Original Article

Vascular Surgery

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Surgical strategy and outcomes in renal cell carcinoma with inferior vena cava tumor extension: A tertiary center experience

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Abstract

Background: Renal cell carcinoma (RCC) may extend into the inferior vena cava (IVC) and, in advanced cases, into the right atrium. Radical nephrectomy with IVC thrombectomy remains the mainstay of treatment; however, the role of cardiopulmonary bypass (CPB) in advanced tumor thrombus remains controversial. This study aimed to evaluate the surgical and early oncologic outcomes of patients with RCC and IVC tumor thrombus and to assess the impact of CPB on perioperative outcomes while cautiously interpreting the findings because of the limited sample size.

Methods: We retrospectively analyzed 22 consecutive patients who underwent synchronous radical nephrectomy and IVC thrombectomy between 2009 and 2025 at a tertiary referral center. Patients were divided into two groups: Group I (n=8), who underwent surgery with CPB (± total circulatory arrest), and Group II (n=14), who underwent surgery without CPB. Tumor thrombus level was classified according to the Mayo clinic classification system. Operative variables, perioperative complications, recurrence rates, and survival outcomes were compared.

Results: Level II thrombus was the most common presentation, whereas all Level IV cases required CPB. Operative time was significantly longer in the CPB group (267.5±121.4 *vs.* 190.4±38.7 minutes, p=0.038). Postoperative bleeding was significantly greater in Group I (p=0.001), whereas transfusion requirements, intensive care unit stay, and total hospital stay did not differ significantly between the groups. Perioperative mortality occurred in two patients (25%) in the CPB group and in none in Group II (p=0.16). The overall recurrence rate was 45% and was significantly higher in Group I (p=0.002). The overall 1-year survival rate was 77.2%, with no significant difference between the groups (p=0.12).

Conclusion: Radical nephrectomy with IVC thrombectomy may provide acceptable perioperative and early survival outcomes in patients with RCC and venous tumor extension. In this limited series, the use of CPB in patients with advanced tumor thrombus did not appear to significantly increase overall morbidity and may improve operative safety in technically demanding cases. Nevertheless, the interpretation of these findings is limited by the unequal distribution of disease stage between the two groups.

Keywords: Renal cell carcinoma, inferior vena cava tumor thrombus, surgical management, cardiopulmonary bypass.

Renal cell carcinoma (RCC) accounts for 4-10% of all cancers, with peak incidence occurring after the age of 60 years. It has a known propensity for vascular invasion and frequently extends into the renal vein and inferior vena cava (IVC), leading to venous congestion. Surgical resection remains the only effective treatment option in these cases.[1] IVC tumor thrombus occurs in approximately 10-25% of patients and extends into the right atrium in nearly 1% of cases. The level of thrombus extension within the IVC is an independent predictor of survival and significantly affects perioperative outcomes. It is also considered a predictor of poor outcomes in patients with metastatic disease. In untreated cases, the median life expectancy is approximately 5 months, and the 1-year survival rate is 29%. However, following surgical treatment, survival rates increase to 25-53%.[2-4] This complex surgery carries considerable operative risk, with reported complication rates ranging from 10% to 30%.[5] Potential complications include massive bleeding and pulmonary tumor thromboembolism. During surgery, clamping of the IVC and liver mobilization are often unavoidable to control venous return, which may negatively affect portal circulation and lower extremity venous return.[1] Therefore, surgical resection is recommended for RCC with IVC tumor thrombus whenever feasible.[6] In certain situations, cardiopulmonary bypass (CPB) may be required. A multidisciplinary approach involving urologists, cardiovascular surgeons, and general surgeons is recommended whenever possible.[7] This study aimed to report our experience with open radical nephrectomy and IVC thrombectomy and to assess the impact of CPB on surgical outcomes in patients with RCC extending into the IVC and right atrium.

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Methods

Study Population

This retrospective study included 22 consecutive patients (12 men and 10 women; mean age, 55.05±14.29 years; range, 23-77 years) who underwent surgical treatment for RCC with IVC tumor thrombus between January 2009 and August 2025 at a tertiary referral center. Patients were divided into two groups based on the surgical strategy: Group I underwent CPB with or without total circulatory arrest (TCA) (CPB ± TCA) (n=8), whereas Group II underwent surgery without CPB (n=14). Demographic and clinical data were retrospectively collected from the hospital database. The level of tumor thrombus was classified according to the Mayo Clinic classification system (Figure 1).[7] Operative time, intraoperative blood loss, transfusion requirements, duration of CPB, and the need for TCA were recorded. Early postoperative outcomes included acute kidney injury, reoperation, postoperative bleeding, thromboembolic complications, length of intensive care unit (ICU) stay, length of hospital stay, and 30 day mortality.

