT was withdrawn from the IVC. This led to profuse hemorrhage that required multiple postoperative transfusions. Two years later, this group changed their approach to pure laparoscopy and used a modified Rummel tourniquet for proximal IVC control (61).

The first report for a laparoscopic approach in level IV cases was conducted in 2015 by Shao *et al.* (62). The procedure was thoracoscopy-assisted in order to place the patient under mild-hypothermic CPB.

Robotic-assisted radical nephrectomy and tumor thrombectomy

In 2011, Abaza (63) reported the first series of transperitoneal robotic radical nephrectomy and tumor thrombectomy of level I–II IVC thrombi for right-sided RCC, including the first cases of minimally invasive cross-clamping of the IVC. Soon after, Bratslavsky *et al.* (64) reported for the first time a purely robotic approach in the case of right-sided RCC with level III TT. The authors were able to dissect, clip, and divide the short veins crossing between the posterior surface of the caudate lobe and the anterior surface of the IVC. In this case, TEE was also used to monitor TT extraction. In 2014, Hui *et al.* (65) combined the use of abdominal robotic assistance with thoracoscopy to manage a case of level III TT whose cranial end was located proximal to the ostia of the major hepatic veins. The proximal IVC was controlled by means of trans-thoracic intrapericardial IVC dissection and the liver hilum was encircled and controlled to allow for safe TT removal. Of note, intermittent apnea was used to optimize exposure. However, a densely adherent TT precluded an exclusively robotic approach requiring open conversion for complete removal and IVC closure.

Two years later, Wang *et al.* (66) reported an initial series of pure robotic radical nephrectomy and tumor thrombectomy. When preoperative renal artery embolization was not performed, the right renal artery was first ligated and divided in the aorto-caval space. For left-sided tumors, the renal artery was previously embolized and required a reposition of the patient in the adequate lateral decubitus (left-side up) once the left renal vein was divided using and endo-GIA stapler. In efforts to avoid patient repositioning, Aghazadeh *et al.* (67) recently developed a single-dock supine purely robotic-assisted approach.

In 2015, Gill *et al.* (68) reported a prospective single-surgeon experience of 16 cases using a purely intracorporeal robotic-assisted approach focused mainly on minimizing the chances for intraoperative pulmonary embolization. For this purpose, a robotic "IVC first-kidney last" approach was developed, evolving shortly after to a "midline first-lateral last" in efforts to decrease the risk of excessive blood loss. The initial steps of the procedure were directed to the midline where the control of the IVC was considered crucial. While distal caval control was gained rather easily, proximal control required transection of the short veins in the cranial direction, anterior retraction of the caudate lobe, ligation of the adrenal vein, and complete circumferential control of the retrohepatic segment of the IVC for tourniquet safe placement. The right renal vein was stapled and a cavotomy was performed to complete TT removal along with IVC wall (i.e., suspected to be invaded) *en-bloc*. For left-sided tumors, embolization of the main renal artery was advised given that venous disconnection was performed before the left renal artery could be properly secured. The patient needed to be moved to a left side-up position and robot console re-docked to complete left radical nephrectomy. Another important surgical aspect was the circumferential excision of the completely occluded IVC with a GIA stapler to prevent dislodgement and embolization of residual bland thrombus located distally.

Soon after, Abaza *et al.* (69) compiled the experience of nine institutions and reported on 32 cases of level II–III TT using the same principles previously described for the robotic approach, with minor technical variations among different surgeons. Kundavaram *et al.* (70) described another additional technical innovation, including the use of a 9 F Fogarty catheter for TT removal to avoid liver mobilization, and venocavoscopy for residual TT detection before cavotomy closure.

Wang *et al.* (71) presented a robotic approach focused on the spatial relationship between the TT cranial end and the location of the hepatic hilum and major hepatic veins, using a 70º lateral flex decubitus and a 7-port configuration (32). The Pringle maneuver was not required in patients with a level IIIa TT. In the case of level IIIb–d TT, liver mobilization was achieved using the piggyback maneuver and the Pringle maneuver was established before clamping the suprahepatic segment of the IVC under TEE. For left-sided tumors, the patients needed to be repositioned to a left-side up position to complete the left radical nephrectomy. The authors later discuss a challenging scenario of level III–IV thrombi (72), excluding cases in which caval invasion was anticipated.

