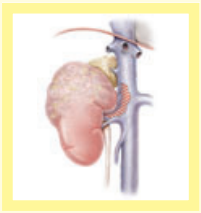
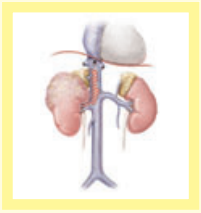
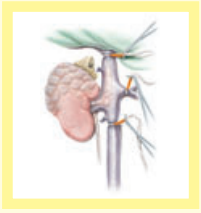
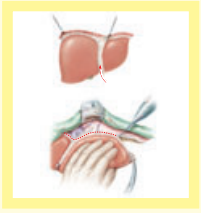
Surgery Illustrated









Tumour nephrectomy with vena cava thrombus

ALEXANDER BACHMANN, MICHAEL SEITZ, ANNO GRASER*, MAXIMILIAN F. REISER*, HANS-JOACHIM SCHÄFERS†, FLORIAN LÖHE‡, KARL-WALTER JAUCH‡ and CHRISTIAN G. STIEF

*Departments of Urology, *Radiology, and ‡Abdominal and Transplant Surgery, University Clinics Munich, Ludwigs-Maximilians-University, Munich and †Department of Thoracic and Cardiovascular Surgery, University Hospitals, Homburg, Germany*

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INTRODUCTION

Until the present, the only curative therapeutic strategy for localized RCC was complete surgical removal. Various thermo-ablative procedures are being developed and evaluated but their definitive role has yet to be defined [1,2]. As complete removal of the malignant renal tissue is the only curative option for the individual patient, and as all forms of neoadjuvant therapy show no consistent results in reducing tumour mass, surgical removal must be considered in cases of locally advanced tumours in the absence of metastases [3]. Furthermore, even in patients with metastatic disease but good overall conditions and good prognostic factors, resection of a locally advanced tumour may be considered before or after initiating adjuvant chemo-immunotherapy [4–7].

A specific form of a locally advanced renal tumour is the tumour with intracaval neoplastic extension, the so-called 'tumour thrombus'. Of renal tumours, 4–10% show such an intracaval neoplastic extension, with 10–25% of these patients presenting with an extension above the hepatic vein up to the right atrium or even into the right ventricle [3]. There has been much debate about the prognostic significance of such a tumour thrombus. Currently most authors agree that the presence of the thrombus itself has no specific prognostic significance if it can be successfully removed. It seems obvious that more advanced thrombi are associated with more advanced tumour stages, and that more advanced stages (and not more locally advanced thrombi) have a dramatic impact on survival. Thus tumour confinement to the renal capsule or intravenous neoplastic extension with no invasion of the vascular wall seems to be related to a 5-year survival of ≥50%; extension through the renal capsule into the perinephric fat or even through Gerota's fascia significantly reduces the patient's life expectancy [8–14].

In general, the prognosis for patients with metastatic renal tumours is poor, with a mean survival of 4–6 months and a 5-year survival of 0–10%. Recent publications show a significant survival advantage in patients who have nephrectomy before adjuvant therapy compared to patients with no nephrectomy [4–7]. As noted, these studies have strengthened the argument for resecting locally advanced RCC in carefully selected patients, even in the presence of metastatic disease, as a preparation for adjuvant strategies.

PLANNING AND PREPARATION

INDICATIONS AND PATIENT SELECTION

Patients with all forms of renal tumour with vena cava thrombus and no metastatic disease are suitable candidates for surgery. In

patients with metastatic disease but good overall health status and good prognostic factors, surgery may be considered after extensive counselling; inclusion in a prospective study (if one is open) is strongly advised.

It is well documented that a multidisciplinary approach, including cardiopulmonary bypass and deep hypothermic circulatory arrest, has dramatically improved the surgical feasibility and results of neoplastic caval thrombi above the hepatic veins. However, because of the need for anticoagulation and the negative implications of hypothermic circulatory arrest on the blood coagulation system, mesenteric perfusion and neurological function, it should be used only when necessary. As an alternative, liver mobilization with selective clamping of the hepatic vessels and the retrohepatic and/or infradiaphragmatic vena cava often enables the safe and complete removal of large thrombi up to the level of the diaphragm [15,16].

From the practical standpoint of an optimal use of human and equipment resources, the most important question before surgery in patients with renal tumours and neoplastic extension into the inferior vena cava is whether or not the individual case can be safely managed with no need for a cardiopulmonary bypass [12]. These situations/instances include small intracaval protrusions and larger intracaval thrombi with a definitive infrahepatic cranial margin (Type 1; Table 1; Fig. 1).

In all other patients, surgery should be done in a location and setting where the options of cardiopulmonary bypass and deep hypothermic circulatory arrest are readily available (Type 2). Some patients with hepatic or suprahepatic neoplastic extension may be safely managed with no cardiopulmonary bypass (Type 2a, Table 1) using liver mobilization and selective vascular clamping. Nonetheless, the need for circulatory arrest cannot always be excluded before surgery, e.g. if there is invasion of the caval wall with the need for extensive and complex vascular grafting, or an unexpected thrombus extension cranial to the diaphragm.

Table 1 Surgical stratification of neoplastic extensions into the inferior vena cava

Type	Details
1	No need for systemic circulatory arrest
	Small intracaval protrusions
	Intracaval thrombi with definite infrahepatic cranial margin
2	Infrastructure for systemic circulatory arrest must be readily available
2a	Need for systemic circulatory arrest possible but unlikely; have a biopump available for veno-venous bypass
	Suprahepatic but infradiaphragmatic intracaval extension
	Supradiaphragmatic extension of free-floating thrombus
2b	Need for systemic circulatory arrest definite.
	Vascular wall infiltration of the suprahepatic inferior vena cava, the hepatic veins or the right atrium
	Pending thrombotic embolism
	Large masses of suprahepatic thrombotic material

Some patients with RCC and intracaval neoplastic extension certainly require the use of cardiopulmonary bypass with deep systemic hypothermia and temporary exsanguination (Type 2b). These patients include cases with broad infiltration of the retrohepatic and/or suprahepatic inferior vena cava, the hepatic veins or the atrium, pending thrombotic embolism or large masses of thrombotic material extending into the right atrium or even the orifice of the tricuspid valve.