Inclusion and Exclusion Criteria

Patients older than 18 years with RCC extending into the IVC, with or without right atrial extension who underwent synchronous nephrectomy and IVC thrombectomy were eligible for inclusion. One 13-year-old patient and one patient with incomplete clinical data were excluded from the study.

Study End Points

The primary end points were early and midterm survival, defined as survival within 30 days and 12 months after the initial intervention, respectively. Additional primary outcomes included the reintervention rate, all-cause mortality, procedural success, and total in-hospital length of stay. Procedural success was defined as complete removal of the tumor thrombus without residual caval or atrial mass on postoperative imaging and the absence of intraoperative mortality.

Secondary end points included ICU length of stay, duration of mechanical ventilation, perioperative blood transfusion requirements, postoperative renal function, as assessed by serum creatinine and urea levels, and the incidence of major complications, including bleeding requiring re-exploration, acute kidney injury, stroke, pulmonary embolism, and postoperative infection.

Follow-up

Clinical follow-up was scheduled at 1, 3, and 6 months postoperatively and annually thereafter. Follow-up assessments included physical examinations, laboratory analyses, and imaging studies. Contrast-enhanced computed tomography angiography (CTA) was routinely performed to evaluate residual or recurrent tumor thrombus, caval patency, and metastatic progression. Transthoracic echocardiography was used to assess right atrial involvement, cardiac function, and the presence of intracardiac recurrence. Additional imaging studies were performed when clinically indicated. Survival status, tumor recurrence, reintervention, and late complications were documented at each follow-up visit.

Preoperative Planning

The Mayo Clinic classification system categorizes RCC with IVC tumor thrombus according to the cranial extent of venous involvement. In Level 0, the thrombus is confined to the renal vein. Level I describes minimal extension into the IVC, typically <2 cm above the renal vein. In Level II, the thrombus extends further within the IVC but remains below the hepatic veins. Level III indicates involvement of the intrahepatic segment of the IVC up to the level of the diaphragm without reaching

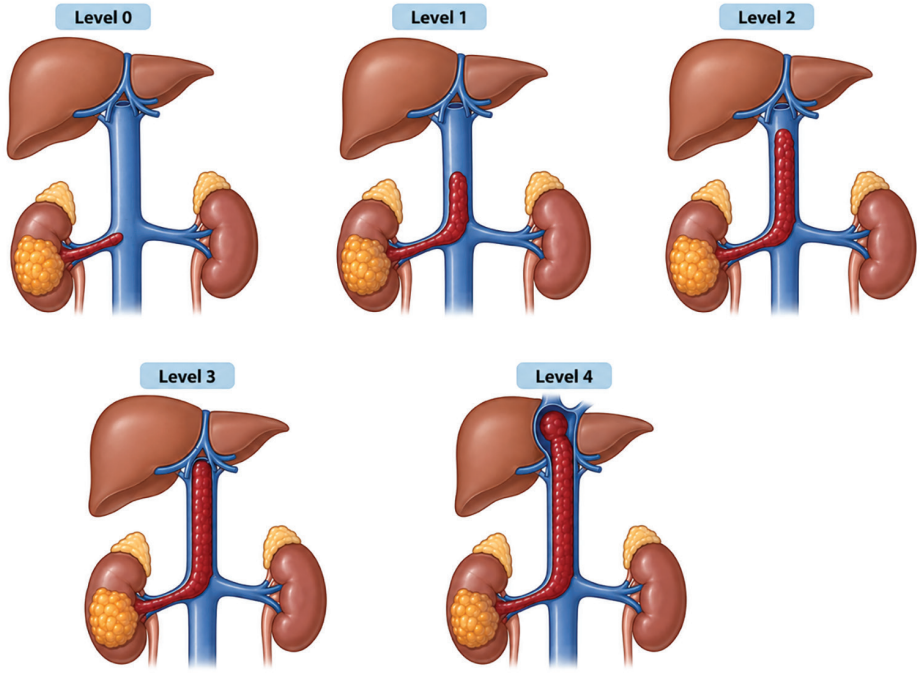


Figure 1. Mayo clinic classification of RCC with IVC tumor thrombus (redrawn and modified from Neves and Zincke[7]).
RCC: Renal cell carcinoma; IVC: Inferior vena cava.

the right atrium. Level IV represents supradiaphragmatic extension, including tumor thrombus reaching or extending into the right atrium.[7]

This staging system is primarily used to guide the operative strategy, as increasing thrombus level is associated with greater surgical complexity and may necessitate advanced techniques such as extensive caval mobilization, hepatic vascular control, or CPB.