Hybrid endovascular-surgical approaches

Hybrid approaches utilizing endovascular and open surgical techniques have been described to gain control of the IVC and reduce the risk of pulmonary embolism in resection of high-level TT. Ho *et al.* (73) describe a hybrid method of endovascular proximal IVC control using reliant balloon and Capturex device in a case of right RCC with extension into the right renal vein and intrahepatic IVC. The reliant balloon was selectively placed to occlude the retrohepatic vena cava at the level of the hepatic veins, and the Capturex device was placed 1 cm above the renal veins. They mention that this technique has significant advantages over the conventional open clamping as it avoids the need for intraabdominal dissection to place the clamps, which is particularly useful in cases where the thrombus extends beyond the retrohepatic cava. Fontana *et al.* (74) also describe the use of the Capturex device to perform cavotomy for a case of TT extension 2 cm from right atrium. However, they mention that due to the paucity of free space between the thrombus and right atrium, they could not utilize a reliant balloon for retrohepatic IVC control, therefore they clamped the IVC and suprahepatic veins.

Points in debate and future perspectives

Minimally invasive techniques represent a great advancement in the evolution of the field of urology, however their role in the setting of RCC with TT is of debate and there remains aspects that requires further investigation (75).

The open approach remains the standard treatment to which other technical variations must be compared. In fact, the aim of the laparoscopic and robotic-assisted approaches is to duplicate those principles already established for the open approach that are already proven to be safe, while adding the advantages of the minimal invasion, like smaller incisions, decreased blood loss, less pain, and earlier recovery (76). Although robotic assistance can generate a false sense of simplicity, it does not exclude the surgeon's need for exhaustive knowledge of the anatomy and planning specific to each detailed case. In addition, to obtain an adequate result, precise handling of the technology is required. The surgeon facing this type of intervention needs extensive previous experience in pelvic and retroperitoneal robotic surgery, as well as acquisition of open abdominal and vascular surgery skills. It is worth mentioning that all series currently available are performed by surgeons with extensive experience in both open and laparoscopic approaches, since they have lived through the transition to laparoscopy and robotics (52).

Undoubtedly, robotic assistance allows for increased precision in instrumental management by eliminating the surgeon's hand tremor and providing amplified vision (53). However, it lacks the tactile feedback that open access provides. This fact may represent a problem during the management of such labile structures as the IVC and the TT, whose inadvertent fragmentation often has devastating consequences for the patient. In addition, the proper management of pneumoperitoneum pressure can be complex to adequately balance blood loss and TT dislodgement, particularly when the patient should be re-positioned many times during the procedure.

A limitation of the robotic series published to date include a small number of very selected patients, whose comparison with the larger series in open surgery is still not possible. Although the data are promising, it is still too early to adequately judge the advantages of this type of approach, and data from prospective studies with the required scrutiny will probably not be available for some time given the infrequency of presentation of this entity.

Conclusions

RCC with vascular involvement remains a surgical challenge that has lasted for more than a century. There are few fields in urology that have undergone such a constant evolution over this period of time. Undoubtedly, what in the past was considered an entity doomed to disaster and in many cases frustrating because of its characteristics, today has become a treatable disease process with promising results of potential hope for the patient. This development has been possible thanks to the progress made in all fields of medicine, which has favored a more accurate preoperative diagnosis and better perioperative management. Adequate classification of the anatomical level reached by the TT inside the IVC has facilitated the creation of surgical strategies to be case specific, and on many occasions have obviated the need for access to cavities other than the abdomen or auxiliary procedures such as CPB for its safe and successful resolution. And more importantly, successful and safe management of RCC with IVC TT requires the use of a multidisciplinary team that includes urology oncology, cardiac surgery, cardiac anesthesia, vascular surgery/transplant surgery/surgical oncology, and perfusionists.

Minimally invasive approaches have proved technical feasibility with acceptable perioperative outcomes in selected patients by means of duplicating the surgical principles established for the open approach. Particularly, robotic assistance has overcome the limitations of the pure laparoscopic approach by expanding surgical indication beyond the easiest case. However, this experience comes from a very selected group of both patients and surgeons. Therefore, it is premature to draw any meaningful conclusions apart from the feasibility. Future directions will aim to better duplicate the open approach and prove non-inferiority of this strategy that in no way can be separated from precise pre-surgical planning, proper selection of the candidate, and refined and reproducible technique.

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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