BJUI Radical nephrectomy with vena caval thrombectomy: a contemporary experience

Matthew G. Kaag, Christien Toyen*, Paul Russo, Angel Cronin[†],
R. Houston Thompson, Jeffrey Schiff, Melanie Bernstein and Manjit Bains*

Urology Service and *Thoracic Service, Department of Surgery, and [†]Department of Epidemiology and Biostatistics, Memorial Sloan-Kettering Cancer Center, New York, NY, USA

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OBJECTIVE

- To report on the contemporary Memorial Sloan-Kettering Cancer Center experience with radical nephrectomy and vena caval thrombectomy.

PATIENTS AND METHODS

- Patients who underwent radical nephrectomy and vena caval thrombectomy without the use of bypass techniques were retrospectively identified.
- Data were collected on intraoperative and pathological findings as well as postoperative complications and oncological outcomes.

RESULTS

- In all, 78 patients underwent radical nephrectomy with off-bypass resection of vena caval thrombus between 1989 and 2009.

What's known on the subject? and What does the study add?

Renal tumours with caval thrombus are relatively rare. Surgical management is the standard of care for lesions of this nature. Small series have been published by other groups, but our understanding of the optimal management continues to evolve.

We present the Memorial Sloan-Kettering Cancer Center series, with a discussion of techniques and complications. Of interest, we include several patients with high-level caval thrombi which were managed without bypass, supporting previous publications by the group from University of Miami.

- The median (interquartile range, IQR) operation duration was 293 (226–370) min, and median (IQR) blood loss was 1300 (750–2500) mL. In all, 10 patients (13%) were confirmed to have intra- or supra-hepatic tumour thrombus (level 3/4), eight of whom required supra-hepatic control of the inferior vena cava (IVC).
- Major (grade 3–5) postoperative complications occurred in 14 (18%), with five postoperative deaths. Disease recurred in 27/62 patients who were considered completely resected at surgery and had adequate follow-up.
- The overall 5-year survival (95% confidence interval) probability was 48% (35–60%).

CONCLUSIONS

- Radical nephrectomy with vena caval thrombectomy is associated with acceptable postoperative morbidity and mortality, and long-term survival is possible in some patients.
- Many level 3/4 thrombi could be safely approached without the use of bypass techniques.

KEYWORDS

RCC, kidney, vena cava, nephrectomy

INTRODUCTION

Despite the recent stage migration in renal cell carcinoma (RCC) with an increased incidence of small, localized tumours, the detection rate of advanced-stage disease has not diminished [1]. Historically, extension of RCC into the inferior vena cava (IVC) has been reported in 5–10% of patients [2,3]. Slightly lower rates of IVC involvement (3–7%) are reported in contemporary series from the Memorial Sloan-Kettering Cancer Center (MSKCC) and the Mayo Clinic [4,5]. Surgical resection is required, and in some cases is

sufficient, for the cure of such advanced disease. In one large series, the 5-year cancer-specific survival after radical nephrectomy and IVC thrombectomy was 32%; patients at lower risk (free of distant metastasis at surgery) enjoyed better outcomes (5-year cancer-specific survival of 59%) [5].

Initial descriptions of the thrombectomy technique describe reliance upon cardiopulmonary bypass and, in some cases, hypothermic circulatory arrest for the resection of thrombi involving the intra- and supra-hepatic IVC [2,3,6]. Subsequently,

venovenous bypass techniques were described with the same goal: obtaining a bloodless operative field to facilitate complex IVC resection and reconstruction [7–9]. Earlier in this decade, investigators at the University of Miami began to describe the application of liver transplantation techniques to aid in the dissection of the intra- and supra-hepatic IVC, eliminating the need for circulatory bypass in their hands [10,11].

Despite advances in targeted systemic therapy, surgical resection remains the critical component in the care of patients with locally

FIG. 1. Schematic depicting the furthest progression of each patient's IVC thrombus. Level 1, within 2 cm of the renal vein os; level 2, ≥ 2 cm above the renal vein os but below the hepatic veins; level 3, intra-hepatic to the level of the diaphragm; level 4, supra-diaphragmatic.

