15 Surgery for Renal Cell Carcinoma with Thrombus Extension into the Vena Cava

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Introduction

Since the last edition of this textbook, new, important observations regarding the management of renal cell carcinoma involving the venous system have emerged and will be incorporated into this revised chapter.

Renal cell carcinoma (RCC) has a tendency, within the natural course of progression, to infiltrate into the venous system of the affected renal unit with rates of extension varying between 4% and 10% [1].

Within this subgroup, an additional 1% of patients may have thrombus extending into the right atrium [2]. The increased utilization of imaging studies will no doubt lead to a decrease in these numbers in the future; however, the gold standard of RCC treatment will remain surgical intervention as first described by Robson in 1969 [3].

Although the radiographic appearance of these renal masses and associated tumor thrombus can be alarming, their removal can be performed in a safe and effective fashion by following the surgical tenets to be discussed in this chapter. In addition to discussing the management of these tumors, we will also present the first author's (JAL) personal outcomes data from 359 patients treated with venous tumor thrombi. Despite the tremendous improvements in cancer therapeutics, the basic tenets of surgical oncology have been constant in our algorithm for managing these complicated cases.

Like most malignancies, the outcomes are improved significantly if there is no invasion of the surrounding structures and absence of lymph node metastasis. Studies suggest 5-year survival rates of between 40% and 68% following radical nephrectomy with tumor thrombectomy [4, 5]. The level of tumor extent has been shown in some studies to correlate with survival, and at our institution we have published our results indicating improved survival for patients with renal vein involvement versus involvement of the IVC suggesting the need for revision of the current TNM system, which occurred in the latest revision of the TNM system [6]. Different institutions have devised a variety of categories based on thrombus extension, and for the purposes of this text, we will refer to our employed system. The operative approach for the most part can be based on level of extension: renal vein, infrahepatic IVC, and suprahepatic IVC/atrial. Although a host of'

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authors have proposed a variety of classification systems, the primary outcome in most cases will depend on the biology of the tumor, the surgical experience, and confidence of the surgeon.

Renal cell carcinoma has long been called the internist's tumor because of the myriad of symptoms this particular malignancy can present with (Chart 15.1) [7]. More concerning are the symptoms that tumor thrombi can produce (Chart 15.2). It is also worth noting that surgeons need to become familiar with the venous anatomy of' the kidney and retroperitoneum which can often vary based on collateral drainage associated with venous tumor thrombus (Fig. 15.1).

The presentation and diagnostic evaluation of RCC and tumor thrombus have been described elsewhere in this text and will not be discussed in detail in this section. Some of the more common imaging studies preferred by our group include 3D-CT reconstructions and MRI with dedicated venous phases (Fig. 15.2). MRV can delineate venous extension [31].

Chart 15.1 Clinical manifestations of Renal Cell Carcinoma

Renal cell carcinoma – paraneoplastic manifestations
Stauffer syndrome – elevated liver function tests with fever and hepatic necrosis
Neuromyopathy
Neuromyopathy
Polycythemia – increased erythropoietin production
Hypertension – increased renin production
Elevated erythrocyte sedimentation rates
Anemia of chronic disease
Cachexia and weight loss
Fever of unknown origin
Elevated alkaline phosphatase
Hypercalcemia – increased parathyroid-related hormone/osteolytic bone mets

Chart 15.2 Renal Cell Carcinoma Thrombus-signs and symptoms

Renal cell carcinoma thrombus signs and symptoms
Caput medusae
Pulmonary embolus
Budd-Chiari syndrome (hepatomegaly, abdominal pain, and ascites)
Varicocele
Bilateral lower extremity edema
Proteinuria

between bland and tumor thrombus which assists greatly in surgical planning and often dictates the need to start presurgical anticoagulation to limit the risk of clot embolus. Traditional cavagrams are also performed at the time of preoperative renal artery embolization (Fig. 15.3). Additionally we employ preoperative TEE, and coronary angiography if indicated, to assess the potential for cardiac revascularization which we have occasionally performed concomitantly. The primary goal of preoperative imaging is to determine the level of the tumor thrombus and to evaluate for metastatic disease. Zini and colleagues have suggested that preoperative measurements of renal vein and IVC diameters with associated tumor thrombus can correlate with rates of ostial wall invasion [8]. The presence of metastatic disease does not necessarily preclude an aggressive approach as data has been accumulating to suggest that solitary metastectomy and cytoreductive procedures improved survival rates [9].

Preoperative Renal Embolization

As discussed earlier in this text, we have found preoperative renal artery angioinfarction to be beneficial in dealing with large renal cell carcinomas with tumor thrombus. We prefer to perform our embolization 2–4 weeks prior to planned nephrectomy (Fig. 15.4). The primary purpose of this technique is to provide some insurance against excessive blood loss and to facilitate ligation of the renal vein prior to the artery. In some instances the embolization can result in tumor shrinkage and thrombus regression. The natural response to embolization often creates a moderate degree of edema (tissue hypoxia and necrosis) which can actually enhance dissection around the renal pedicle, especially in patients with extensive hilar adenopathy. This same process can induce tumor necrosis that activates natural killer cells [10, 11]. Embolization success can often be determined by assessing the venous system via renal vein palpation. Postinfarction syndrome (5% of patients) is often characterized by flank pain, fevers, chills, malaise, hematuria, transient hypertension, and hyponatremia [12]. In our

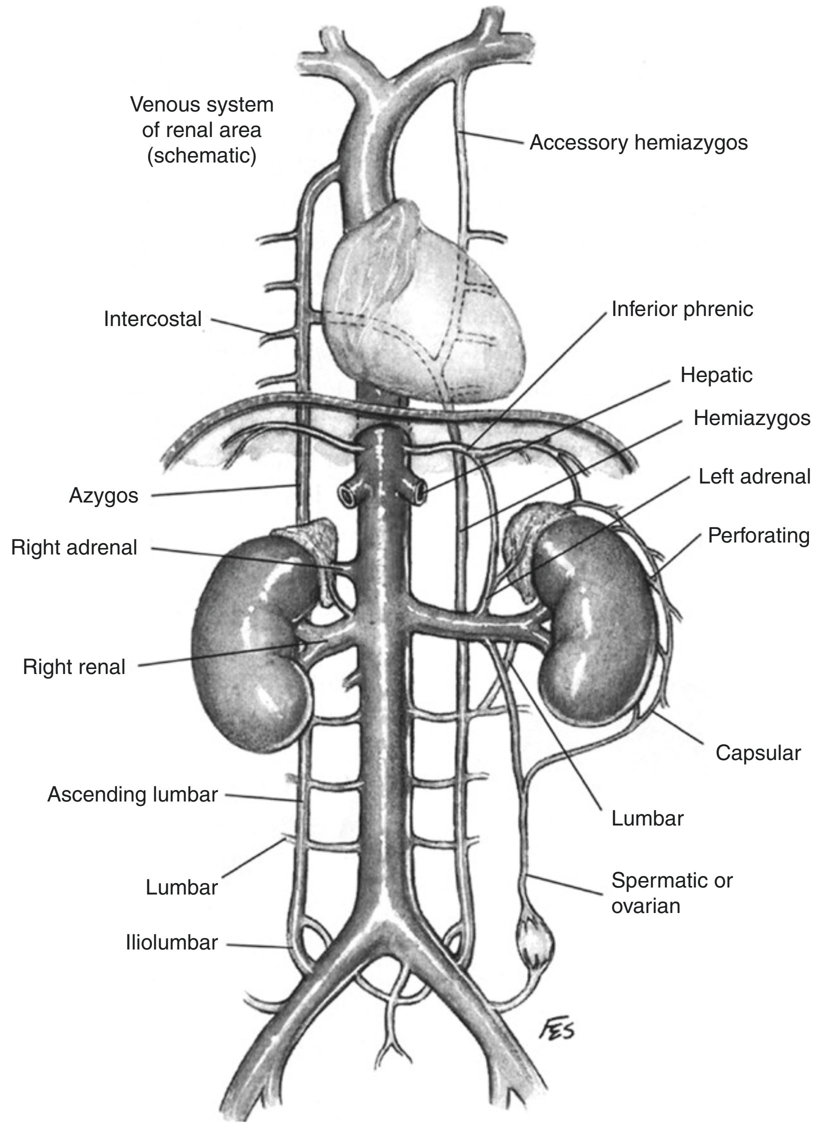


Fig. 15.1 Relevant venous anatomy of the kidney and retroperitoneum

experience younger, healthier patients tend to present with more severe symptoms which may require hospitalization for analgesics and monitoring; however, all symptoms are eventually self-limiting.

Renal Vein Tumor Thrombus

Tumors with renal vein thrombus can be managed with an approach similar to a radical nephrectomy; however, we do advocate a thoracoabdominal incision with generous exposure to provide insurance against blood loss (Fig. 15.5). After exposure is obtained, the kidney and renal pedicle are exposed as well as the inferior vena cava. As mentioned previously the renal artery is palpated to assure that a successful embolization has been completed. The tumor thrombus can usually be palpated and in some instances milked out of the IVC to provide room for placement of two Satinsky clamps at the confluence of the renal vein and IVC. A scalpel is used at the level of the IVC to circumscribe the renal vein ostium, and the Satinsky clamp nearest the renal vein is removed leaving a cuff of IVC above the second