SPECIFIC EQUIPMENT/MATERIALS

For type 1 surgery: Vessel loops, straight vascular clamps, various sizes of Satinsky clamps; mid- and large vascular clips to occlude lumbar veins.

For type 2a surgery (liver mobilization and select clamping of hepatic and caval vessels): Instruments for type I surgery plus straight vascular clamps, mid- and large vascular clips, and vascular monofilament sutures for dissecting small retrohepatic veins between liver and vena cava. For procedures with extended clamping of the vena cava: veno-venous bypass pump, large bore venous catheter (17 F).

For type 2b surgery (open heart surgery with cardiac arrest and deep hypothermia): Standard cardiopulmonary bypass set, aortic cannula, large-bore single venous cannula (to be placed just into the right atrial appendage), aortic cross-clamp, cardioplegia cannula, narrow (1 cm) 60° retractor for visualization of the cranial portion of the inferior vena cava, vascular dissector.

SPECIFIC PATIENT POSITIONING

Place the patient in hyperlordosis; if cardiopulmonary arrest is planned, place the arms along the body and take care to leave the inguinal region and the suprasternal groove undraped.

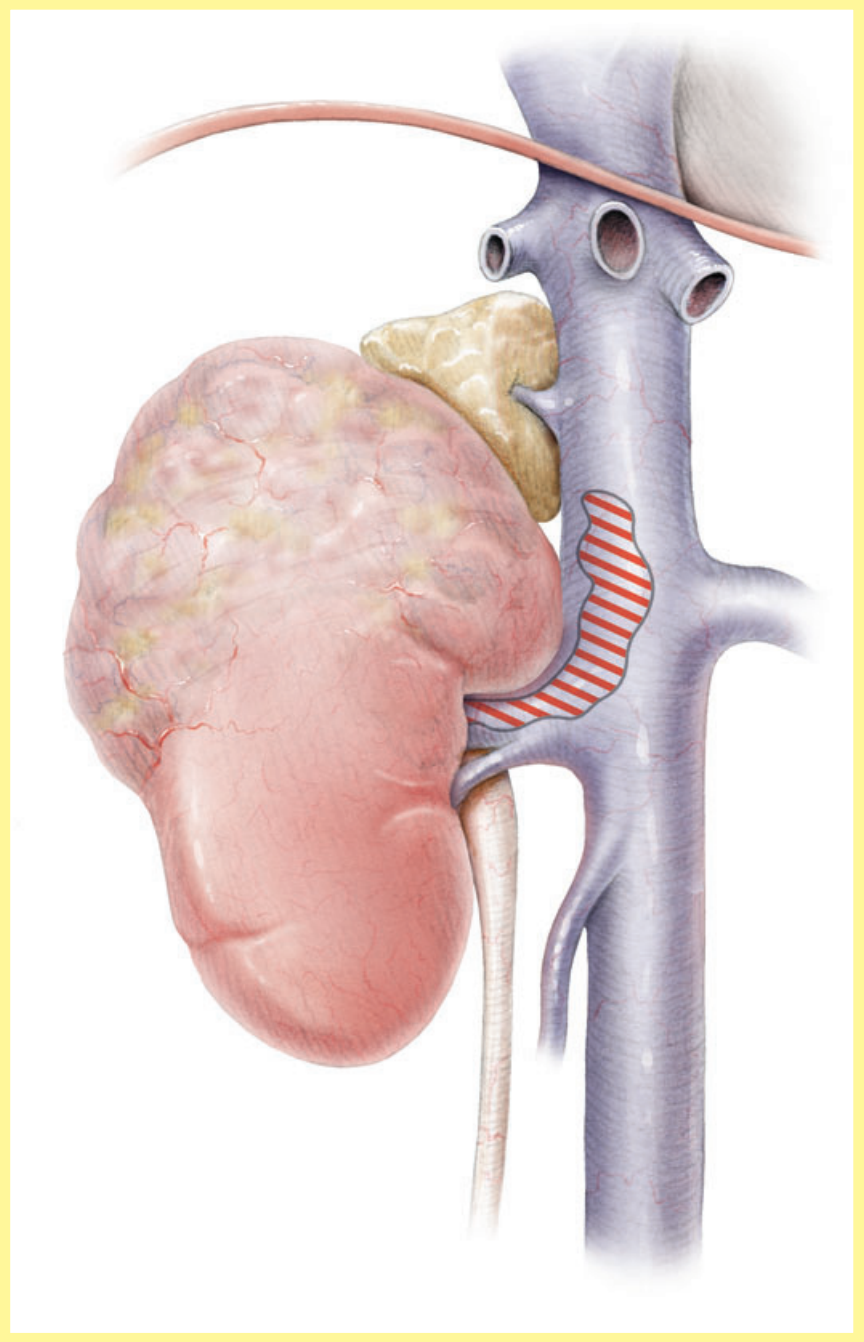
SURGICAL STEPS

As the surgical proverb 'nothing is better than exposure except more exposure' is especially true in advanced renal tumours, surgical incisions should be chosen that allow both an optimal approach to the tumour itself and vascular control.

Figure 1

Tumours with type 1 thrombi allow a wide variety of surgical incisions that mostly depend on the tumour size and the surgeon's individual preference. For right-sided tumours, we prefer a right 'hemi-chevron' (unilateral subcostal) incision; alternatively, a thoraco-abdominal approach is frequently used in the urological community. For left-sided tumours, a chevron incision (bilateral subcostal) seems to be best suited for removing the tumour from a left laterocolic approach and adequate caval exposure from a right laterocolic approach.