PATIENTS AND METHODS

After institutional review board approval, we performed a retrospective review of our prospectively maintained nephrectomy database. We identified patients who had undergone radical nephrectomy with IVC thrombectomy without circulatory bypass. Patients with thrombi involving only the renal vein were excluded. We stratified patients by thrombus level at the time of surgery as previously described by Nesbitt *et al.* [3] in 1997 (Fig. 1), and also by surgical approach to the IVC (IVC controlled above vs below the liver). Data were reported regarding clinical presentation, intraoperative findings, tumour pathology, postoperative course and oncological outcomes. Complications were recorded, categorized and graded using a modified version of the Clavien system [13] as described previously (Table 1) [14]. Complication data were confirmed via careful review of all patient charts and outpatient notes. Complications were recorded up to 30 days after surgery. Due to the nature of the procedure and expected blood loss, we excluded transfusion requirement as a complication, and report that data separately. Thromboembolic events (deep vein thrombosis or pulmonary embolus) were radiographically confirmed. Ileus was defined as the inability to tolerate oral feeding by postoperative day 5 or nausea, vomiting or distension requiring nasogastric drainage, fluid support or parenteral nutrition. Complication grades ≥ 3 are considered major complications.

TABLE 1 Postoperative complication grades

Grade	Description
Grade 0	No event
Grade 1	Bedside intervention or oral medication
Grade 2	Intravenous medication, total parenteral nutrition, enteral nutrition, thromboembolic event requiring heparin
Grade 3	Operation, interventional radiology, angiography, intubation, transfer to intensive care, haemodialysis
Grade 4	Chronic disability, organ resection
Grade 5	Death

advanced RCC, including those with IVC thrombi. As described, the technique continues to evolve. In 1991 Burt [12] reported the initial experience with IVC thrombectomy without cardiovascular bypass at MSKCC in nine patients. In the present study, we report

our updated single-institution experience with radical nephrectomy and off-bypass IVC thrombectomy, with attention to intraoperative findings, postoperative morbidity and mortality, and oncological outcomes.

Descriptive statistics were compiled for all pre- and postoperative findings. Survival analysis was by the Kaplan–Meier technique and included all patients surviving the day of surgery with adequate (>30 days) follow-up in survivors. Univariate predictors of survival were determined using the log-rank test. $P < 0.05$ was considered to indicate statistical significance and all analyses were two-tailed. Multivariate analyses were not attempted due to the small number of patients and events. All statistical calculations were carried out using Stata 8.2 (College Station, TX, USA).

RESULTS

Between 1989 and 2009, 3610 patients underwent resection of a renal mass at MSKCC. IVC involvement was confirmed at surgery in 84 (2%) of them. Six (7%) patients

who underwent thrombectomy on cardiopulmonary or venovenous bypass (all cases done before 1996) were excluded, leaving 78 patients in our population of interest. The median (interquartile range, IQR) age of the group was 63 (55–70) years, and 60 (77%) of them were men. At presentation, 64 (82%) patients were symptomatic, while 15 (19%) had distant (beyond the retroperitoneal lymph nodes) metastases. Further demographic details are reported in Table 2.

SURGICAL TECHNIQUE AND INTRAOPERATIVE FINDINGS

Operative details are recorded in Table 3. Detailed information regarding patients with level 3/4 thrombi can be found in Table 4. Briefly, 10 (13%) patients were found to have level 3/4 thrombi at surgery, eight of whom were approached with supra-hepatic control of the IVC as outlined below. The remaining 70 (90%) patients, including one with level 3 and one with level 4 thrombus, were successfully approached with infra-hepatic vascular control only. Extensive involvement of the IVC wall by tumour was discovered in 12 (15%) patients, and completely resected with IVC reconstruction in 11 patients. Thrombectomy was not completed in one patient who had

undergone a previous, failed attempt at resection at an outside hospital. In this case, a level 4 thrombus was found to be circumferentially invading the intrahepatic IVC wall over a considerable distance. It was

felt that thrombectomy would be at best incomplete, if not immediately fatal; nephrectomy was completed without thrombectomy. The patient survived 5 years before dying of unknown causes.