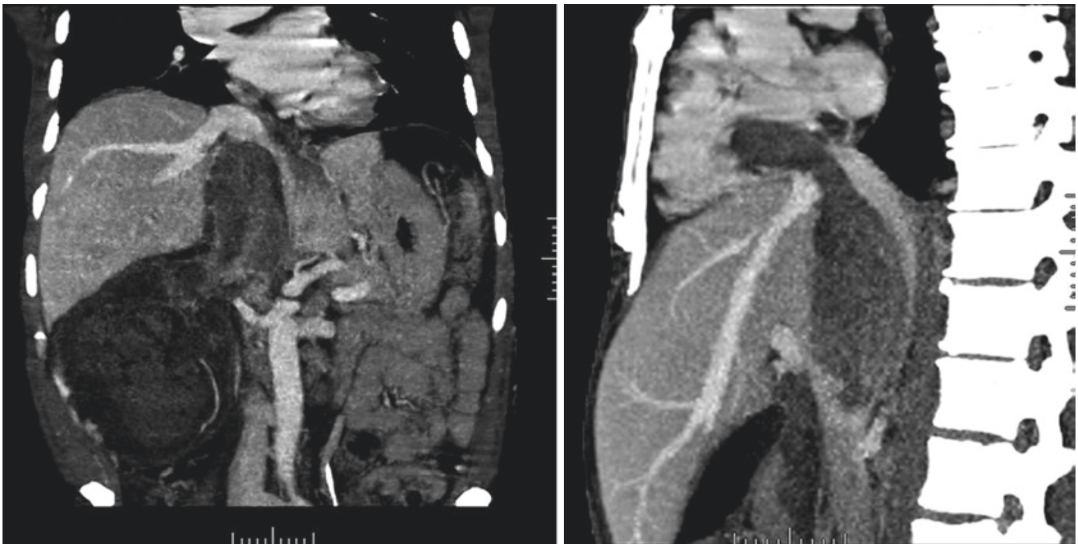


Fig. 15.2 Imaging reconstructions demonstrate extension of a large right renal cell carcinoma with tumor extension into the right atrium

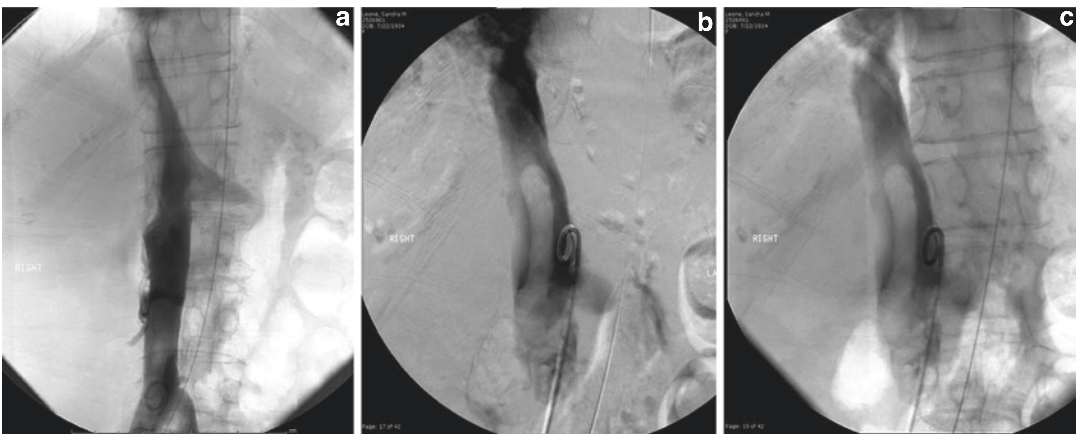


Fig. 15.3 Cavagram series demonstrating thrombus within the inferior vena cava. MRI is used in conjunction to differentiate tumor from bland thrombus

clamp in place to facilitate reconstruction of the IVC with 4-0 polypropylene suture in a running fashion (Figs. 15.6, 15.7, 15.8, and 15.9).

Infrahepatic Tumor Thrombus

As discussed earlier the preoperative imaging is crucial to establish the distal extension of the thrombus and rule out the need for cardiopulmonary bypass. The anesthesiologist should perform transesophageal echocardiography prior to the start of the case. We have published our approach to these tumors multiple times over the past 20 years and still approach most of these thrombi with a thoracoabdominal incision in the majority of cases [13, 14]. Upper pole masses can be mobilized more easily with a thoracoabdominal incision. With left-sided tumors, posing some difficulty because of the length of the renal vein and associated collaterals that tend to develop, these patients will also undergo renal angioin-

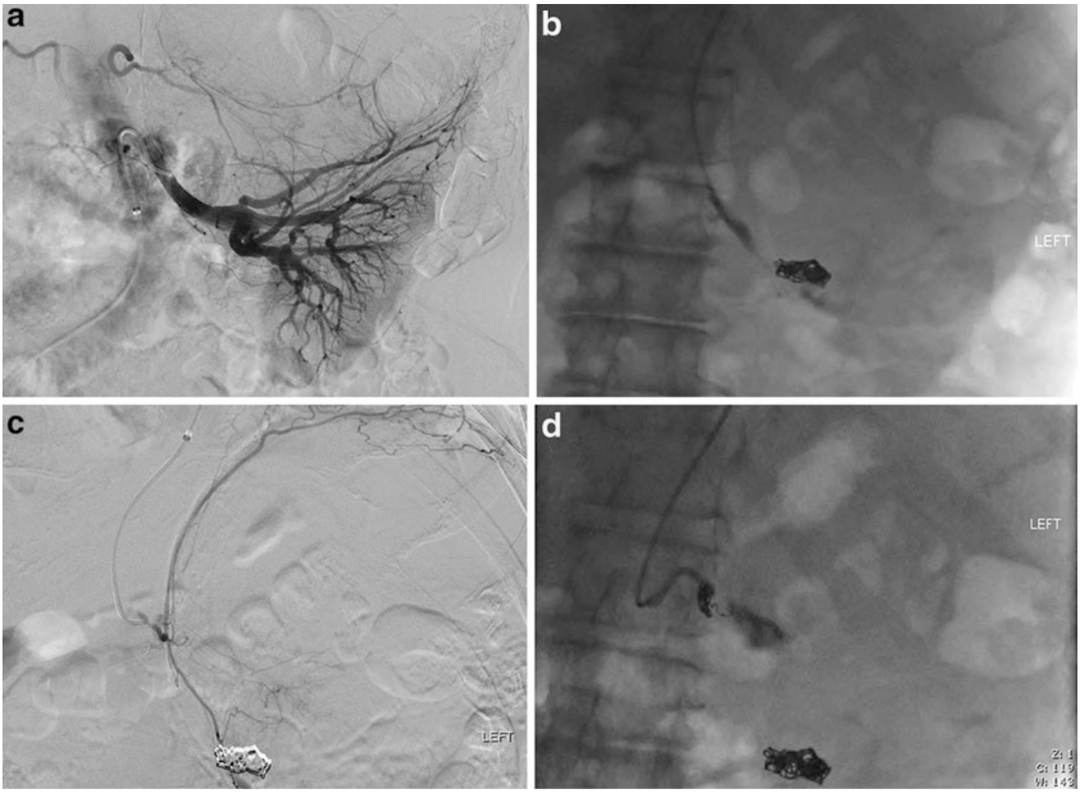


Fig. 15.4 (**a**) Left aortogram demonstrating hypervascular left renal mass. (**b**) Left brachial artery was accessed for embolization of left renal artery using purified ethanol followed by platinum coils. (**c**) Inferior phrenic artery was cannulated and demonstrated tumor vascularity. Embolization performed with purified ethanol and coils. (**d**) Successful embolization of inferior phrenic artery with diminished flow to left kidney

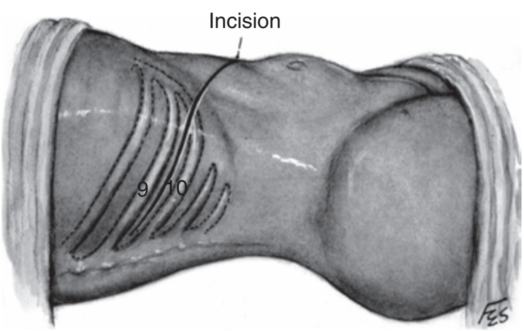


Fig. 15.5 Thoracoabdominal incision for renal vein tumor thrombus. Curve-linear supratenth incision extending to the midline

farction prior to resection. We usually approach left-sided tumors through a chevron incision. It should be mentioned that these cases can be prolonged and the initial placement of Bookwalter retractors must be done with caution to prevent excessive pressure on the bowel and most importantly the liver. A liver hematoma can occur during the case and become somewhat troublesome to deal with at the end of the case. The caudate lobe will need to be exposed and retracted, often exposing the portal hepatis. Perforating minor hepatic veins can be sacrificed with impunity to improve mobility of the caudate lobe and IVC. Simple lacerations to the liver can be treated with argon laser or electrocautery with larger defects requiring Surgicel or Gelfoam bolsters.

Unlike cases involving cardiopulmonary bypass and renal vein thrombi, the portion of the IVC with thrombi should be approached with a "no-touch technique," as much as possible, until the Rummel tourniquet has been placed cephalad and caudal to the thrombus with an additional tourniquet on the contralateral renal vein (Fig. 15.10). Inadvertent injuries to the IVC will

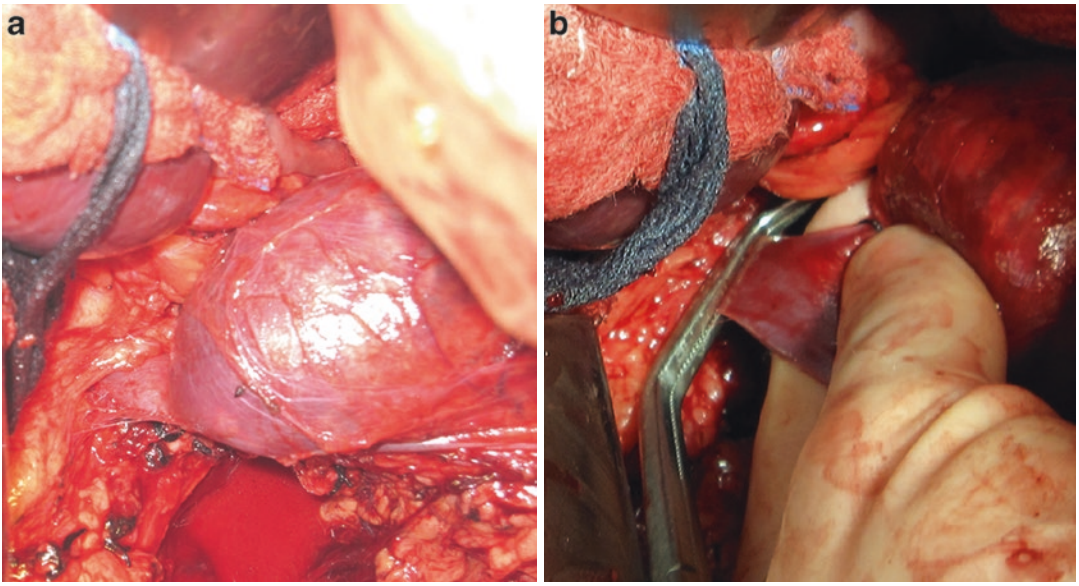


Fig. 15.6 Large renal vein thrombus is milked back to expose the confluence of the RV/IVC for placement of the Satinsky clamp