Tumour excision starts with a laterocolic incision and medial mobilization of the colon. The kidney is then mobilized within Gerota's fascia en bloc with the adrenal gland, except for cases with a history of pulmonary embolism or a pending embolism. Here, primary dissection of the infrahepatic vena cava is done before mobilizing the kidney and a vessel loop is placed cranial to the thrombus' end and pulled semi-tight to avoid thromboembolic complications in case of (partial) thrombus disruption. After ligating and cutting the ureter and renal artery, the vena cava is dissected below the renal veins up to the level of the hepatic vein(s); the contralateral renal vein is also dissected. Vessel loops are placed around the veins at the sites of planned clamping to ensure total vascular occlusion.



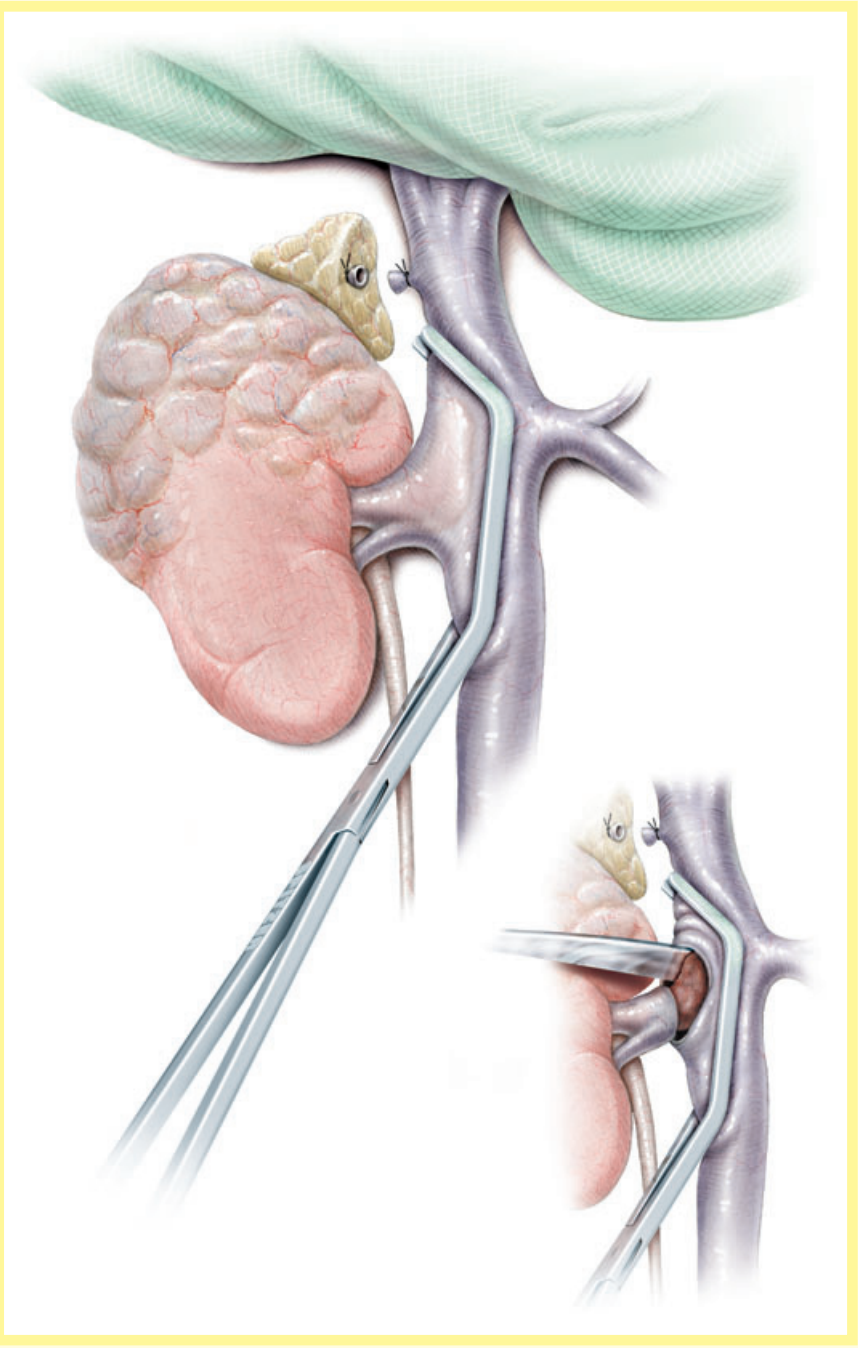


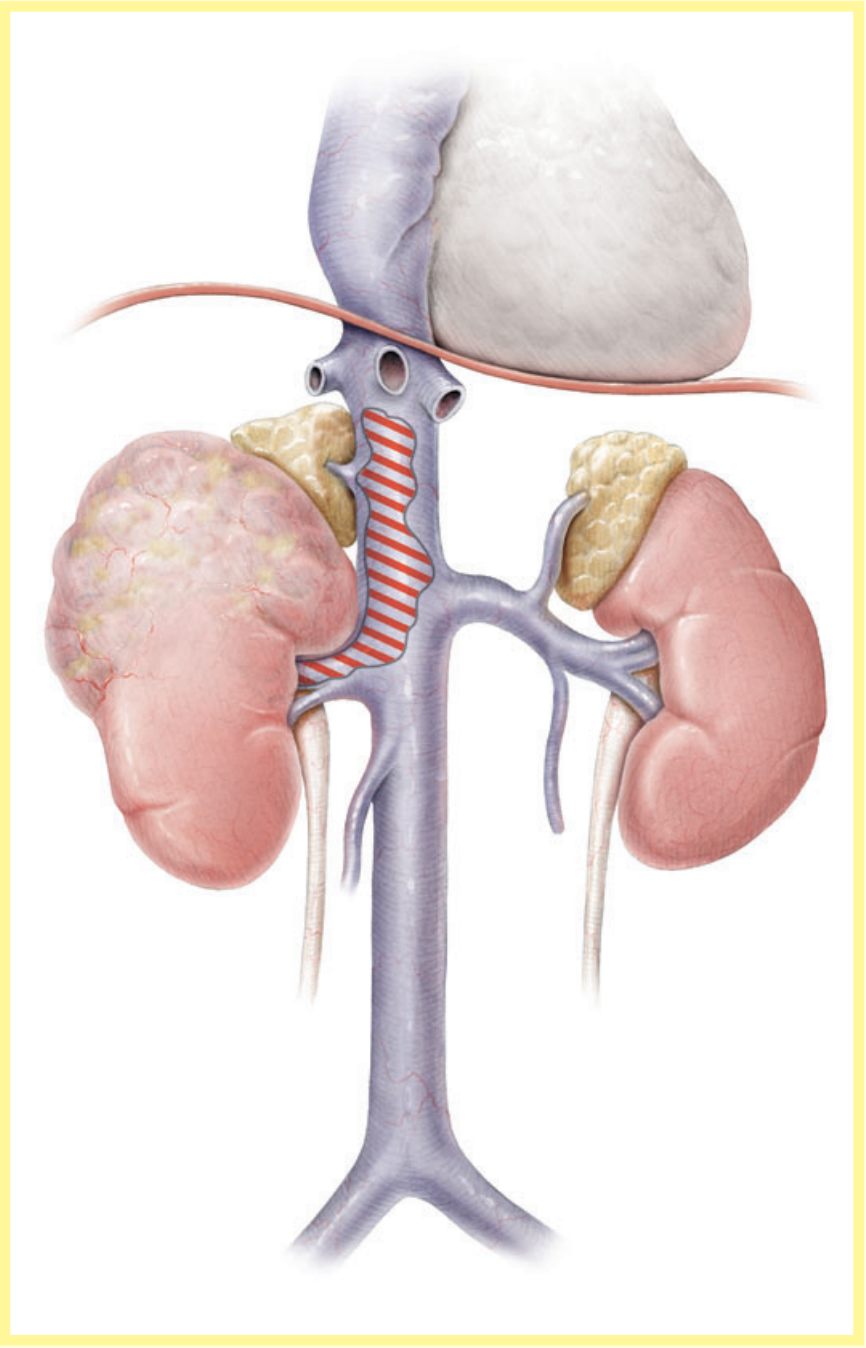
Figure 2

In the case of a small intracaval thrombus protrusion we use one (or in larger thrombi, two) Satinsky clamp(s) on the perirenal inferior vena cava, excising the renal vein to allow en bloc resection of the renal tumour and the thrombus.

For larger infrahepatic thrombi, we place vascular clamps on the infrarenal cava, the contralateral renal vein and the infrahepatic vena cava; the lumbar veins are clipped. The renal vein is then resected (and, if needed, the vena cava incised ventrally) to allow en bloc resection of the renal tumour. The caval incision is closed by a 4/0 polypropylene running suture.

Figure 3

As a sternotomy may be required in type 2 thrombi, we exclusively use the 'chevron' vs 'hemi-chevron' incision in these patients, as described above. In a patient with a history of pulmonary embolism or a pending embolism, the vena cava is first dissected above the thrombus, mostly at the infradiaphragmatic level and a vessel loop placed around the cava which is then partially constricted. In all other cases, we initially do a formal radical nephrectomy (if indicated, with excision of adherent organs). To minimize blood loss in the case of complete circulatory arrest and subsequent heparinization, we usually do the radical nephrectomy in type 2 cases before removing the thrombotic material; the renal vein is double-clamped, the renal tumour removed and the thrombus fixed to the renal vein stump by a suture ligature.