Procedural Details

Through a right-sided incision, the abdominal wall was dissected in an anatomical fashion. The peritoneum was opened, the colon was mobilized medially, and the retroperitoneal space was entered. The kidney was circumferentially dissected using sharp and blunt techniques with intermittent application of LigaSure. The ureter and gonadal veins were ligated and divided. At the renal hilum, the renal artery and vein were isolated, ligated, clipped, and transected. In patients with supradiaphragmatic tumor extension (Level IV), CPB was initiated through a median sternotomy with bicaval venous cannulation after systemic anticoagulation (Figures 2-4). If IVC cannulation was unsuccessful, direct superior vena cava cannulation combined with right femoral vein cannulation was performed. After aortic cross-clamping and antegrade cardioplegia, diastolic arrest was achieved. The patient was cooled to 18 °C, and TCA was instituted. The IVC was opened longitudinally at the perihepatic level, and the tumor mass was resected. Tumor extension into the right atrium was confirmed, and a right atriotomy was performed. The tumor thrombus extending from the right atrium to the level of the renal vein within the IVC was completely removed. Nephrectomy was then completed. The IVC was primarily repaired using 4-0 polypropylene sutures. After removal of the aortic cross-clamp and gradual hemodynamic stabilization, the patient was successfully weaned from CPB, and protamine was administered. In patients who did not require CPB, the same surgical principles were applied. Proximal and distal inflow occlusion of the infradiaphragmatic IVC was achieved, and the tumor thrombus was removed accordingly. A cell salvage system was not used.

This study was approved by the Regional Ethics Committee of İstanbul University-Cerrahpaşa (decision no: İUC KAEK 2025/413, approval number: 2025/413, date: 07.07.2025) and was conducted in accordance with the principles of the Declaration of Helsinki. Written informed consent was obtained from all participants.



Figure 3. Resected Level III tumor thrombus.

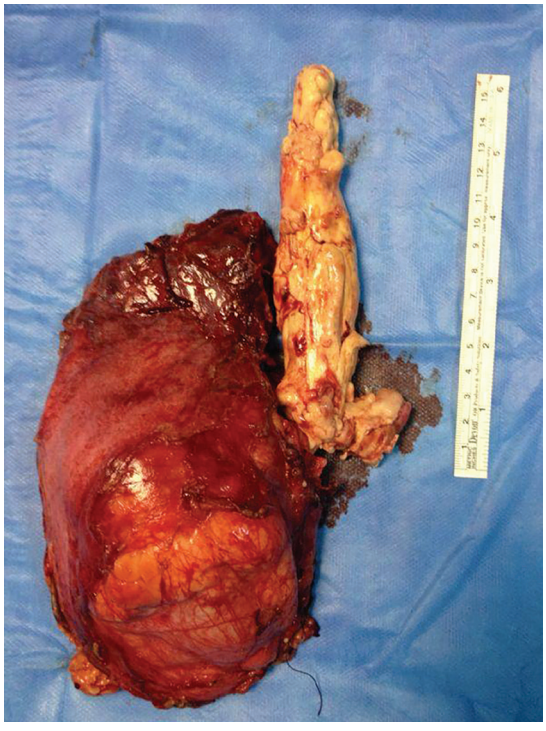


Figure 2. Resected Level II tumor thrombus.

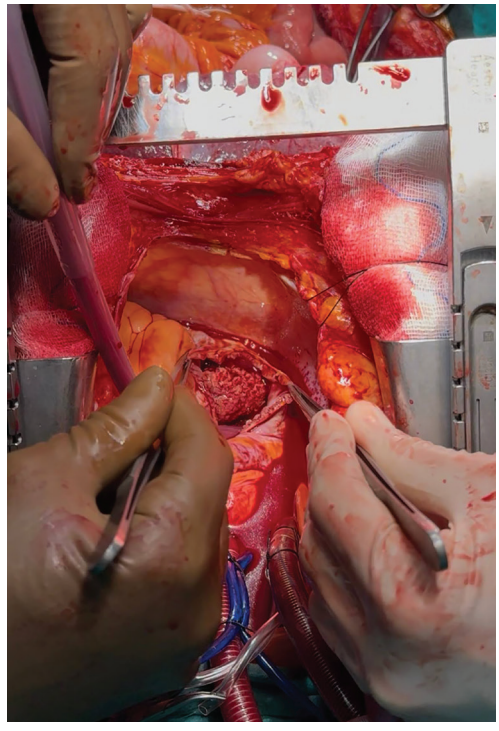


Figure 4. Resected Level IV tumor thrombus.

Statistical Analysis

Statistical analyses were performed using SPSS for Windows, version 21 (SPSS Inc., Chicago, IL, USA). The distribution of continuous variables was assessed using the Kolmogorov-Smirnov test to determine normality. Categorical variables were expressed as frequencies and percentages, whereas continuous variables were presented as mean ± standard deviation. Comparisons of continuous variables between groups were performed using either the Student's t-test or the Mann-Whitney U test, as appropriate. Kaplan-Meier analysis was used to evaluate survival rates. Associations between categorical variables were assessed using the chi-square test or Fisher's exact test, as appropriate. A p-value <0.05 was considered statistically significant.