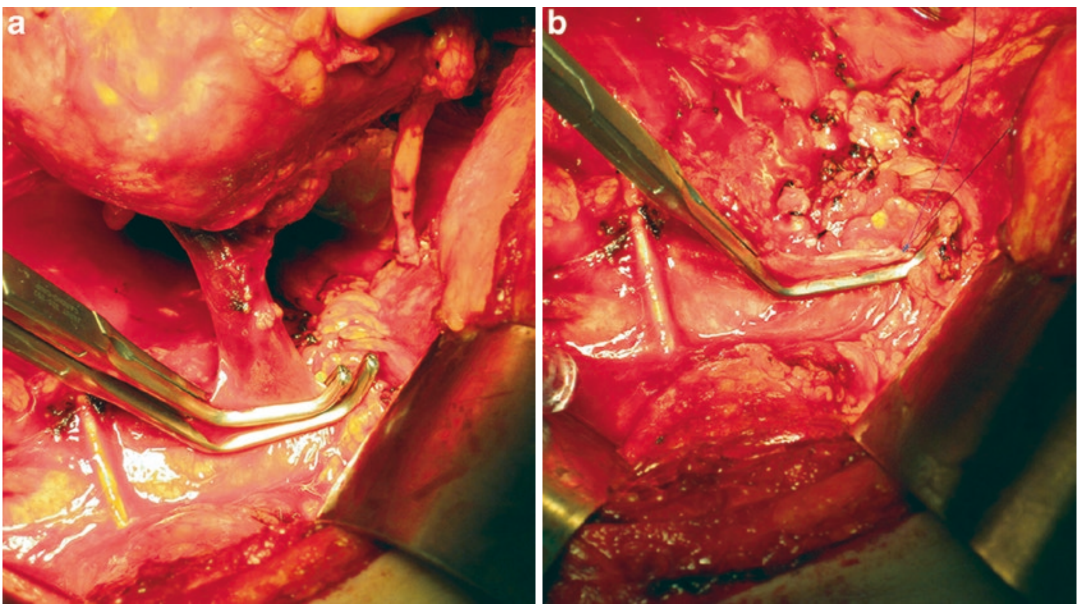


Fig. 15.7 A second Satinsky clamp is placed taking caution not to limit the circumference of the IVC following caval reconstruction

occur if one performs enough resections, and these injuries are best dealt with utilizing gentle pressure proximally and distally. We advocate utilizing sponge spicks for pressure and Allis clamps to reapproximate the defect before oversewing with 4-0 Prolene sutures. Likewise, inadvertent damage to the aorta is best approached with gentle pressure and closure with Prolene figure-of-eight pledgeted sutures and placement of Surgicel or Gelfoam over the repair. A common sense approach when dealing with injuries of large vessels is to avoid making more than one hole at a time.

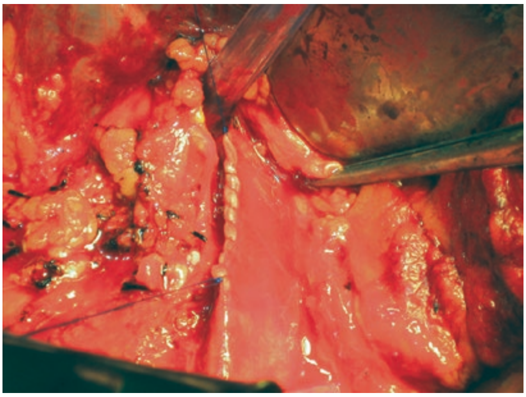


Fig. 15.8 Closed cavatomy with running 4-0 polypropylene (Prolene)

In many instances, preoperative imaging will detect significant lumbar veins that deserve respect during dissection. Once these major venous tributaries are isolated the surgeon can then address the-ipsilateral renal artery. Although our colleagues in radiology have certainly perfected the embolization technique, we still palpate the renal artery to rule out incomplete embolization. If any question exists, one can utilize intraoperative Doppler. If there is still concern we strongly advocate isolation, ligation, and division of the renal artery before tumor thrombectomy with large Hem-o-Lok clips-or Suture ligation.

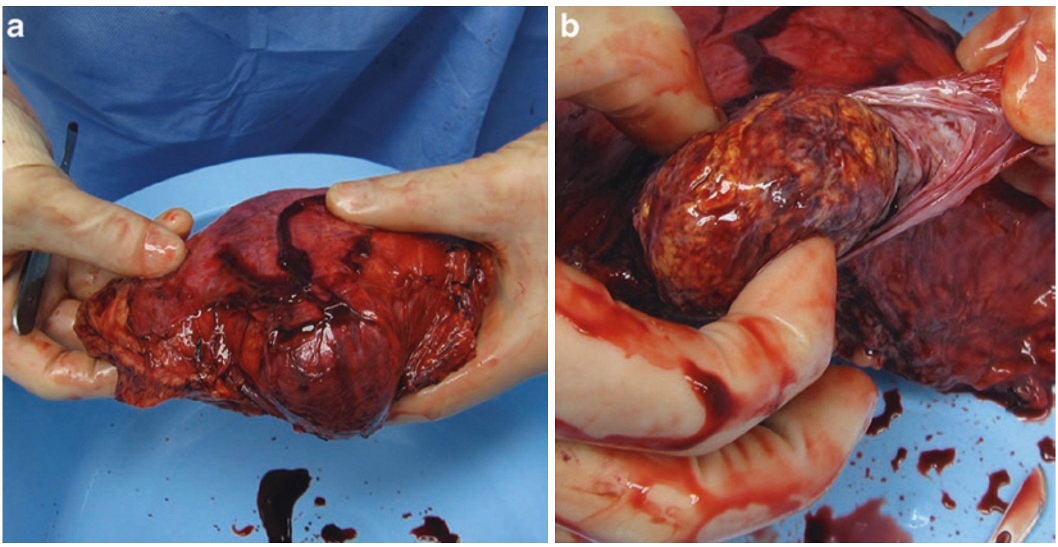
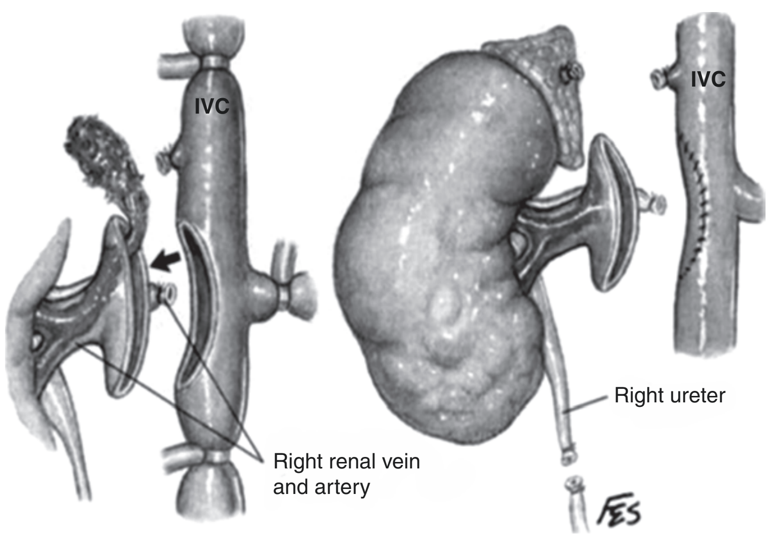


Fig. 15.9 Kidney specimen with thrombus in the renal vein

Fig. 15.10 Removal of infrahepatic tumor thrombus demonstrating placement of the Rummel tourniquets. Occasionally large lumbar veins will need to be dissected and treated with tourniquets as well



Tumor thrombectomy should only be started after the arterial supply has been addressed with ligation and division or successful embolization. Before making the cavatomy, we like to take a moment to reassess all our tourniquets and have the attention of operating room staff in case of unexpected blood loss. Once the tourniquets are tightened, we start with, a simple anterior longitudinal "hockey-stick" cavatomy with Potts scissors over the thrombus (Figs. 15.11, 15.12, 15.13, 15.14, 15.15, 15.16, and 15.17). Once there is adequate exposure, a small spatula or narrow 1/8-in malleable ribbon is used to free the thrombus from the caval wall. Significant back bleeding following cavotomy is almost always due to a missed lumbar vein. An Allis

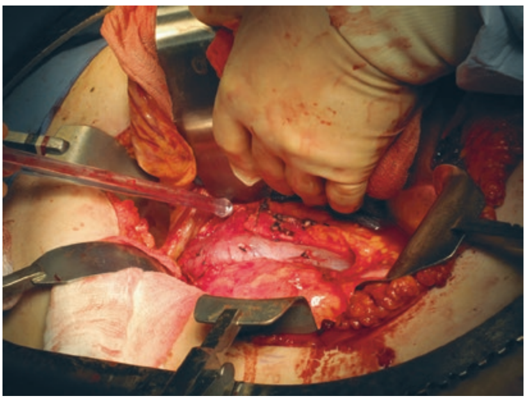


Fig. 15.11 Left renal cell carcinoma with tumor thrombus at the renal vein confluence. Patient had a previous caval filter placed precluding atraumatic placement of Satinsky clamps

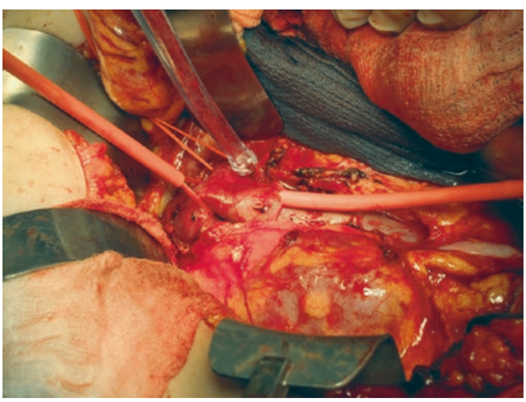


Fig. 15.12 Smaller *red* vessel loop in foreground isolated the contralateral retrocaval right renal artery. The caudal Rummel tourniquet is around the proximal portion of the inferior vena cava above the previous filter. Cephalad Rummel tourniquet encompasses the suprarenal IVC and contralateral right renal vein