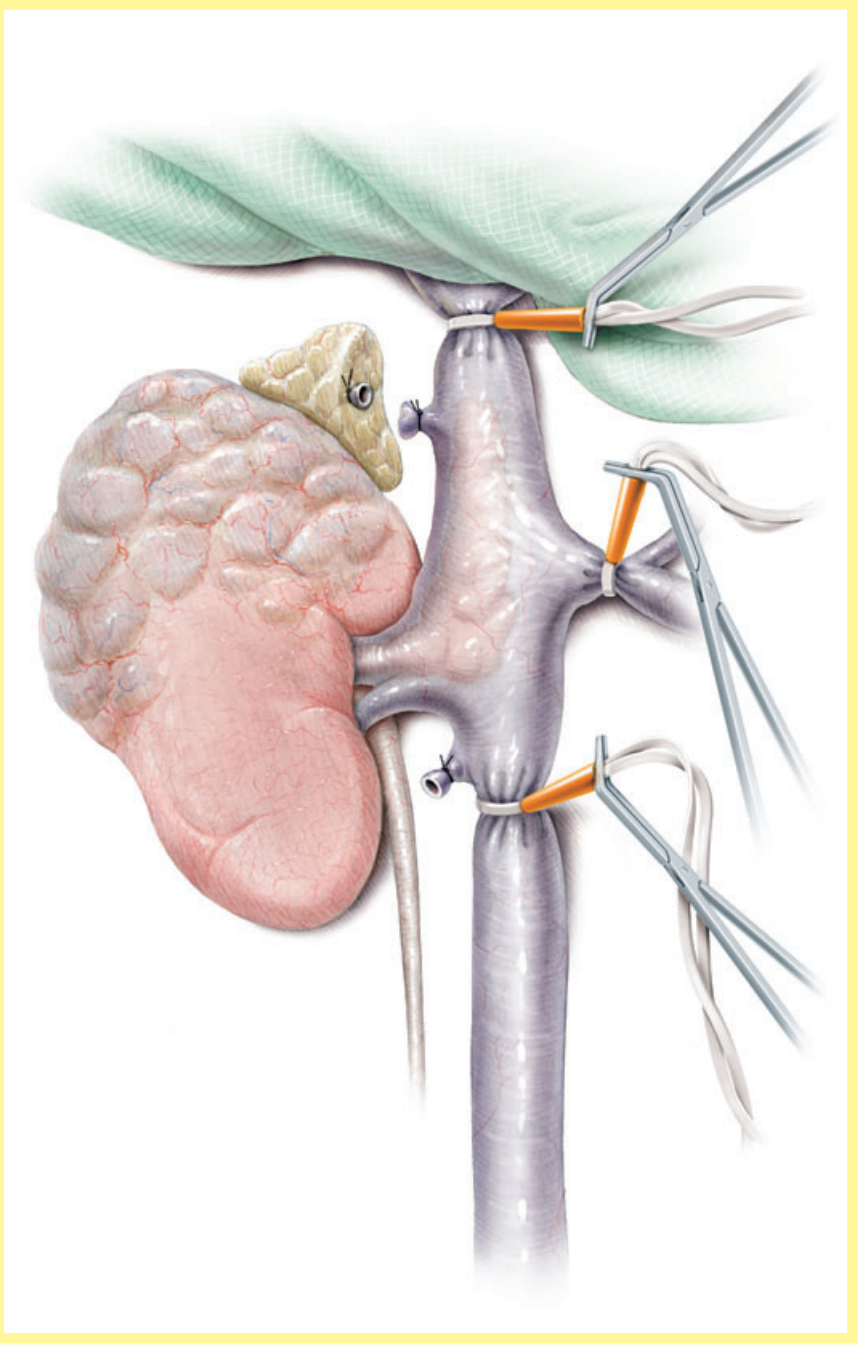
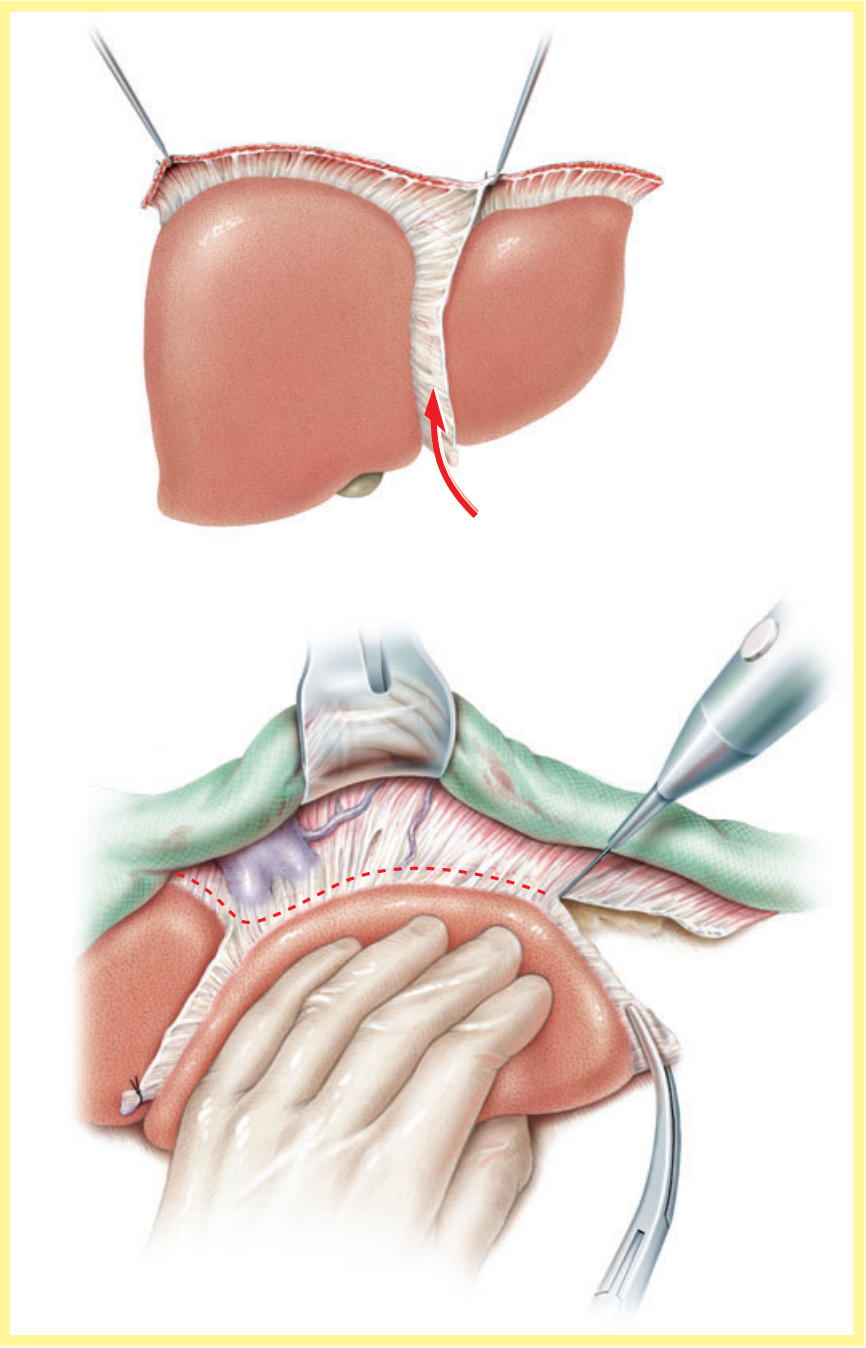


Figure 4

The vena cava is dissected free ≈3 cm below the renal veins and up to the level of the hepatic veins. The contralateral renal vein is dissected; existing lumbar veins are clipped or ligated and transected. If, at this stage, the cranial margin of the thrombus can be palpated at or below the level of the hepatic vein, clamps are placed similarly as described above. We incise the vena cava longitudinally on the anterior aspect, evert the thrombus, excise the renal vein from inside and extract the thrombus. Cavotomies are closed by running sutures. Should the thrombus reach up to the intrahepatic vena cava but below the diaphragm and is floating freely, the liver is mobilized.

Figure 5

Start the liver mobilization by dissecting the falciform ligament (arrow) and the triangular ligament beginning from the left lobe.