Variable	<i>n</i> (%) or median (IQR)	TABLE 2 <i>Patient characteristics</i>
No. of patients	78	
Sex		
Male	60 (77)	
Female	18 (23)	
Age at surgery		
Median (IQR)	63 (55–70)	
ASA score (<i>n</i> = 75)*		
1	1 (1)	
2	30 (40)	
3	44 (59)	
Symptoms at presentation*		
None	14 (18)	
Local	57 (73)	
Systemic	20 (26)	
Bilateral disease		
Synchronous	3 (4)	
Asynchronous	1 (1)	
Absent	74 (95)	
Distant metastases at presentation		
Present	15 (19)	
Absent	63 (81)	

*ASA, American Society of Anesthesiologists. Percentages do not necessarily add up to 100% as Patients could have local and systemic symptoms.

TABLE 3 Intraoperative findings and postoperative outcome by thrombus level

	Total	Thrombus level		
		1	2	3/4
<i>N</i> (%)	78	24 (31)	44 (56)	10 (13)
Median (IQR) operative time, min	293 (226–370)	225 (190–310)	297 (245–386)	363 (293–440)
Median (IQR) estimated blood loss, mL	1300 (750–2500)	1000 (300–2000)	1500 (1000–2750)	1900 (1200–3400)
Approach to thrombus, <i>n</i> (%)*				
Suprahepatic	8 (10)	0 (0)	0 (0)	8 (80)
Infrahepatic	70 (90)	24 (100)	44 (100)	2 (20)
Tumour adherent to IVC wall, <i>n</i> (%)				
Yes	12 (15)	0 (0)	9 (20)	3 (30)
No	66 (85)	24 (100)	35 (80)	7 (70)
Median (IQR) length of stay, days	7 (5–11)	6 (4–9)	7 (5–11)	6.5 (6–11)
Transfused, <i>n</i> (%)				
Yes	51 (65)	15 (62)	28 (64)	8 (80)
No	27 (35)	9 (38)	16 (36)	2 (20)
Median (IQR) no. of units transfused [†]	3 (2–7)	2 (1–7)	4 (2–7.5)	6.5 (2–10)
Postoperative mortalities, <i>n</i> (%)				
Yes	5 (6)	2 (8)	3 (7)	0 (0)
No	73 (94)	22 (92)	41 (93)	10 (100)

*Approach defined by level of highest vascular control.

[†]Number of units transfused among patients receiving transfusion.