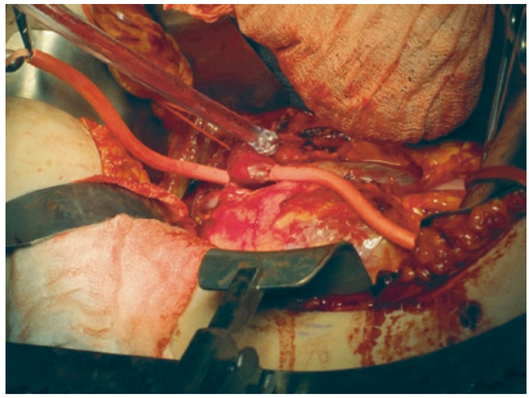


Fig. 15.13 Rummel tourniquets are cinched in place in preparation for anterior longitudinal cavatomy

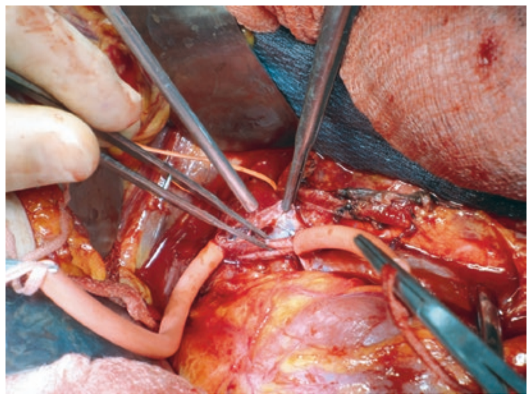


Fig. 15.14 Cavatomy demonstrates IVC filter

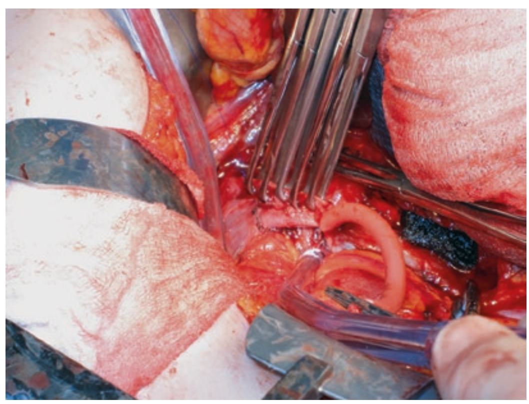


Fig. 15.15 After removal of thrombus and ligation of the left renal vein, Allis clamps are utilized to reapproximate IVC prior to reconstruction

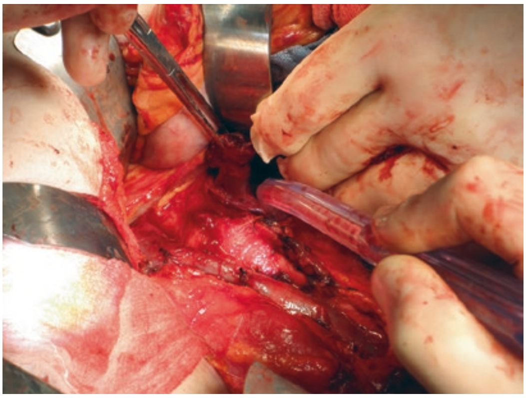


Fig. 15.16 Left renal vein with tumor thrombus noted in the lumen. Cavatomy has been closed with running 4-0 Prolene suture

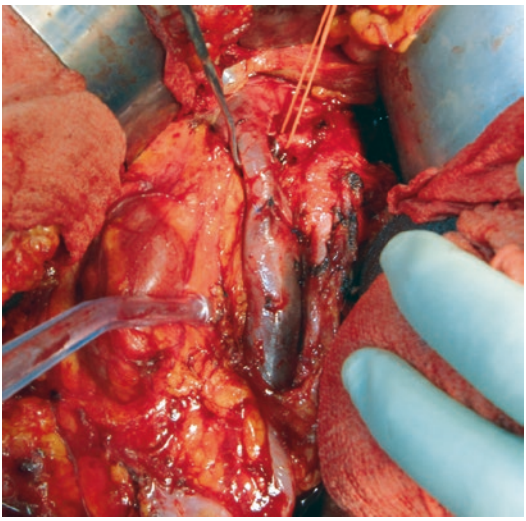


Fig. 15.17 Closed cavatomy

clamp can serve as a tag while placing figure-of-eight stitches, in some cases; however, if the vein retracts, one must be prepared to place large figure-of-eight sutures into the musculature.

After the tumor thrombus has been cleared the caval wall should be inspected for any evidence of invasion. Although the infrarenal and suprarenal IVC can be resected, in some cases, we do advocate primary repair with PTFE grafts or a pericardial patch. Prior to completing the primary caval closure the Rummel tourniquets are released sequentially starting at the infrarenal position to purge the system and minimize embolus risk. A running 4-0 polypropylene (Prolene) is our suture of choice. The inferior vena cava can be reapproximated primarily as long as the circumference is maintained at above 50% of its original size. Suture line bleeding can be managed with placement of Surgicel over the incision. After the cavatomy is closed, we then proceed with a standard radical nephrectomy.

Retrohepatic, Supradiaphragmatic, and Atrial Tumor Thrombus

Our experience with hypothermic circulatory cardiopulmonary bypass is one of the largest in the literature and remains our gold standard for resection of tumors at or above the major hepatic veins or within the right atrium [13, 14, 17]. In addition to describing our technique, we would also like to highlight other surgical techniques utilized by our contemporary colleagues in managing these complex cases via an intra-abdominal approach focusing on maximizing mobilization of the right lobe of the liver.

Venovenous Bypass (Caval-Atrial Shunt)

Our colleagues have reported their utilization of venovenous bypass for caval tumor thrombectomy in patients not able to tolerate the loss of cardiac output (hypotension) associated with cross clamping and whose tumor thrombus is nonadherent, and fails to extend into the right atrium [15]. The vena cava is mobilized and controlled at the infrarenal level, at the level of both renal veins and the intrapericardial portion. With adequate control a 20-F venous cannula may be placed in the IVC caudal to the tumor thrombus. An 8–14 F cannula is then inserted into the right brachial vein or right atrium for venous return. The cannulas are connected to an electromagnetic centrifugal pump, and bypass is initiated to maintain flow to the right side of the heart. Hepatic venous bleeding can be quite bothersome with this technique and may be addressed with a Pringle maneuver for a total of 45 min. Likewise the major hepatic veins can also be cross clamped if necessary. Additional bleeding is sure to arise from the lumbar/azygous systems and can be difficult to control; however, it may be a necessary risk to take in those patients unable to tolerate cross clamping of' the caval system.

Liver Mobilization

We initially reported our technique and results of mobilizing the liver by dividing the triangular and coronary ligaments to facilitate exposure of the retrohepatic IVC in the 1980s [13, 14]. We have utilized this technique successfully in many patients with retrohepatic tumors extending to the level of the hepatic veins and the intrapericardial IVC. We are delighted that our colleagues at other major institutions have published equivalent results utilizing similar liver mobilization techniques that expose the retrohepatic IVC, allowing access to the IVC at the level of the hepatic veins or just above. Ciancio and colleagues at the University of Miami have utilized a technique similar to the one we originally described, dividing the ligaments (falciform, triangular, superior coronary, and ligamentum teres) and utilizing the Pringle maneuver via the foramen of Winslow [16] (Figs. 15.18 and 15.19). Following these steps, the major hepatics are the only structures in continuity with the IVC. Tumor thrombus can be gently milked below the hepatics in some instances without the need for bypass, unless there appears to be invasion of the hepatic venous system, the thrombus extends into the atrium, or there is concern that the thrombus has invaded the supradiaphragmatic wall of the IVC. The essential maneuver in this approach is to displace the tumor thrombus below the hepatic veins to avoid liver congestion.

Russo and colleagues at MSKCC have published their experience with off-bypass techniques for the removal of tumor thrombus in 78 patients between 1989 and 2009. Authors here also utilized venovenous bypass and liver mobilization techniques as previously described to remove suprarenal tumor thrombus, concluding that retrohepatic (n = 7) and suprahepatic (n = 3) tumor thrombus could be removed without the need for bypass.

Traditional Cardiopulmonary Bypass (Median Sternotomy)

At our institution [17] we utilize a chevron incision to evaluate tor any metastatic disease that may have been undetected by preoperative imag-

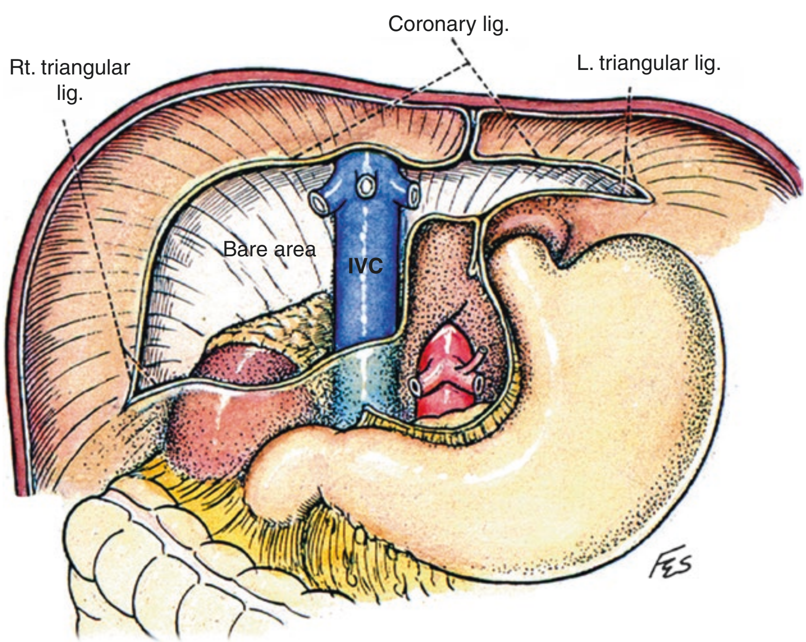


Fig. 15.18 Anterior schematic of the infrahepatic IVC demonstrating the relationship between the major hepatic veins and the diaphragm