Results

Sample Size, Demographics and Baseline Risk Factors

A total of 22 patients (12 men and 10 women; mean age, 55.05±14.29 years; range, 23-77 years) who underwent synchronous nephrectomy and IVC thrombectomy were included in this retrospective study. Hypertension, diabetes mellitus, coronary artery disease, peripheral artery disease, and chronic obstructive pulmonary disease were present in 8 (36.3%), 2 (9%), 9 (40.9%), 3 (13.6%), and 3 (13.6%) patients, respectively.

Right-sided RCC was observed in 15 patients (68.2%), whereas left-sided RCC was observed in 7 patients (31.8%). The most common presenting symptom was flank pain, reported in 10 patients (45.5%), followed by hematuria in 3 (13.6%), fatigue and weight loss in 3 (13.6%), shortness of breath in 2 (9%), abdominal distention in 2 (9%), peripheral edema in 1 (4.5%), and pulmonary embolism in 1 (4.5%) (Table 1).

The IVC tumor thrombus was classified according to the Mayo clinic classification. Level II thrombus was the most common, occurring in 9 patients (40.9%), followed by Level IV in 6 patients (27.2%). Level I thrombus was identified in 5 patients (22.7%), whereas Level III thrombus was observed in only 2 patients (9%).

Perioperative Outcomes

Additional procedures were performed in selected patients, including cholecystectomy in 8 patients (36.4%), concomitant coronary artery bypass graft surgery (CABG) in 2 patients (9%), and simultaneous mitral valve replacement (MVR) in 1 patient (4.5%). Regarding TCA, 6 of the 8 patients in Group I required TCA because of tumor extension into the right atrium and the associated technical challenges. The total operative time was significantly longer in Group I (267.5±121.4 minutes) than in Group II (190.4±38.7 minutes) (p=0.038).

The mean transfusion requirement was higher in Group I (3.37±2.92 units) than in Group II (1.78±1.96 units), although the difference was not statistically significant (p=0.14). Postoperative bleeding was significantly greater in Group I (647.42±89.47 mL) than in Group II (393.59±68.22 mL) (p=0.001). No significant difference was observed between the groups in postoperative creatinine levels (p=0.972). The mean ICU stay was longer in Group I (4.78±5.93 days) than in Group II (2.25±1.98 days), although the difference was not statistically significant (p=0.15). The length of hospital stay was also longer in Group I (9.67±6.10 days) than in Group II (7.45±3.89 days); however, the difference did not reach statistical significance (p=0.30). The overall mean follow-up duration was 464.3±107.0 days. The mean follow-up duration was shorter in Group I (13.94±9.12 months) than in Group II (15.23±5.31 months), with no

Table 1. Baseline demographic and clinical characteristics of Group I (with CPB) and Group II (without CPB)

	Group I (with CPB) (n=8)	Group II (without CPB) (n=14)	Total (n, %)	p-value
Age (years, mean ± SD	58.14±15.57	49.63±12.84		0.185
Symptom at diagnosis (%)				
Dyspnea	3	4	7 (29.1%)	0.63
Flank pain	7	10	17 (70.8%)	0.38
Lower extremity edema	4	4	8	0.31
Hematuria	2	3	5	0.84
Abdominal distension	4	5	9	0.51
Fatigue + weight loss	5	7	10	0.57
Pulmonary embolism	2	1	3	0.24
DM	1	1	2	0.67
HT	2	6	8	0.40
CAD	4	5	9	0.51
PAD	1	2	3	0.90
COPD	-	3	3	0.27
Side (right/left)	3/5	4/10	7/15	0.66
Mayo classification				
Type I	-	5	5	-
Type II	-	9	9	-
Type III	2	-	2	-
Type IV	6	-	6	-

DM: Diabetes mellitus; HT: Hypertension; CAD: Coronary artery disease; PAD: Peripheral arterial disease; COPD: Chronic obstructive pulmonary disease; CPB: Cardiopulmonary bypass; SD: Standard deviation.

statistically significant difference (p=0.67) (Table 2). Two patients (25%) in Group I died during the perioperative period, whereas no perioperative deaths occurred in Group II; however, this difference was not statistically significant (p=0.16). The overall rate of distant metastasis/recurrence was 45% (10/22) and was significantly higher in Group I (p=0.002). The overall 1-year survival rate was 77.2% (17/22), with no significant difference between the two groups (p=0.12) (Table 2).