TABLE 4 Operative data and outcomes for individual level 3/4 patients

Thrombus level	Incision	Approach to IVC	Pathological size, cm	Blood loss, mL	Postoperative course and outcome
1 3	Flank (transperitoneal) + median sternotomy	Aberrant course of IVC required median sternotomy with control of the intra-pericardial IVC with a vessel loop, infra-hepatic cavotomy	8	3400	LOS 4 days. No complications. Recurred 7 months after surgery in IVC and retroperitoneal nodes. Alive with disease, on sunitinib at last follow-up 1.5 years after surgery
2 3	Thoraco-abdominal	Tumour milked back and vessel loop used to control IVC just below common hepatic veins	12.2	3400	LOS 7 days. ICU stay for prolonged mechanical ventilation. Liver and retroperitoneal/mediastinal recurrence 5 years after surgery. Alive 7.5 years after surgery, following interferon, then bevacizumab + sunitinib
3 3	Chevron	DeWeese clip at atrial-caval junction (left open) and a Rumel tourniquet. Rumel tourniquets at infra-renal IVC, contralateral renal vein and portal triad. Infrahepatic cavotomy	8	1200	LOS 6 days. Uncomplicated hospital course. Alive, no evidence of disease 10 years after surgery
4 3	Chevron	Moretz clip at atrial-caval junction, Rumel tourniquets at infra-renal IVC and contralateral renal vein, and portal triad. Infrahepatic cavotomy and Fogarty balloon for thrombus extraction	11	4000	LOS 15 days. Postoperative course complicated by mild volume overload and ileus. Patient died of other causes 1.4 years after surgery
5 3	Chevron	Moretz clip at atrial-caval junction. Rumel tourniquets at infrarenal IVC and contralateral renal vein. Thrombus milked down below common hepatics and vascular clamp placed above. Infra-hepatic cavotomy with resection of IVC wall	12	1200	LOS 34 days. Course complicated by SIADH and ascites/pericardial effusion due to hepatic venous congestion. The latter responded to open drainage and removal of the Moritz clip. Patient died of disease 7 months after surgery
6 3	Thoraco-abdominal	Moretz clip at atrial-caval junction. Rumel tourniquets at infra-renal IVC and contralateral renal vein. Thrombus milked below common hepatics and clamp placed above. Infrahepatic cavotomy	8	800	LOS 11 days. ICU stay postoperatively for hypotension, pulmonary insufficiency. Alive without evidence of disease 12 years after surgery
7 3	Chevron	Supra-hepatic IVC encircled with Rumel but not clamped. Rumel tourniquets placed on infra-renal IVC and contralateral renal vein. Manual pressure to occlude supra-diaphragmatic IVC. Infrahepatic cavotomy	7.8	5000	LOS 7 days. Hospital course complicated by atrial fibrillation. Re-admitted to outside hospital in renal failure requiring dialysis 2 weeks after discharge. Known lung metastases at surgery, not resected. Alive with disease 3 months after surgery
8 4	Chevron	Suprahepatic IVC exposed, not clipped; tourniquet left open around IVC below liver. Thrombus was freely mobile on examination and was withdrawn intact through cavotomy and tourniquet tightened once thrombus was clear	7.7	450	LOS 5 days. Uneventful hospital course. Tumour recurrence within the intra-hepatic IVC required cavotomy with resection of IVC wall 7 years after initial surgery. Now alive and free of disease 10 years after initial surgery
9 4	Chevron	Allen clip at atrial-caval junction (left open). Rumel tourniquets placed on infra-renal IVC and contralateral renal vein. Manual pressure to occlude supra-diaphragmatic IVC. Infrahepatic cavotomy	14	2500	LOS 6 days. Uneventful postoperative course. Local (IVC and retroperitoneal) recurrence 6 months after surgery. Received interferon but died of disease 1.2 years after surgery
10 4	Thoraco-abdominal	Supra-hepatic IVC exposed. Examination revealed tumour thrombus circumferentially invading the IVC wall and completely occluding the intra-hepatic IVC. Thrombus transected with renal vein, nephrectomy completed but thrombus left <i>in situ</i>	8.2	1300	LOS 6 days. Uneventful hospital course. Survived 6 years after surgery. Died of unknown cause

LOS, length of stay; SIADH, syndrome of inappropriate antidiuretic hormone hypersecretion.

Level 1 and 2 thrombi were approached through a variety of incisions (sub-costal, thoraco-abdominal, hemi-chevron, chevron, flank) depending upon surgeon preference. Infra-hepatic thrombi required vascular control of the infra-renal IVC, contralateral renal vein, and supra-renal IVC followed by cavotomy and tumour extraction. The infra-hepatic approach was used successfully in one level 3 and one level 4 thrombus deemed freely mobile at resection. In both cases the thrombi were felt not to be adherent within the IVC based on MRI. Tourniquets were placed on the infra-renal IVC, contralateral renal vein, and supra-renal IVC, but the supra-renal tourniquet was not tightened. The level 3 thrombus was gently drawn back into the infra-hepatic IVC before cavotomy, and the tourniquet was cinched above it. The level 4 thrombus was evaluated once the IVC was exposed above the liver and was thought to be freely mobile. The cavotomy was performed and the thrombus withdrawn, aided by the back-bleeding from the suprarenal vena cava. Both thrombi were withdrawn intact without embolization (see Table 4 for further details).