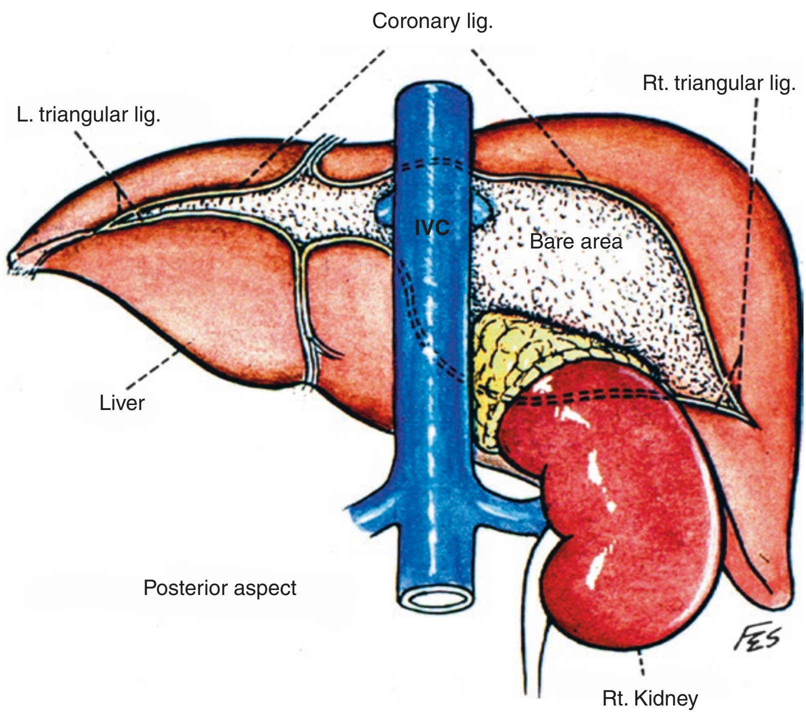


Fig. 15.19 Posterior view of the IVC

ing. A Kocher maneuver is performed to expose the infrarenal IVC and interaortocaval region. The retrohepatic IVC is exposed with a Langenbeck maneuver (liver mobilization cephalad and to the left by division of the right triangular and coronary ligaments) (Fig. 15.20). The kidney is mobilized with the exception of the renal vein and tumor thrombus paying close attention to hemostasis (Figs. 15.21 and 15.22). The renal artery is divided with a pair of Hem-O-Lok clips and a 0-silk suture leaving the renal vein as the sole attachment [17]. Any significant bleeding will be exposed and difficult to control following systemic heparinization for cardiopulmonary bypass. After the kidney has been mobilized, the entire inferior vena cava is exposed to the level of the diaphragm and distal to the common iliac bifurcation. The contralateral renal vein is also exposed to avoid damage during the cavatomy. Utilizing this approach mandates complete mobilization of the IVC in order to secure complete hemostasis, and avoid bleeding from anticoagulation necessary to initiate cardiopulmonary bypass. An undesirable consequence of this approach is that the complete mobilization of the IVC exposes the patient to a greater risk of a pulmonary embolus than the minimal access approach to be discussed in the next section.

At this time the patients are placed on systemic heparin and traditional bypass initiated with cannulation of the ascending aorta providing arterial return and venous drainage by means of the superior vena cava and right common femoral vein. Thiopental and methylprednisolone are administered as the core temperature is cooled to 18–20 C and the head and abdomen are packed with ice. Approximately 95% of the blood volume is removed providing an essentially bloodless operating field for at least 40 min before neurological sequelae can develop. Retrograde cerebral perfusion or utilization of trickle flow rates between 5 and 10 ml/kg per minute can exceed this length of time.

Next the right atrium is opened and distal control obtained, and any atrial thrombus may be removed to prevent any embolic events during the cavatomy and removal of the infradiaphragmatic tumor thrombus (Fig. 15.23). After distal control is obtained, an anterior cavatomy is made from the renal vein ostium to the level of the minor hepatic veins above the caudate lobe of the liver. The thrombus is removed with patient in

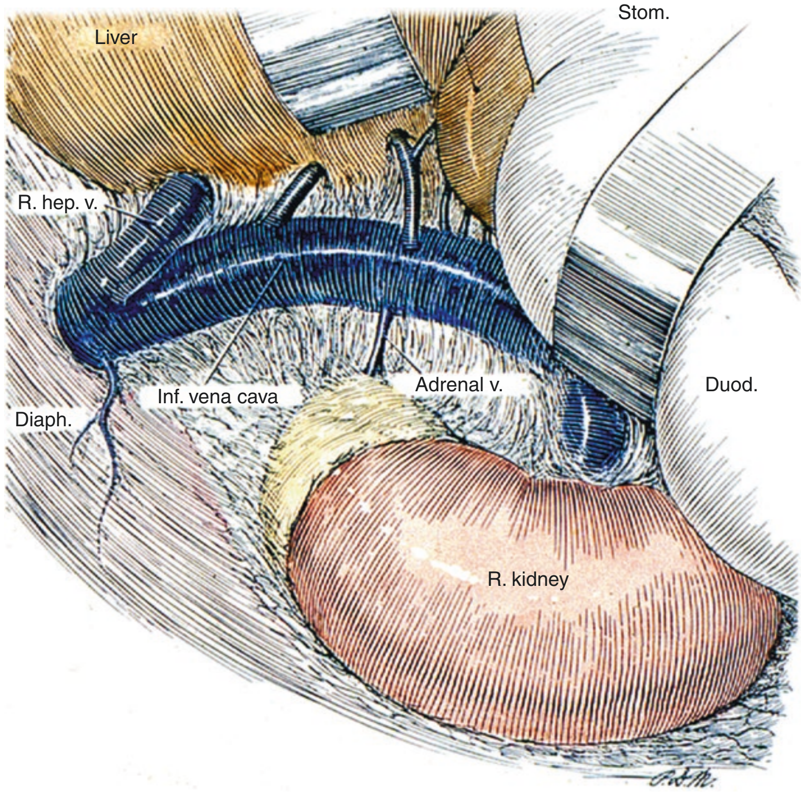


Fig. 15.20 Langenbeck

Trendelenburg's position and using positive pressure respirations. Ideally, the thrombus and the kidney are removed as one unit. Venacavascopy can be performed via the right atriotomy or the cavatomy from below to assure complete clearance of the thrombus, The cavatomy is closed with a running 4-0 Prolene suture (Figs. 15.24, 15.25, 15.26, and 15.27). This approach has been replaced, in our practice, completely by the minimal access approach discussed in the next section. If there is a need for coronary revascularization the traditional approach should be employed.

Cardiopulmonary Bypass (Minimally Access Approach)

First described at our institution in 1998 [18], we have adopted this technique in all patients requiring cardiopulmonary bypass in an effort to shorten the length of surgery and improve postoperative outcomes (decreased mechanical ventilation support and transfusion rates). Following a chevron incision, the IVC is only exposed along the anterior surface without mobilization of the IVC or the kidney; thus reducing the possibility of a pulmonary embolus. At this point, the CT surgeons begin with a 3-cm infraclavicular incision to mobilize and isolate the right subclavian artery. A right 3-cm transverse parasternal incision is made over ribs 3–5, and the respective cartilage is divided and the right internal thoracic artery may require ligation. A pericardial incision is made, and stay sutures are placed in the right atrium in anticipation for a formal atriotomy. An 8-mm synthetic graft is anastomosed to the right subclavian artery as systemic heparinization is instituted. A two-staged venous cannula is inserted into the right atrium and directed into the superior vena cava tor venous return.

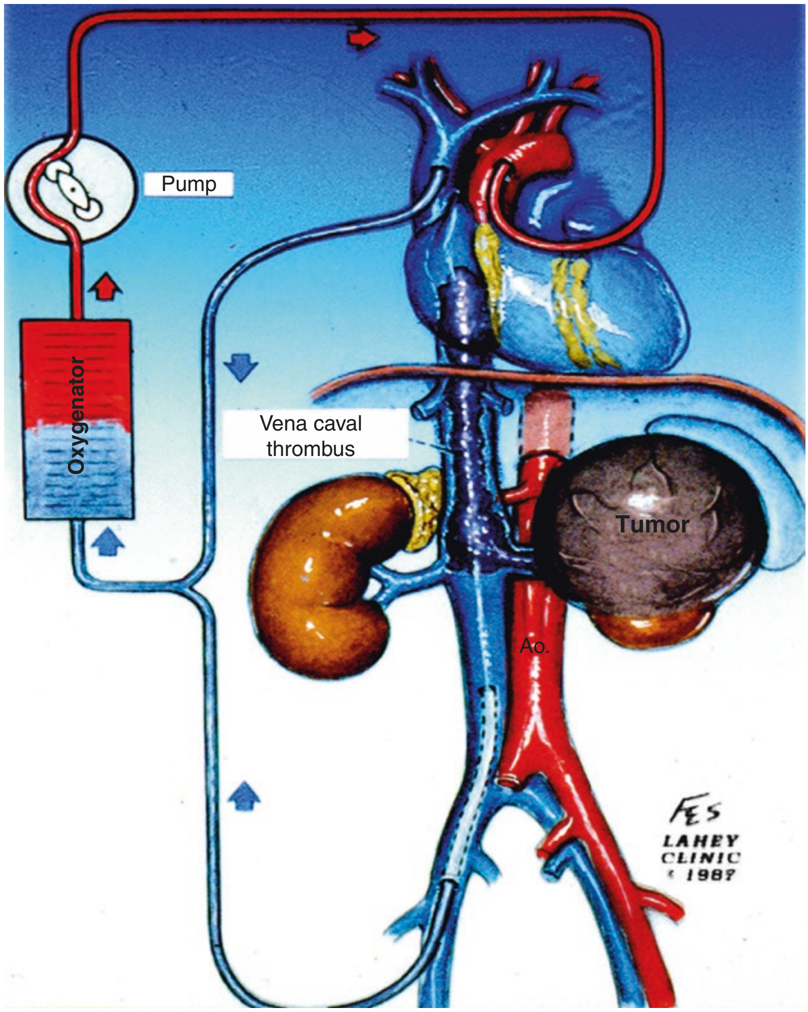


Fig. 15.21 Traditional cardiopulmonary bypass

Cardiopulmonary bypass and deep hypothermic circulatory arrest are initiated as discussed earlier (Fig. 15.28). After appropriate cooling, a formal atriotomy is made and any distal tumor thrombus is extracted. Complete mobilization of the IVC is performed again paying attention to potential bleeding that will resurface during rewarming while heparinized. A cavatomy is performed and the tumor thrombus removed as described in previous sections. Radical nephrectomy is performed, after the IVC is closed, while the patient is being rewarmed and protamine sulfate, fresh frozen plasma, platelets, and desmopressin are administered in order to offset coagulopathies.