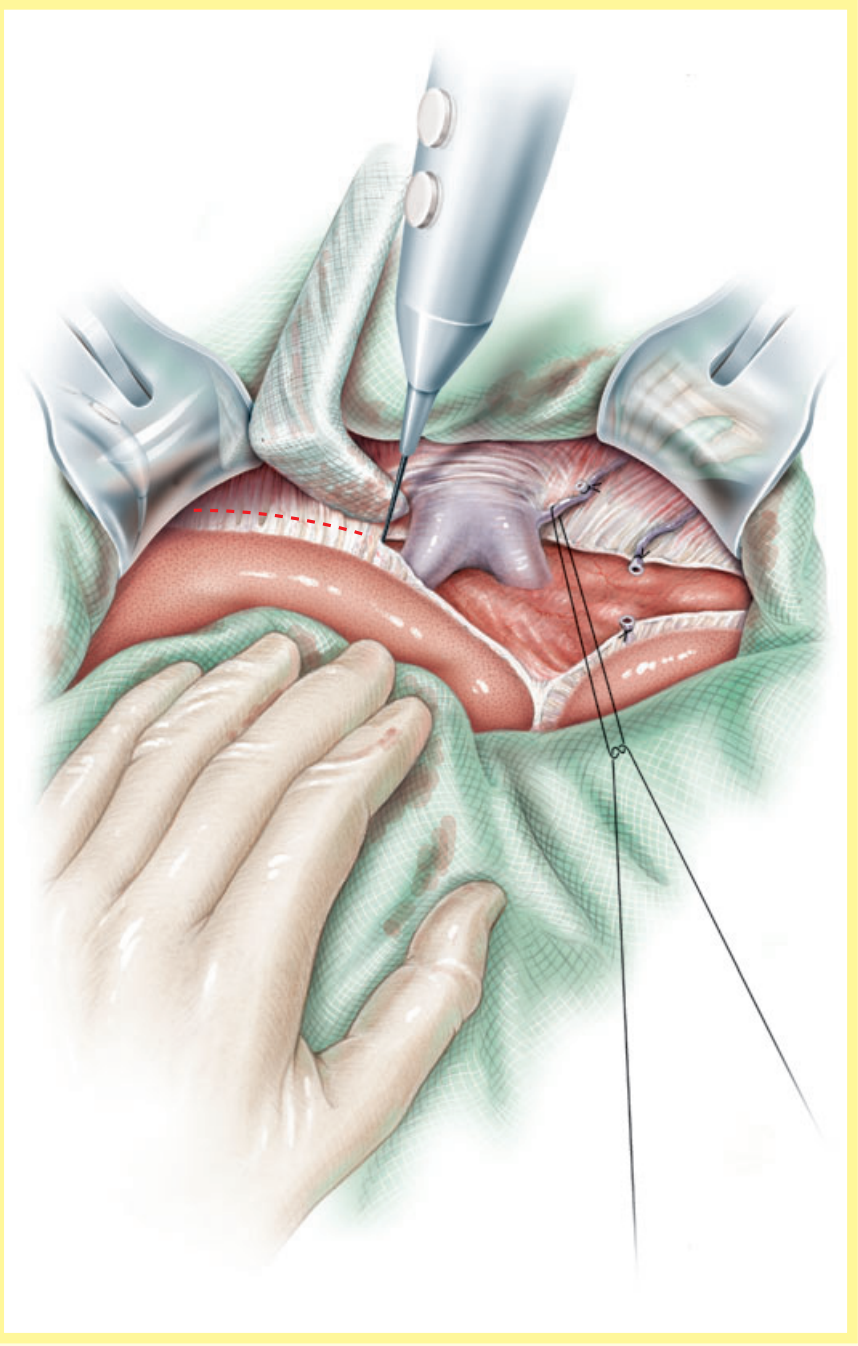
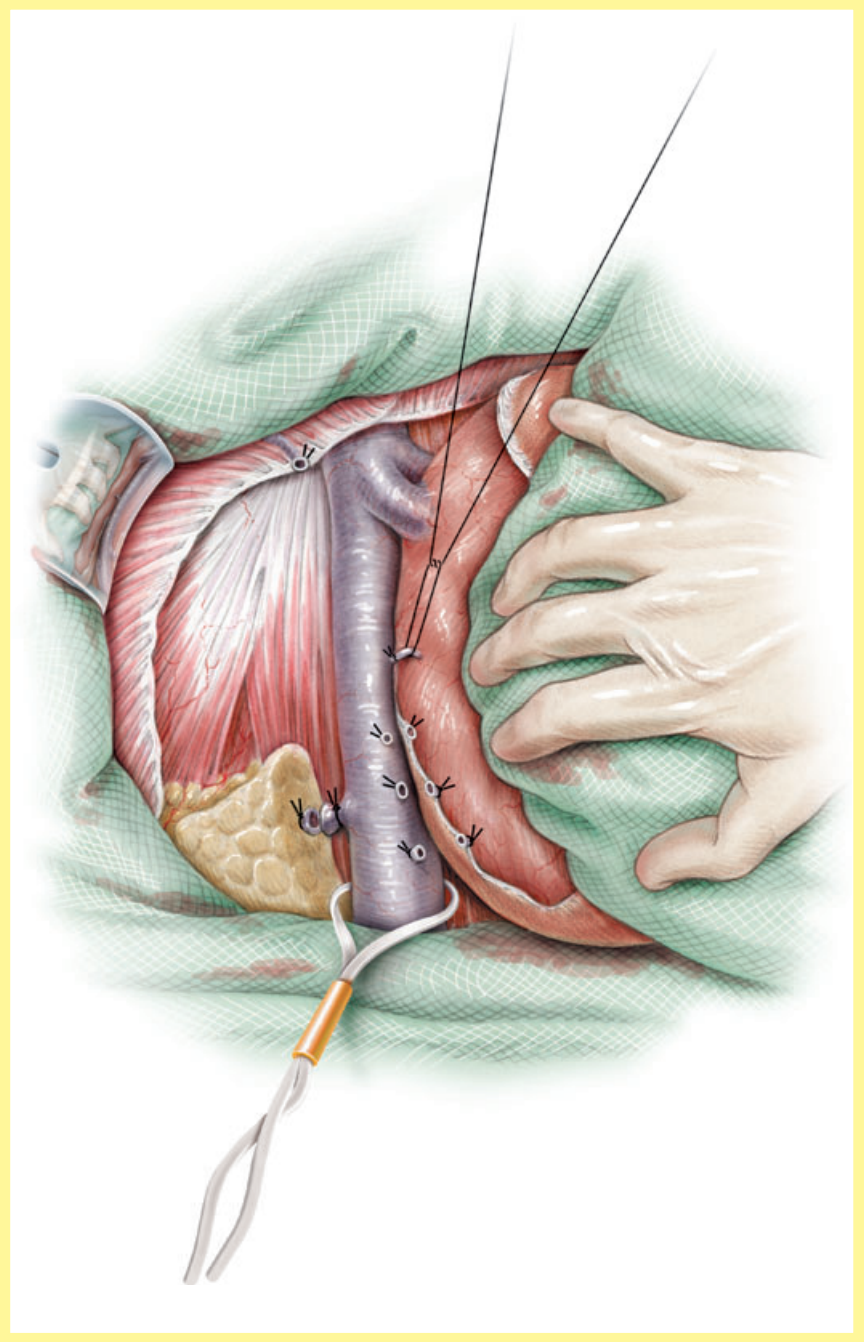