In all, six of 10 level 3/4 thrombi were addressed via a chevron incision, a thoraco-abdominal approach was used in three, and one patient with a left-sided IVC required a combined approach via chevron incision and median sternotomy. In all cases, attempts were made to mobilize the kidney and ligate the renal artery before addressing the IVC thrombus. In all but one case (median sternotomy for adequate access to the intra-pericardial IVC in a patient with aberrant anatomy), level 3/4 thrombi that could not be addressed solely by an infra-hepatic approach were accessed via mobilization of the liver and a trans-diaphragmatic approach to the intra-pericardial IVC where necessary. A vascular clip was then placed around the IVC at this level, often left in the open position. A Rumel tourniquet was used if the surgeon preferred. Manual compression or the Rumel tourniquet could then be used in combination with the Pringle manoeuvre to control retrograde flow as the IVC was opened and the thrombus extracted. Retrograde flow was re-established before closure of the cavotomy to flush all tumour debris from the IVC. Trans-oesophageal echocardiography (TEE) was available but not routinely used. In all patients with level 3/4 thrombi, thoracic surgery was involved in preoperative planning and the operation itself. Detailed description of the

TABLE 5 Summary of the most common complications experienced

Complications	Thrombus level			
	Total (n = 77)	1 (n = 24)	2 (n = 43)	3/4 (n = 10)
Minor complications (grade 1–2) ranked by frequency, n (%)				
Cardiac	12 (16)	3 (13)	8 (19)	1 (10)
Gastrointestinal	7 (9)	1 (4)	6 (14)	0 (0)
Renal	4 (5)	1 (4)	1 (2)	2 (20)
Thromboembolic	4 (5)	0 (0)	4 (9)	0 (0)
Neurological	3 (4)	2 (8)	1 (2)	0 (0)
Total with minor complication*	28 (36)	5 (21)	20 (47)	3 (30)
Major complications (grade 3–5) ranked by frequency, n (%)				
Pulmonary	9 (12)	1 (4)	6 (14)	2 (20)
Cardiac	3 (4)	0 (0)	2 (5)	1 (10)
Renal	3 (4)	0 (0)	2 (5)	1 (10)
Wound	1 (1)	1 (4)	0 (0)	0 (0)
Gastrointestinal	1 (1)	0 (0)	0 (0)	1 (10)
Total with major complication*	14 (18)	1 (4)	9 (21)	4 (40)

*Some patients had more than one major or minor complication.

surgical approach and outcome for each of the level 3/4 patients is shown in Table 4.

HOSPITALIZATION AND COMPLICATIONS

The median (IQR) length of stay was 7 (5–11) days. Transfusions (autologous or non-autologous blood) were necessary in 51 (65%) patients, with a median (IQR) of three (two to seven) units transfused in those receiving blood. There were no intraoperative mortalities. Four patients died during the 30-day postoperative period (three in hospital, one after discharge). One additional death occurred at 33 days after surgery, after a prolonged postoperative intensive care stay, and is included as a postoperative mortality in the present analysis [total of five (6%) postoperative mortalities]. No patient with a level 3/4 thrombus died within the 30-day postoperative period. Complication data were available for 77 patients. Fifty-five complications were noted in 33 (43%) patients, but major complications were seen in only 14 (18%). Complications are presented by thrombus level in Table 5. Cardiac and pulmonary complications were most common overall. Severe pulmonary complications were usually respiratory failure requiring reintubation, often as part of multi-organ system failure, and were the most common cause of death in the postoperative period. Four patients were reported with ileus, one of whom required total parenteral nutrition; three patients required haemodialysis and one had documented pulmonary embolus. After

surgery, four (5%) patients had documented emergency room visits and three (4%) had documented re-admissions.

PATHOLOGICAL FINDINGS

The median (IQR) tumour diameter was 9.5 (8–12.2) cm with the majority (87%) found to be conventional clear cell cancer. Lymph node dissection was documented in 62 (79%) patients, with positive nodes found in 11/62 (18%). The median (IQR) node count was eight (three to 16) among those undergoing lymphadenectomy. A positive soft tissue surgical margin (not venous margin) was documented in six (8%) patients. Detailed pathological information is reported in Table 6.