Comparative Effectiveness of Median Sternotomy Versus Minimal Access Cardiopulmonary Bypass and Circulatory Arrest for Resection of Renal Cell Carcinoma with Inferior Vena Caval Extension

We recently published our outcomes of cardiopulmonary bypass using the traditional median sternotomy vs minimal access surgery for patients with RCC above the level of the hepatic veins [27, 28]. From 1986 to 2012, 70 radical nephrectomies with concomitant inferior vena cava (IVC) thrombectomies were performed at our institution using median sternotomy ($n = 23$ patients) and minimal access ($n = 47$ patients) techniques. Preoperative patient characteristics, pathologic data, and organ-specific postoperative

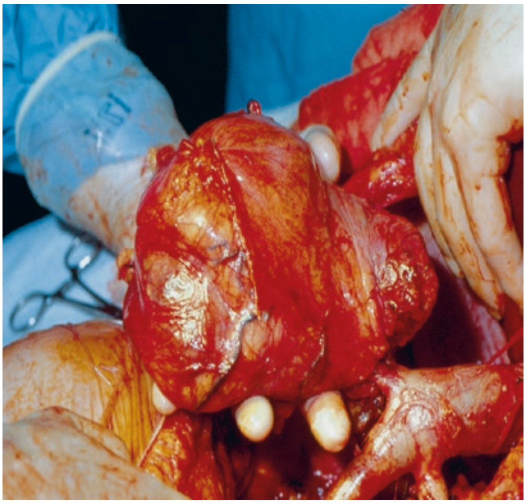


Fig. 15.22 Complete mobilization of the affected kidney with traditional cardiopulmonary bypass

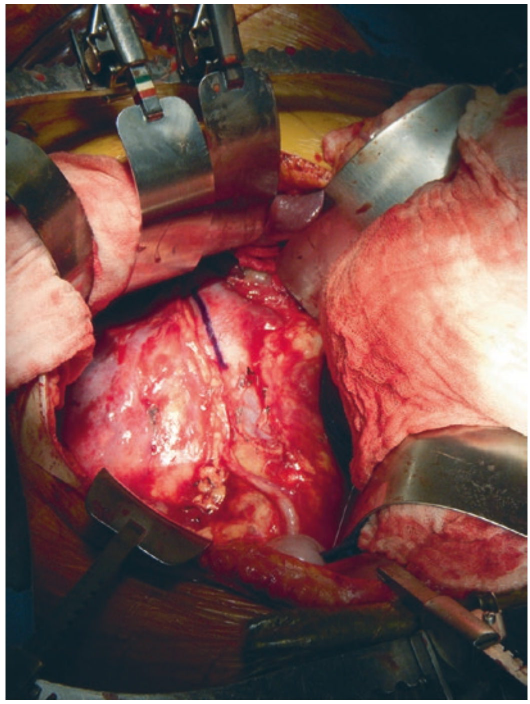


Fig. 15.24 Planned anterior longitudinal cavatomy for larger right renal cell carcinoma with caval tumor thrombus

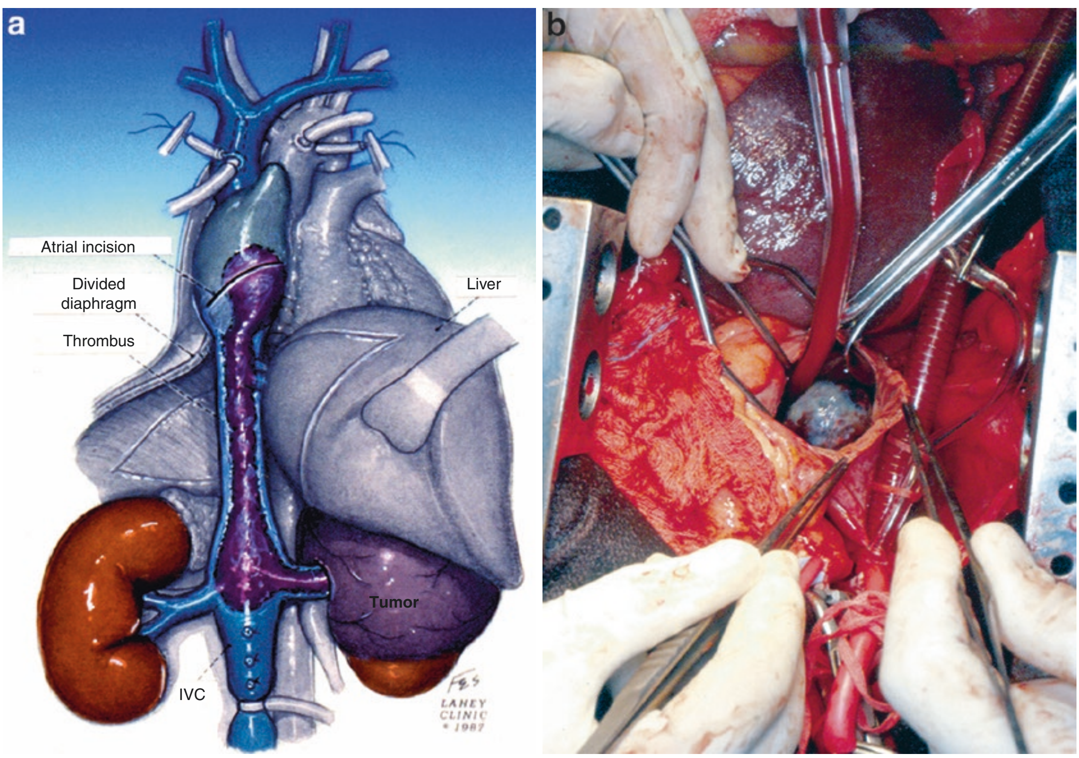


Fig. 15.23 Right atriotomy demonstrating tumor thrombus in the right atrium

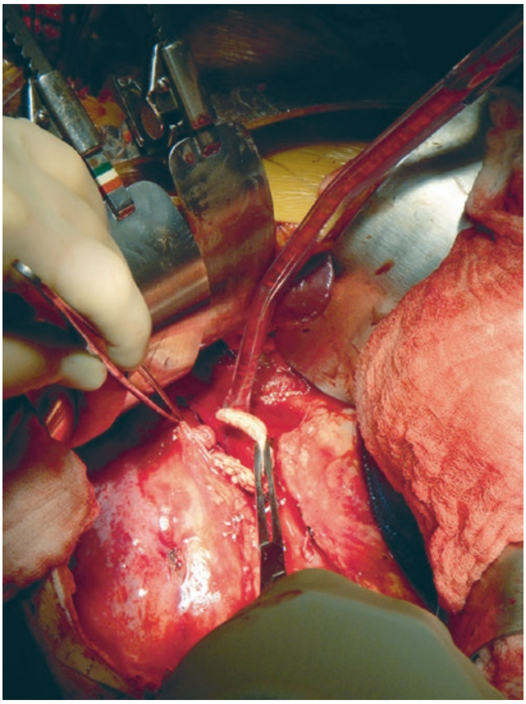


Fig. 15.25 Following cavatomy the thrombus is removed with a pair of forceps and the caval wall is inspected for invasion

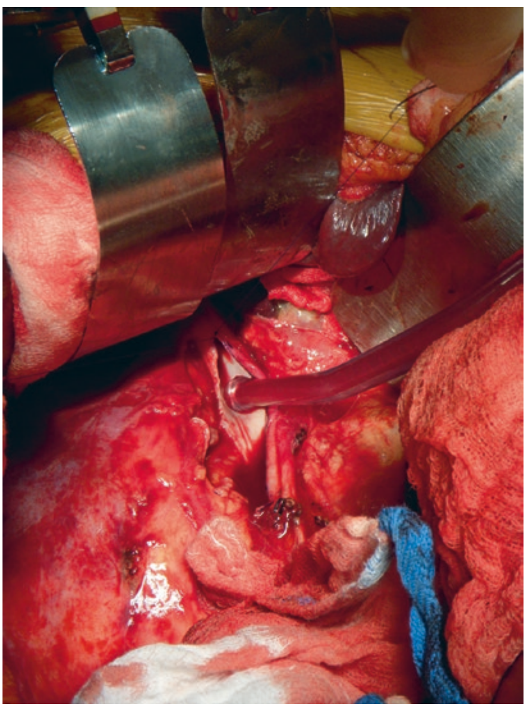


Fig. 15.26 The caval wall is inspected for any of caval wall invasion. A running 4–0 polypropylene suture is started at the cephalad portion of the cavatomy

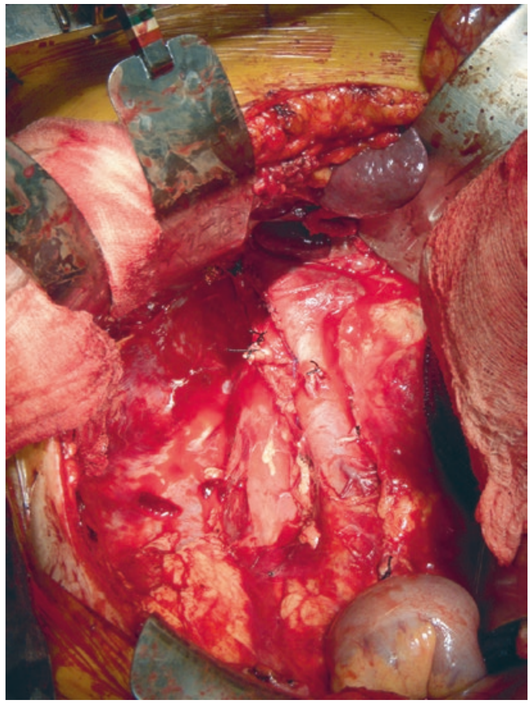


Fig. 15.27 The renal artery is double ligated with 0-silk suture and the cavatomy is closed without significant reduction in the lumen diameter. The gonadal vein has been sacrificed in the foreground

complications and follow-up data were compared between these groups. Estimates of overall and recurrence-free survival were constructed using Kaplan-Meier curves and compared using log-rank testing.