Figure 6

Dissecting the coronar ligament reveals the major hepatic veins and the infradiaphragmatic vena cava. Cutting the left diaphragmatic vein is advisable.

Figure 7

A view to the retrohepatic vena cava after complete mobilization of the right lobe. Small hepatic veins are dissected between vascular clips or sutures. The orifice of the right hepatic vein into the infradiaphragmatic vein is shown. A loop is placed to the infrahepatic vs. cava.



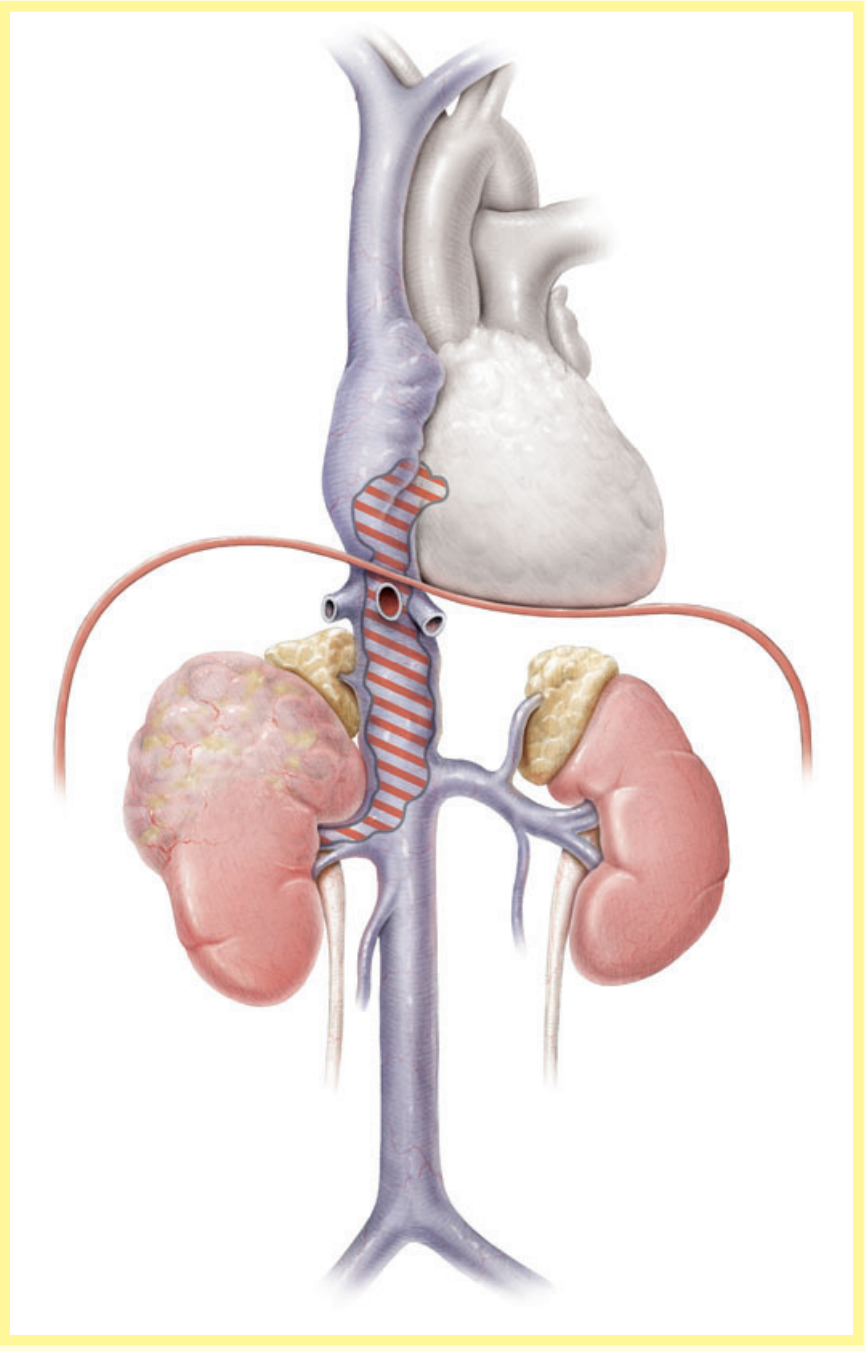


Figure 8

Surgical incision and removal of the renal mass for type 2b tumours is comparable to type 2a tumours.

SURGICAL STEPS

After caudal vascular clamping as described above, the liver hilum and the vena cava clamped infradiaphragmatically (as are the inferior vena cava and the collateral renal vein). Excision and extraction are done as described above. If the thrombus is floating freely from intrahepatically up to the atrium, a similar approach is chosen, but without clamping the vena cava infradiaphragmatically. With the liver and inferior vena cava being retracted, a clamp is placed on the cava below the diaphragm or intrapericardially. Complete mobilization of the liver from the diaphragm is mandatory to expose the vena cava. Dissection of all caudal liver veins up to the main hepatic veins helps to give exposure of the entire circumference of the vena cava. After incising the cava and everting the thrombus, the clamp is placed on the infrahepatic vena cava, the first clamp removed, circulation of the liver restored and the procedure continued as described above.