ONCOLOGICAL OUTCOMES

In all, 65 (83%) patients were deemed completely resected at the time of surgery, including seven of 10 patients with level 3/4 thrombi; four of 15 patients with known distant (non-nodal) metastases underwent complete metastasectomy, including one patient with an adrenal metastasis identified and resected at surgery. There were 62 of 65 completely resected patients who had postoperative follow-up (two expired before discharge and one was lost to follow-up); of these, 27 (41%) experienced disease recurrence. There were six local recurrences and 25 distant recurrences. The median recurrence-free survival was 87 months; the

TABLE 6 Pathological findings

Variable	
Maximum tumour diameter, cm	
Median (IQR)	9.5 (8–12.2)
Mean (range)	10.1 (3.5–20)
Pathologic stage, n (%)	
T3b	66 (85)
T3c	3 (4)
T4	9 (11)
Fuhrman grade, n (%) (n = 65)	
2	15 (23)
3	28 (43)
4	22 (34)
Tumour histology, n (%)	
Clear cell	68 (87)
Chromophobe	2 (3)
Unclassified	4 (5)
Lymph node counts (n = 62)*	
Median (IQR)	8 (3–16)
Lymph node status, n (%) (n = 62)*	
Positive	11 (18)
Negative	51 (82)
Surgical margin status, n (%)	
Negative	40 (51)
Positive vein	34 (44)
Positive soft tissue	6 (8)

*Data displayed for patients with lymph node data documented.

TABLE 7 Univariate predictors of overall survival by log-rank test

	5-year survival probability	(95% CI)	P
Overall (n = 76)	0.48	(0.35–0.60)	–
Local symptoms			
No	0.46	(0.20–0.69)	0.73
Yes	0.49	(0.33–0.62)	
Systemic symptoms			
No	0.57	(0.41–0.69)	<0.001
Yes	0.19	(0.03–0.43)	
Metastasis at surgery			
No	0.58	(0.43–0.70)	<0.001
Yes*	–	–	
Lymph node status (n = 62)			
Negative	0.57	(0.40–0.71)	0.003
Positive	0.21	(0.03–0.49)	
Soft tissue margin			
Negative	0.52	(0.38–0.64)	0.05
Positive†	–	–	
Fuhrman grade (n = 65)			
2	0.78	(0.46–0.92)	0.001
3	0.53	(0.29–0.72)	
4	0.30	(0.10–0.52)	
Tumour stage			
T3b or T3c	0.60	(0.44–0.73)	0.006
T4	0.17	(0.01–0.52)	
Thrombus level			
1 or 2	0.53	(0.37–0.67)	0.8
3 or 4	0.67	(0.28–0.88)	
Tumour diameter			
≤7	0.51	(0.19–0.76)	0.9
>7	0.57	(0.40–0.70)	

*No patient with metastatic disease at surgery remained alive at 5 years.

†No patient with a positive soft tissue margin (not vein margin) remained evaluable at 5 years; of six with positive soft tissue margins, two were lost to follow-up, four were deceased.

FIG. 2. Kaplan–Meier curve depicting overall survival after radical nephrectomy with IVC thrombectomy without cardiopulmonary bypass. Grey lines represent 95% confidence intervals.

median follow-up for those not experiencing an event was 55.5 months.

The median overall survival for the entire cohort was 55.5 months; the median follow-up time for survivors was 51 months (Fig. 2). Univariate predictors of survival with 5-year survival probabilities are reported in Table 7.

DISCUSSION

Complete surgical resection remains the only reliable means of achieving cure in patients with advanced RCC. Historically, large series report 5-year cancer-specific survival rates of 46–51% in locally advanced disease ($\geq T3a$) with surgery alone [15,16]. Targeted systemic therapies could extend the survival of patients with metastatic RCC [17], and could benefit patients with locally advanced disease as well [18]. The most appropriate application of targeted therapy and surgery in treating locally advanced or distantly metastatic RCC has not been clearly defined. Studies assessing the efficacy of cytoreduction before interferon-alpha immunotherapy have shown a benefit with maximal surgical debulking [19,20]. Prospective clinical trials are needed to assess the role of cytoreductive

nephrectomy in conjunction with contemporary targeted therapies.