There were no significant differences with respect to patient demographics or preoperative comorbid conditions between the minimal access (MA) and median sternotomy (MS) groups. The MA group showed a significant reduction ($P < 0.05$) in the duration of postoperative mechanical ventilation, length of ICU and hospital stay, operative time, and number of blood transfusions compared to MS patients. Overall and organ-system-specific complications demonstrated a decreased incidence of wound infection (37.9% v. 12.5%, $P = 0.0135$) and sepsis (14.3% v. 0%, $P = 0.0137$) in patients undergoing the MA approach. Perioperative mortality was significantly reduced in the MA group (30.4% v. 8.5% $P = 0.0179$). Recurrence-free survival in the MS group was 0.59 years and 1.2 years in the MA group ($P = 0.06$).

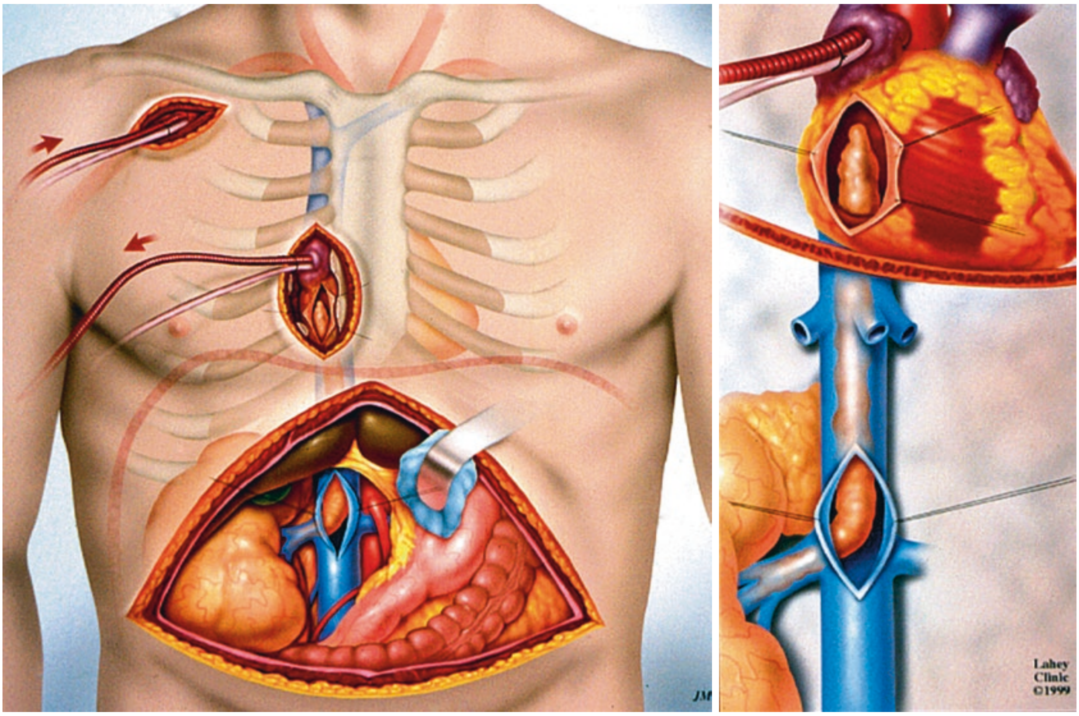


Fig. 15.28 Minimally invasive cardiopulmonary bypass for removal of a large right renal mass with tumor thrombus extending to the right atrium. Schematic demonstrates right subclavian artery graft and right atrial venous cannulation

For all of the abovementioned reasons, we no longer perform the traditional median sternotomy approach and clearly prefer the minimal access surgical approach for cardiopulmonary bypass (CPB) and deep hypothermic circulatory arrest (DHCA) during the resection of RCC with extensive tumor thrombus, because it provides similar oncologic control with decreased duration of mechanical ventilation, length of stay, and infection-related complications. We believe that our findings suggest that MA techniques provide significant advantages over MS and suggest its use to our surgical colleagues as safe and effective.

Occluded Vasculature Management

In certain situations, there may be extensive tumor thrombus involving the contralateral renal vein, hepatic veins, or common iliac veins. In certain situations the thrombus may be of a bland vascular nature, secondary to venous stagnation, and is often easiest removed with gentle flushing. For adherent clot, we recommend using Fogarty balloon catheters for removal. In theory, one could also utilize endoscopy techniques with stone basket retrieval systems although we have yet to personally perform this procedure. Bland thrombus is often more difficult to remove from the venous System because of its gelatinous nature and adherence.

Caval Wall Resection and Caval Interruption

Regardless of the level of the tumor thrombus, one must inspect the caval wall for suspected invasion and perform a partial or complete resection. Studies suggest that invasion may be present in up to 23% of cases with the majority occurring at the renal vein ostium [13, 14, 19]. Caval reconstruction can be performed with synthetic patches (polytetrafluoroethylene) or biological substitutes (autologous saphenous vein or pericardial patches). During a right radical nephrectomy, the IVC can be ligated or resected, provided the left renal vein is sacrificed distal to the gonadal, lumbar, and adrenal tributaries. Left renal masses with associated thrombus can undergo suprarenal IVC ligation following procedures to extend right venous outflow (autotransplantation or saphenous interposition vein graft to the splenic, portal, or inferior mesenteric vein).

Minimally Invasive Techniques and Tumor Thrombectomy

Renal cell carcinoma with tumor thrombi limited to the renal vein can be treated with pure laparoscopic approaches in many instances, if room is available to place Hem-O-Lok clips without compromising the vena cava or risking a thrombotic event [20]. Laparoscopy has been utilized in the past with hand-assist for removal of IVC tumor thrombi, utilizing intraoperative ultrasound to identify the extent of the tumor thrombus [21]. Hand-assist provides a tactile advantage over pure laparoscopy that is crucial in some cases to confirm ultrasound estimates of tumor thrombus and assist in placing clamps involving the inferior vena cava. The Ohio State University group has published their results utilizing the da Vinci robot to treat five patients with tumor involving the inferior vena cava [22]. While other reports in the literature have explored the possibility of robotic radical nephrectomy and IVC thrombectomy and reconstruction, in my opinion, the risks outweigh the benefits of this approach. In addition, in my experience, the very large size of most of the renal tumors, in general, obviates the benefits of the minimally invasive approach for this clinical problem.

A Novel Approach: Combination of Interventional Radiologic Tumor Extraction and Surgery

A 54-year-old male, with a right renal cell cancer and IVC thrombus at the cavoatrial junction, unfortunately developed a pulmonary embolus 2 weeks before being referred to us for surgery. Following our evaluation, the cardiothoracic surgeons were concerned about the possibility of a massive cytokine release from recently infarcted lung tissue resulting in death that might occur after cardiopulmonary bypass and circulatory arrest. The tumor was angioinfarcted and the patient heparinized, in an effort to delay the needed surgery for 3 months. In spite of angioinfarction the patient began having severe gross hematuria requiring transfusions. He was reevaluated, and we found that the IVC thrombus grew into the right ventricle. This critical situation demands a creative, novel approach. In conjunction with our interventional cardiologist, we were able to place the patient on an extracorporeal oxygen membrane (ECMO) device, whereupon the cardiologist extracted the tumor thrombus down to the level of the renal vein. We were then able to do a radical nephrectomy and IVC thrombectomy without the need to resort to cardiopulmonary bypass and circulatory arrest, thus avoiding the expected massive cytokine release. The patient did extremely well, and he is NED 3 years following surgery [29].

A link to the video of this procedure is listed below.

This novel approach, that of combining interventional removal of tumors above the diaphragm with radical nephrectomy and IVC thrombectomy, may create a new paradigm for the management of supradiaphragmatic tumors in properly selected patients.

Partial Nephrectomy and Tumor Thrombus

Radical nephrectomy (RN) with/without thrombus excision (ThE) is the undisputed standard treatment for kidney cancer (KC) with renal and/or caval thrombus (Th). However, partial nephrectomy (PN) ± ThE may be considered in rare cases when imperative indications exist.

The International RCC-IVC tumor thrombus consortium, founded in 2007, retrospectively reviewed our database of 3000 patients undergoing surgery for RCC with tumor thrombus at 23 institutions between 1971 and 2014. Primary outcomes analyzed were overall (OS) and cancer-specific survival (CSS), renal function variation after surgery, and complications. Secondary outcomes were predictors of OS and CSS for imperative partial nephrectomy cases (IPN). To reduce bias the IPN group was matched with the RN using a propensity score with greedy algorithm on the basis of age, gender, tumor size, TNM, and histology.

Forty-two patients, reported by Giancarlo Marra and associates, underwent imperative partial nephrectomy and tumor thrombectomy. All thrombi were ≥level I; five patients experienced Clavien ≥3 complications with two complication-related deaths. At 27.3 (IQR = 7.1–47.7) months OS and CSS were 54.8% and 78.6%, whereas at 9.7 (IQR = 1.4–43.7) months eGFR change was −17.3 ± 27.0 mL/min. On univariate analysis tumor size, preoperative eGFR, transfusions, hospital stay, high serum creatinine, operating time (OT), complications, lymphadenectomy, and metastases related to an increased risk of death. After matching (n = 38 per arm) no significant differences were present except for tumor necrosis (IPN 39.5%; 15.8%; $P = 0.01$), thrombus level ($P = 0.02$)**,** so too for OT ($P = 0.27$), peri-operative transfusions ($P = 0.74$), and complications ($P = 0.35$). Five-year OS and CSS for imperative partial nephrectomy (IPN were 57.9% and 73.7% respectively with no significant differences with RN (OS 63.2 $P = 0.611$; CSS 68.4 $P > 0.99$). After 14.9 months creatinine and eGFR changes were (+0.4 ± 0.6 mg/dL and − 23.2 ± 37.3 ml/min; $P = 0.2879$). It would appear that in unusual, highly selected cases due to imperative indications, partial nephrectomy and tumor extraction may be an alternative to radical nephrectomy, and tumor extraction for RCC with tumor thrombus, yielding noninferior oncological outcomes, functional outcomes, and complications. Further studies are needed to determine the role of partial nephrectomy and thrombus extraction (PN ± ThE) for RCC patients with a tumor thrombus [30].