Discussion

In this study, we evaluated and compared the outcomes in terms of operative time, blood loss, blood transfusion requirements, length of ICU stay, length of hospital stay, and perioperative and early mortality rates. Total operative time, postoperative bleeding, and distant organ metastasis/recurrence rates were higher in Group I. However, although these parameters were higher in Group I patients who underwent CPB, the differences were not statistically significant. A possible explanation is that the disease was more advanced in Group I patients, with tumor thrombus extending into the right atrium. In addition, it should be noted that concomitant procedures, such as CABG and MVR, were performed in three patients. Early postoperative survival improved in both groups, suggesting that performing surgical thrombectomy rather than considering stage IV patients inoperable contributed to improved survival outcomes.

In patients diagnosed with RCC with an IVC thrombus, radical surgery, including radical nephrectomy with surgical IVC thrombectomy, is considered the mainstay of treatment. In addition, preoperative imaging with contrast-enhanced MRI or CT angiography is mandatory. For optimal exposure and control of the subdiaphragmatic IVC, specific surgical maneuvers and techniques are employed, with and without CPB. Long-term survival and improved quality of life can be achieved through meticulous preoperative planning, effective teamwork, coordination, and surgical expertise.[1] At our institution, every patient with RCC and an IVC thrombus is discussed by a multidisciplinary tumor board comprising urologists, oncologists, cardiovascular surgeons, and general surgeons.

The optimal treatment for patients with RCC and an IVC thrombus remains controversial and technically challenging.[8] Most authors state that for level I and level II RCC with an IVC thrombus, proximal and distal clamping of the IVC after exploration is sufficient for resection of these tumor thrombi. However, for level III or level IV thrombi extending to the diaphragm or into the right atrium, more complex interventions may be required, including the use of CPB, to control back-bleeding from the IVC and portal venous system and to prevent distal congestion.[9]

In general, these challenging cases should be carefully planned and managed by a multidisciplinary team comprising specialists in urology, cardiovascular surgery, and general surgery. There are four surgical options for the treatment of level III RCC with an IVC thrombus. The first is the "clamp-and-go" technique without CPB, in which the IVC is clamped proximally and distally whenever possible. The second is the use of a passive shunt without initiating CPB, allowing venous blood distal to the IVC clamp to return directly to the right atrium. The third option is the use of a CPB-assisted shunt between the IVC and femoral artery. The fourth option is standard CPB using a heart-lung machine. However, the use of CPB remains controversial.[8] For patients with level IV RCC and an IVC thrombus, we generally prefer CPB because it reduces bleeding, helps prevent air embolism, and makes the procedure technically easier to perform.

Nguyen et al.[10] evaluated the impact of CPB in 362 patients with level III and IV RCC with IVC tumor thrombus and reported that CPB did not improve perioperative mortality, morbidity, or overall survival. In contrast, Yano et al.[8] advocated the routine use of CPB in patients with level IV tumors. They further suggested that, particularly in cases with intra-atrial thrombus extension, deep hypothermic circulatory arrest may be required despite the associated risk of coagulopathy.[11,12] To mitigate CPB-related complications, such as coagulopathy and neurological and systemic adverse events, veno-venous bypass has also been proposed as an alternative strategy in selected patients.[13-18] Therefore, based on our findings, we believe that the use of CPB does not increase the risk of tumor progression.

Table 2. Postoperative outcomes of Group I (with CPB) and Group II (without CPB)

	Group I (with CPB) (n=8)	Group II (without CPB) (n=14)	p-value
Duration of surgery (min)	267.5±121.4	190.4±38.7	0.038*
Post operative Bleeding (mL)	647.42±89.47	393.59±68.22	0.001*
Blood transfusion (units)	3.3±2.9	1.7±1.9	0.14
ICU stay (days)	4.78±5.93	2.25±1.98	0.15
Length of hospital stay (days)	9.67±6.10	7.45±3.89	0.30
Follow-up (months)	13.94±9.12	15.23±5.31	0.67
Cholecystectomy	2	6	0.40
TCA (min)	25.47±4.5	-	-
Distant organ metastasis/recurrence rates	7	3	0.002*
Perioperative death	2	-	0.16
1-year survival rate	6	11	0.12

TCA: Total circulatory arrest; CPB: Cardiopulmonary bypass; ICU: Intensive care unit.