Surgical resection offers some patients with IVC extension of their renal tumours the opportunity for long-term survival. In 2004 Rabbani *et al.* [4] reported the MSKCC experience with 31 patients who had IVC tumour extension. As part of a larger study evaluating tumour histology in patients with renal vein or IVC involvement, they presented a 5-year actuarial recurrence-free probability of 59% for the IVC thrombus population. Lymph node status, involvement of contiguous structures and the presence of distant metastasis at diagnosis have been shown to impact postoperative survival in this group [5,21,22]. The data in the present study confirm the efficacy of nephrectomy with IVC thrombectomy in achieving long-term

survival in some patients, and support the role of lymph node, Fuhrman grade, metastasis at diagnosis, systemic symptoms at diagnosis, and tumour stage as significant predictors of survival. The significance of these variables is somewhat unclear in the absence of a multivariate analysis.

Radical nephrectomy with IVC thrombectomy is a complex procedure that requires a well-trained, experienced and integrated operative team involving urological, thoracic and, if appropriate, hepatobiliary surgeons. However, with sufficient support, these operations can be completed in reasonable time, with reasonable risk to the patient. Published series describe perioperative mortality in 5–8% of patients undergoing excision of thrombus from the IVC [5,10,23]. Early complications (≤ 30 days after operation) are reported in 17–48% of patients [5,23] and have been shown to vary with thrombus level [5]. Our outcomes (6% perioperative mortality, 43% early complications, 18% major complications) compare well with the published literature. Our complication rate is at the upper limit of the reported range, but this probably stems from our stringent reporting methods [14].

The group from the University of Miami has described their success in managing IVC thrombi without the use of bypass techniques extensively, theoretically reducing the risk of associated coagulopathy and neurological sequelae [10,11]. We confirm, in a subgroup of our patients, that even complex intra-hepatic and supra-hepatic tumour thrombi could be addressed without circulatory bypass. Bypass techniques have not been used in MSKCC for the resection of caval thrombi since 1996. Patients with clinical evidence of supra-diaphragmatic caval wall invasion or extensive atrial involvement are referred to other institutions for bypass. This has been necessary once in the last 5 years. Other groups have advocated the use of intraoperative TEE to monitor thrombus level, particularly during resection of level 3/4 thrombi [24]. We believe it is most useful in patients with the indications for cardiopulmonary bypass listed earlier. Thus while TEE is available intraoperatively, it is not used routinely at MSKCC. There were no perioperative fatalities among the 10 patients with level 3/4 thrombi. In one patient, thrombectomy could not be completed because of clinically undetected, extensive involvement of the intra-hepatic caval wall by tumour. Circumferential invasion along

the length of the intra-hepatic IVC made it unlikely that this patient would have been successfully resected even on cardiopulmonary bypass. Of 10 patients with level 3/4 thrombi, seven were deemed completely resected at the time of surgery, and seven of 10 survived more than 5 years or were alive at last follow-up. In addition, two patients with IVC recurrences (one initially resected elsewhere, one from the present series) underwent successful resection of their recurrence using the technique outlined earlier. Both patients remained alive at last follow-up, 1.5 and 8 years after resection, respectively.

The present study is a retrospective review of a single institutional experience and, as such, is subject to certain biases and limitations. The complication data are limited by the information available in the patients' charts. Emergency room visits and outside admissions might not have been reported by patients and thus might not have been captured by our review. We are also limited by the small number of patients in the present series. Finally, it is possible that the absence of cardiopulmonary bypass support could reduce the number of level 4 thrombi in the present series and potentially skew the survival outcomes.

In conclusion, RCC with associated caval thrombus presents a rare but substantial surgical challenge. In the present study, we show, as others have, that complete surgical resection could result in long-term disease-free survival in these patients. Bypass-assisted approaches to caval thrombectomy could still be necessary when complex vascular reconstruction is anticipated. The approach must be selected with consideration for the tumour anatomy on clinical staging and the surgeon's experience. However, the present report provides further evidence that resection of level 3/4 thrombi could be safely accomplished without the use of intraoperative circulatory bypass, and with satisfactory oncological outcomes.

CONFLICT OF INTEREST

None declared.

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Correspondence: Paul Russo, Department of Surgery, Urology Service, Memorial Sloan-Kettering Cancer Center, 1275 York Ave Box 213, New York, NY 10065, USA. e-mail: russop@mskcc.org

Abbreviations: IQR, interquartile range; IVC, inferior vena cava; MSKCC, Memorial Sloan-Kettering Cancer Center; TEE, transoesophageal echocardiography.