Incising the right tendinous part of the diaphragm from lateral to the caval opening might help to approach the inferior caval vein and the right atrium, allowing a clamp to be placed on the junction between vena cava and right atrium; using this manoeuvre, it may be a sufficient approach avoiding sterniotomy. If more complex procedures with longer cross clamping of the vena cava is necessary, the use of a veno-venous bypass pump is advisable to avoid venous congestion of the preserved contralateral kidney and lower body.

Similarly, the vena cava is dissected infrarenally to the hepatic veins. After sternotomy and opening the pericardium, the cardiopulmonary bypass is instituted using aortic and right atrial cannulation. Care is taken not to pass the venous cannula too far into the right atrium, to avoid embolizing the tumour thrombus. The patient is cooled to a 'safe' temperature, measured by a nasopharyngeal temperature probe. The safety of circulatory arrest is mainly aimed at the time of interrupted cerebral blood flow, without incurring neurological complications. For a duration of arrest of 20 min, a nasopharyngeal temperature of 20–21°C appears to be adequate; for 30 min of arrest, 16–18 °C is necessary. If longer periods are anticipated for complete elimination of intrahepatic tumour, continued perfusion of the arch vessels may be considered while clamping the aorta distal to the arch, to minimize blood loss through the abdominal field.

Once the desired temperature is reached, the ascending aorta is cross-clamped and cardioplegia given. The right atrium is opened with an incision from the right atrial appendage to the inferior vena cava. This gives excellent exposure of right atrium and the orifices of the cranial hepatic veins and minimizes the chance of tumour embolism.

In most instances the tumour is adherent to the wall of the vena cava at the level of the diaphragm. These adhesions can easily be mobilized using a vascular dissector until the hepatic veins become visible. Now the vena cava is longitudinally incised on the anterior aspect, the thrombus mobilized caudally and everted. This is followed by circumferential incision of the caval wall at the entrance of the renal vein from inside and extraction of the complete thrombus. If the thrombus is adjacent to the caval wall, sharp dissection is applied. If broad tumour growth inside the right atrium makes this manoeuvre impossible, its removal in the cranial and caudal part may be necessary. To assure complete removal of the thrombotic material, the tricuspid valve, the inferior vena cava and the hepatic veins are carefully inspected for remaining thrombi or residual fragments infiltrating or coating the vascular walls. After removal, the atrial and caval incisions are closed by running sutures.

If there is persistent bleeding from vascular sutures due to coagulatory dysfunctions, bleeding is controlled rather by using fibrin glue or haemostyptic fleeces than by too many attempts at suturing, that possibly cause a narrowing of the caval diameter.

Diffuse bleeding or bleeding from suture holes is usually the consequence of platelet dysfunction in conjunction with cardiopulmonary bypass and hypothermia. This can be minimized with the systemic administration of aprotinin (4–6 MU), which is often given after circulatory arrest to limit the potential negative impact on cerebral microcirculation during circulatory arrest. In addition, the use of platelet concentrates may be helpful if bleeding persists despite aprotinin.

If the caval wall had to be resected, a reduction in diameter by a third seems acceptable. If more caval wall was resected, replacing the entire caval segment by a ring-enforced 28 mm Goretex prosthesis should be preferred over venous patching.

POSTOPERATIVE CARE

For sufficient drainage, we place a Blake drain for 24–48 h. However, the benefit of abdominal drains after caval procedures is not evidence-based. In the presence of diffuse bleeding caused by coagulatory dysfunction, a drain placed under the right lobe of the liver parallel to the vena cava is helpful to evacuate any possible haematoma and for monitoring. This drain should be removed after 48 h at most. A perioperative single-shot antibiotic is administered when alloplastic materials are placed in caval procedures, but no specific postoperative antibiotic therapy is necessary.

Alter combined thoraco-abdominal surgery, the patient is extubated using standard criteria. Mediastinal or pleural drains are removed after 24–48 h. There is no firm evidence that prophylactic use of antibiotics is necessary or helpful. Nevertheless, a 48-h course of a first- or second-generation cephalosporin is commonly given. Early mobilization from bed (starting in the first 24 h) minimizes the chances of thrombosis, pulmonary embolism and atelectasis.

FROM SURGEON TO SURGEON

Whenever the tumour tissue within the vena cava is surrounded by blood and contrast medium, respectively, infiltration of the vessel wall can be excluded. However, neoplastic tissue extending beyond the vessel wall is a clear indication of invasion of the wall of the inferior vena cava. However, if neither sign is present, cross- sectional imaging is inconclusive concerning the issue of vessel wall invasion.

In contrast-enhanced CT, tumour thrombi show more attenuation than in an unenhanced scan. Usually, no native scan is taken, so that this feature cannot be verified. In MRI, clots adherent to the tumour thrombus have signal patterns different from tumour tissue, which depend on the age and composition of the clot (methaemoglobin, haemosiderine, etc.) [17].

Difficulties may arise if the tumour extends into the single hepatic veins and adheres to the vein walls. This changes the cranial part of the operation from very simple 'uncorking' of the vena cava to careful surgical dissection of individual hepatic veins, and thus requires a markedly longer period of circulatory arrest. Exposure of the veins is difficult, but can be achieved with a retractor. To prolong the safe period of circulatory arrest, the aortic arch is best clamped just beyond the level of the left subclavian artery, and perfusion of the arch can then be resumed with a flow rate of 1 L/min, or as necessary to achieve an arterial pressure of >40 mmHg while maintaining hypothermic conditions. The hepatic veins must then be completely dis-obliterated.

In the worst case, infiltration of the neoplastic thrombus at the diaphragmatic level may require a prosthetic interposition with reinsertion of the hepatic vein in one patch like in ante situ liver resection.

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Correspondence: Christian G. Stief, Department of Urology, Klinikum Großhadern, Ludwig-Maximilians-Universität, Marchioninistr. 15, D81377 München, Germany.
e-mail: christian.stief@med.uni-muenchen.de