In our study, no significant differences were found between patients who underwent CPB and those who did not with respect to perioperative morbidity and mortality. In addition, in our series, CPB was routinely used in all level IV patients, whereas none of the level III patients underwent CPB. Instead, we prefer a case-by-case approach. Because CPB has both advantages and disadvantages, we carefully weigh its risks and benefits before deciding whether to use it. Particularly in level IV patients, CPB not only maintained hemodynamic stability throughout the operation but also enabled aspiration of blood from the surgical field and reinfusion into the circulation, thereby reducing the need for blood transfusions.[8]

Although CPB offers several advantages in complex tumor thrombus surgery, its potential complications must always be considered. These include heparin-related coagulopathy, cannulation-related complications, and the risk of distal or proximal embolization. Additionally, concerns have been raised regarding the potential for tumor cell dissemination and subsequent metastasis associated with CPB, particularly because of suction (cell-saver) aspiration and reinfusion of blood during surgery. However, it remains unclear whether such metastases are attributable to the intrinsic biological behavior of the tumor or to intraoperative tumor cell dissemination related to CPB and suction-assisted blood reinfusion.[8]

When thrombectomy is performed through the right atrium without CPB support, meticulous precautions must be taken to prevent air embolism. In patients with level III and IV tumors, another important consideration is clamping of the hepatoduodenal ligament, that is, performing the Pringle maneuver to simultaneously occlude the portal vein and hepatic artery and thereby control hepatic venous flow. In cases of level III tumor thrombus in which CPB is not used, if the tumor burden is high, the duration of hepatoduodenal ligament clamping may exceed 30 minutes. Although the liver is relatively resistant to ischemia, prolonged clamping may lead to mesenteric ischemia, which is more susceptible to ischemic injury, and may also cause bowel congestion. Therefore, the recommended safe clamping time is 8-25 minutes (<30 minutes). Prolonged clamping has been associated with bacterial translocation, paralytic ileus, and non-occlusive intestinal ischemia.[8,14,15] Yano et al.[8] reported that no cannulation-related complications were observed in their series of six patients with level III or IV tumor thrombus who underwent IVC cannulation. Similarly, we observed no cannulation-related complications in our series. Master et al.[9] evaluated 140 patients and compared outcomes between two groups according to the surgical team. They found significantly shorter operative times (5.3 *vs.* 6.7 hours; p=0.009) and ICU length of stay (0.4 *vs*. 2.2 days; p=0.001) in the dedicated surgical team. In our study, however, operative times and ICU stays were somewhat longer. We believe that this difference is primarily attributable to our relatively small patient cohort. Nevertheless, our findings support the concept that the more frequently a dedicated surgical team performs this procedure, the better the clinical outcomes are likely to be.

In addition, Yano et al.[8] reported that, excluding three patients who had distant metastases preoperatively, 8 of the remaining 13 patients (62%) developed metastases within the first postoperative year. Among these eight patients, lung metastases were detected in six, liver metastases in four, lymph node metastases in two, and adrenal metastasis in one patient. However, no statistically significant difference was observed between patients who underwent CPB and those who did not with respect to distant organ metastasis. Master et al.[9] analyzed 140 patients and found that disease recurrence occurred in 25% of cases during follow-up. In addition, nearly one-fourth of the patients subsequently received systemic therapy. Similarly, in our study, comparable recurrence rates were observed (45%, 10/22), and no significant difference was found between the CPB and non-CPB groups. The most common metastatic sites were the lungs (n=6) and the liver (n=6). Despite these recurrence rates, the reported 5-year survival rate of 52-60% further emphasizes the importance of radical surgery in this patient population.[8,16] In our study, the 1-year survival rate was 77.2% (17/22).

There are reports suggesting that the prognostic impact of the intraoperative tumor thrombus level remains controversial. Patients with RCC limited to the renal vein (without IVC invasion) have significantly better survival than those with IVC involvement (p =0.002). However, once the thrombus extends into the IVC, the thrombus level does not appear to have a statistically significant impact on survival (p=0.868).[5] In the early postoperative period (within 30 days), complications related to nephrectomy or tumor thrombectomy have been reported in approximately 15% of patients, whereas perioperative mortality has been reported to be 2-3%.[5] In our study, the perioperative mortality rate was 9% (2/22), and the early complication rate was 22.7% (5/22). In patients with RCC, the tumor recurrence rate can be as high as 31% at a median follow-up of 1.6 years after surgery.[17]

In addition to transjugular balloon occlusion of the suprahepatic IVC, extensive and meticulous liver mobilization is used in cases of subdiaphragmatic retrohepatic thrombus.[18,19] For level III and IV tumor thrombi, the piggyback liver mobilization technique represents an alternative surgical approach.[20] Although open surgery remains the mainstay of treatment for RCC with IVC tumor thrombus, novel surgical innovations continue to evolve. Median sternotomy may be indicated to obtain intrapericardial IVC control in patients with retrohepatic or suprahepatic tumor thrombus. Robot-assisted IVC thrombectomy for level II-III thrombi is gaining popularity; however, its application in patients with level III-IV IVC thrombi remains limited.[21] The higher recurrence rate observed in the CPB group may be explained by the fact that these patients predominantly presented with more advanced disease. Therefore, this difference is unlikely to be attributable solely to the use of CPB and is more likely associated with a greater tumor burden and more advanced disease. In addition, Nguyen et al.[10] reported that, in a study of 362 patients with RCC and IVC tumor thrombus, the use of CPB was not associated with worse survival. Our mid-term outcomes are consistent with these findings. Therefore, CPB should not be avoided when clinically indicated.