At our institution we have an extensive experience utilizing partial nephrectomy to preserve renal function, and have done several partial nephrectomies with renal vein involvement with good results; however, we would only advocate this approach with tumor thrombus in patients with imperative indications for partial nephrectomy, or with tumor involving the major branches of the renal vein with a patent main renal vein, or in a patient with a solitary kidney. However the work of the International consortium, as well as Kim and colleagues, who described two surgical cases with solitary kidneys and tumor thrombus in the renal vein that were spared hemodialysis and remained disease-free at 9 and 24 months, respectively, is noteworthy [23]. We applaud these outcomes; however, we recommend that surgeons undertaking this approach be familiar with extracorporeal bench surgery and renal autotransplantation.

Neoadjuvant Chemotherapy and Tumor Thrombus

As discussed earlier, on rare occasions thrombus in the renal vein or IVC has dramatically decreased in size with the neoadjuvant use of improved chemotherapeutic agents and has resulted in downgrading in some instances. The hypervascular nature or these tumors makes them ideal targets for vascular endothelial growth factor (VEGF) inhibitors. A report from Takeda and colleagues discusses a case in which Sorafenib was used presurgically resulting in a 43% regression in the size of the tumor thrombus, which retracted into the renal vein from the vena cava allowing nephrectomy to proceed [24]. Rini and colleagues recently published supportive phase II trial data in patients with renal vein or IVC extension with tumor shrinkage after neoadjuvant Sunitinib for locally advanced renal cell carcinoma [25]. Data from current investigational studies will help determine the appropriate timing of nephrectomy.

Tumor Thrombectomy and Metastectomy

Metastatic RCC has been shown in some patients to disappear following removal of the affected kidney, a concept known as the Lazarus effect. At our institution, we advocate removal of accessible pulmonary metastatic disease when possible. In most instances a pulmonary metastectomy, first described by Barney and Churchill, for anterior lower lobe lesions is concomitantly performed with nephrectomy utilizing endovascular staplers and Doyen clamps [26]. We remain optimistic that nonpulmonary metastatic sites may become amenable to resection as we continue to see great strides in molecular targeted chemotherapeutic agents. Our colleagues at the European Organization for Research and Treatment of Cancer are randomizing patients with metastatic disease to neoadjuvant Sunitinib followed by nephrectomy and vice versa.

Personal Experience

The senior surgeon (JAL) of our group has treated 359 patients with renal cell carcinoma and renal vein or caval tumor thrombus. Tumor thrombus level of extension and survival outcomes data are illustrated in Figs. 15.29, 15.30, 15.31, 15.32, and 15.33. Our patient population includes a 2/3 male predominance with an average age of 62. Our complication and survival rates are well within the average of our contemporary colleagues at other major centers. One of our major contributions to managing these complex cases has been the implementation of a minimally invasive approach for cardiopulmonary bypass resulting in decreased blood loss, length of mechanical ventilation, analgesic requirements, duration of surgery, and hospital stay [28].

Another area of involvement in which we have personally participated in is the IRCC-IVC Tumor Thrombus Consortium. Dr. Juan I. Martinez-Salamanca and Dr. John A. Libertino formed the International RCC-IVC Thrombus Consortium in 2007. The consortium now maintains a database for over 3000 patients, from 23 institutions around the globe, suffering from this condition.

International Renal Cell Carcinoma: Venous Thrombus Consortium (IRCC-VTC)

Many lessons have been learned as a result of the collaborative efforts of this international consortium and are best summarized in a recent publication from the consortium [31]. On the basis of the analysis of a clinical, surgical, and pathologic data set from the largest cohort of patients with RCC and venous involvement to date, several issues concerning prognostic factors, operative procedures, and surgical outcomes in this setting have been addressed.

Lessons learned from the consortium include: the recognition of tumor thrombus anatomic level as an independent survival predictive factor, the confirmation of radical surgery

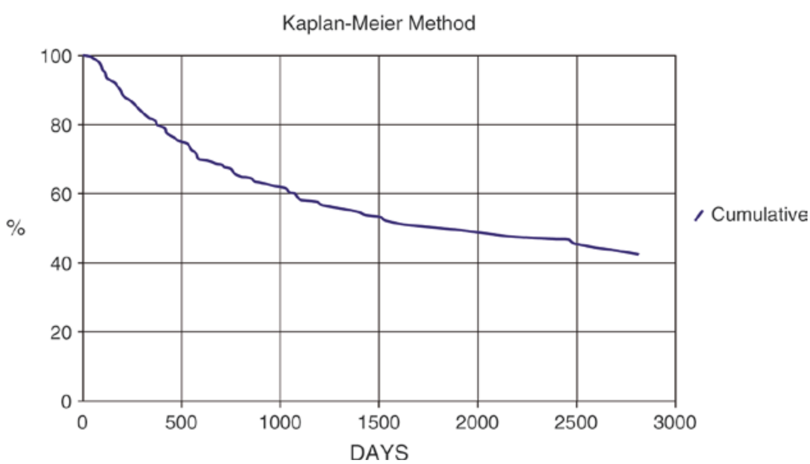


Fig. 15.29 Overall disease-specific survival (n = 300) median – 18 months, mean – 44 months

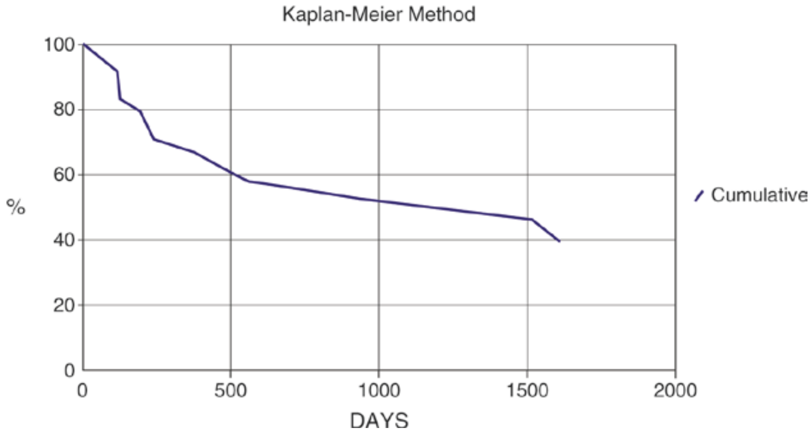


Fig. 15.30 Overall disease-specific survival – atrium (n = 31)

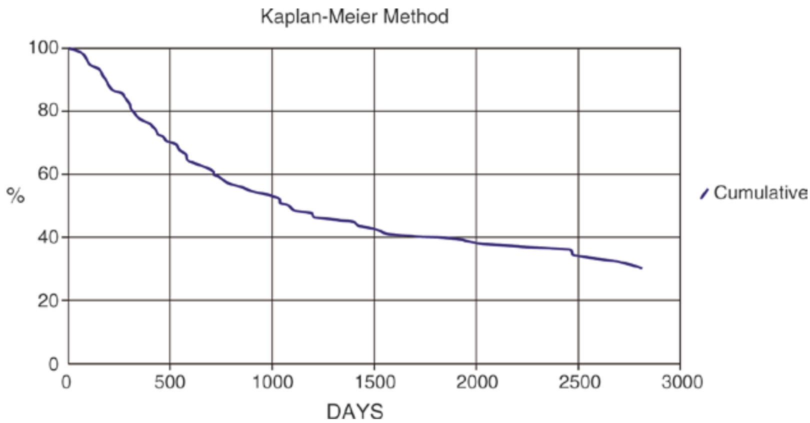


Fig. 15.31 Overall disease-specific survival – vena cava (n = 146)

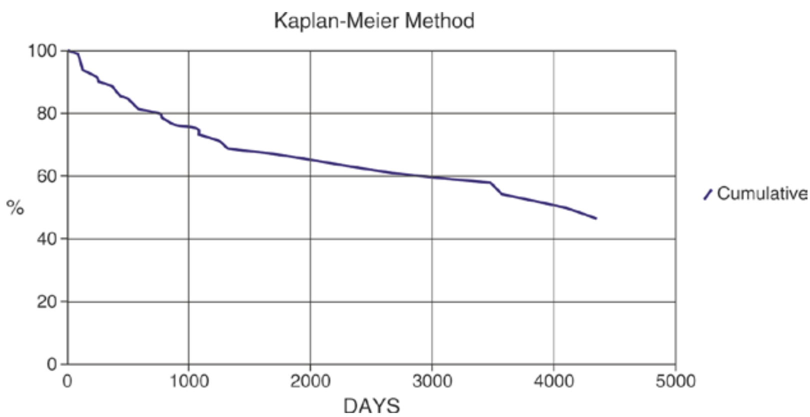
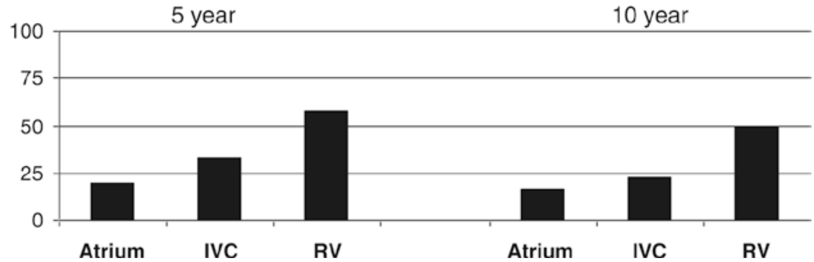


Fig. 15.32 Overall disease-specific survival – renal vein (n = 123)

as the mainstay of treatment for these patients even in the metastatic setting, the identification of papillary histological subtypes as a magnifier of oncologic risk when compared to other pathological subtypes, and the description of a direct relationship between the tumor thrombus level and severity of complications, making this a strong predictor of perioperative complications in patients with RCC and tumor thrombus.

Fig. 15.33 Cancer-specific survival



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