In our study, cell salvage was not used in any of the surgical procedures. Although opinions differ, there is currently no evidence indicating that the use of cell salvage adversely affects oncological outcomes.[22]

The present study has several limitations. First, the sample size was relatively small compared with those of larger published series. Second, the study was retrospective in design, which inherently introduced the potential for selection bias. Third, although we compared RCC patients with IVC tumor thrombus who underwent surgery with and without CPB, the CPB group consisted predominantly of patients with level IV

thrombi, whereas the non-CPB group included mainly patients with level I-II thrombi. Because of the limited number of patients, a direct comparison between level III-IV patients managed with and without CPB could not be performed. Future studies with larger cohorts may allow for a more balanced comparison. Fourth, larger prospective studies with adequately powered populations are required to validate our findings. Fifth, because of the small sample size, a multivariable analysis was not feasible. Finally, longer-term follow-up is necessary to better assess oncologic outcomes and survival.

In conclusion, this limited series demonstrates that the use of CPB in the surgical management of patients with RCC and IVC tumor thrombus may not increase perioperative complication rates, except for increased postoperative bleeding. However, these findings should be interpreted with caution because of the imbalance in disease stage between the groups. Conversely, CPB may facilitate operative management in carefully selected high-risk patients. Although CPB may be associated with prolonged ICU and hospital stays, we believe that its contribution to operative safety and surgical success may outweigh these disadvantages in complex tumor thrombus surgery.

Ethics

Ethics Committee Approval: This study was approved by the Regional Ethics Committee of İstanbul University-Cerrahpaşa (decision no: İUC KAEK 2025/413, approval number: 2025/413, date: 07.07.2025) and was conducted in accordance with the principles of the Declaration of Helsinki.

Informed Consent: Written informed consent was obtained from all participants.

Footnotes

Authorship Contributions

Concept: B.A., Ç.D., D.G.; Design: Ç.T.Ü., O.O.B., D.G., S.N.Ö., G.İ.; Data Collection or Processing: B.A., U.D., E.Ç.; Analysis or Interpretation: B.A., S.B.D.; Literature Search: B.A., S.B.D.; Writing: B.A., S.B.D.

Conflict of Interest: One of the authors of this article (S.B.D.) is a member of the Editorial Board of this journal. He was completely blinded to the peer review process of the article. No conflict of interest was declared by the authors.

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References

1. Hevia V, Ciancio G, Gómez V, Álvarez S, Díez-Nicolás V, Burgos FJ. Surgical technique for the treatment of renal cell carcinoma with inferior vena cava tumor thrombus: tips, tricks and oncological results. Springerplus. 2016;5:132. doi: 10.1186/s40064-016-1825-1.
2. Martínez-Salamanca JI, Linares E, González J, Bertini R, Carballido JA, Chromecki T, et al. Lessons learned from the international renal cell carcinoma-venous thrombus consortium (IRCC-VTC). Curr Urol Rep. 2014;15:404. doi: 10.1007/s11934-014-0404-7.
3. Tilki D, Nguyen HG, Dall'Era MA, Bertini R, Carballido JA, Chromecki T, et al. Impact of histologic subtype on cancer-specific survival in patients with renal cell carcinoma and tumor thrombus. Eur Urol. 2014;66:577-83. doi: 10.1016/j.eururo.2013.06.048.
4. Lwin AA, Pollock GR, Chipollini J. Cytoreductive nephrectomy in patients with metastatic renal cell carcinoma and venous thrombus-trends and effect on overall survival. Ann Transl Med. 2019;7(Suppl 6):S196. doi: 10.21037/atm.2019.07.21.
5. Blute ML, Leibovich BC, Lohse CM, Cheville JC, Zincke H. The Mayo clinic experience with surgical management, complications and outcome for patients with renal cell carcinoma and venous tumour thrombus. BJU Int. 2004;94:33-41. doi: 10.1111/j.1464-410X.2004.04897.x.
6. Wang B, Li H, Ma X, Zhang X, Gu L, Li X, et al. Robot-assisted laparoscopic inferior vena cava thrombectomy: different sides require different techniques. Eur Urol. 2016;69:1112-9. doi: 10.1016/j.eururo.2015.12.001.
7. Neves RJ, Zincke H. Surgical treatment of renal cancer with vena cava extension. Br J Urol. 1987;59:390-5. doi: 10.1111/j.1464-410x.1987.tb04832.x.
8. Yano D, Yokoyama Y, Tokuda Y, Kato M, Mashiko Y, Kuwabara F, et al. Multidisciplinary surgical approach for renal cell carcinoma with inferior vena cava tumor thrombus. Surg Today. 2022;52:1016-22. doi: 10.1007/s00595-021-02415-1.
9. Master VA, Ethun CG, Kooby DA, Staley CA, Maithel SK. The value of a cross-discipline team-based approach for resection of renal cell carcinoma with IVC tumor thrombus: a report of a large, contemporary, single-institution experience. J Surg Oncol. 2018;118:1219-26. doi: 10.1002/jso.25271.
10. Nguyen HG, Tilki D, Dall'Era MA, Durbin-Johnson B, Carballido JA, Chandrasekar T, et al. Cardiopulmonary bypass has no significant impact on survival in patients undergoing nephrectomy and level III-IV inferior vena cava thrombectomy: multi-institutional analysis. J Urol. 2015;194:304-8. doi: 10.1016/j.juro.2015.02.2948.
11. Chowdhury UK, Mishra AK, Seth A, Dogra PN, Honnakere JH, Subramaniam GK, et al. Novel techniques for tumor thrombectomy for renal cell carcinoma with intraatrial tumor thrombus. Ann Thorac Surg. 2007;83:1731-6. doi: 10.1016/j.athoracsur.2006.12.055.
12. Jibiki M, Iwai T, Inoue Y, Sugano N, Kihara K, Hyochi N, et al. Surgical strategy for treating renal cell carcinoma with thrombus extending into the inferior vena cava. J Vasc Surg. 2004;39:829-35. doi: 10.1016/j.jvs.2003.12.004.
13. Simon RM, Kim T, Espiritu P, Kurian T, Sexton WJ, Pow-Sang JM, et al. Effect of utilization of veno-venous bypass vs. cardiopulmonary bypass on complications for high level inferior vena cava tumor thrombectomy and concomitant radical nephrectomy. Int Braz J Urol. 2015;41:911-9. doi: 10.1590/S1677-5538.IBJU.2014.0371.
14. Dello SA, Reisinger KW, van Dam RM, Bemelmans MH, van Kuppevelt TH, van den Broek MA, et al. Total intermittent Pringle maneuver during liver resection can induce intestinal epithelial cell damage and endotoxemia. PLoS One. 2012;7:e30539. doi: 10.1371/journal.pone.0030539.
15. Manassero F, Mogorovich A, Di Paola G, Valent F, Perrone V, Signori S, et al. Renal cell carcinoma with caval involvement: contemporary strategies of surgical treatment. Urol Oncol. 2011;29:745-50. doi: 10.1016/j.urolonc.2009.09.018.
16. Karnes RJ, Blute ML. Surgery insight: management of renal cell carcinoma with associated inferior vena cava thrombus. Nat Clin Pract Urol. 2008;5:329-39. doi: 10.1038/ncpuro1122.
17. Dashkevich A, Bagaev E, Hagl C, Pichlmaier M, Luehr M, von Dossow V, et al. Long-term outcomes after resection of stage IV cavoatrial tumour extension using deep hypothermic circulatory arrest. Eur J Cardiothorac Surg. 2016;50:892-7. doi: 10.1093/ejcts/ezw136.
18. Metcalfe C, Chang-Kit L, Dumitru I, Macdonald S, Black P. Antegrade balloon occlusion of inferior vena cava during thrombectomy for renal cell carcinoma. Can Urol Assoc J. 2010;4:E105-8. doi: 10.5489/cuaj.892.

19. Ciancio G, Soloway M. Endoluminal occlusion of the inferior vena cava in renal cell carcinoma with retro- or suprahepatic caval thrombus. BJU Int. 2006;98:915. doi: 10.1111/j.1464-410X.2006.06473_1.x.

20. Komarov RN, Rapoport LM, Belov YV, Germagenova EK, Chernyavskii SV, Ismailbaev AM, et al. Surgical treatment of renal cell carcinoma with tumor thrombosis of the inferior vena cava and the right heart: how we do it. Urologia. 2023;90:470-5. doi: 10.1177/03915603221143566.

21. Zhang Y, Bi H, Fu Y, Zhang H, Zhang S, Liu K, et al. Cephalic inferior vena cava non-clamping technique versus standard procedure for robot-assisted laparoscopic level II-III thrombectomy: a prospective cohort study. Int J Surg. 2023;109:1594-602. doi: 10.1097/JS9.0000000000000209.

22. Wu WW, Zhang WY, Zhang WH, Yang L, Deng XQ, Ou MC, et al. Survival analysis of intraoperative blood salvage for patients with malignancy disease: a PRISMA-compliant systematic review and meta-analysis. Medicine (Baltimore). 2019;98:e16040. doi: 10.1097/MD.0000000000016040.