Multi-Institutional Experience with Robotic Nephrectomy with Inferior Vena Cava Tumor Thrombectomy

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Purpose: Since the first report of robotic management of renal tumors with inferior vena cava tumor thrombi, few additional cases have been reported in the literature. We report our combined experience with this procedure, to our knowledge the first multi-institutional and largest series reported to date.

Materials and Methods: A retrospective, multi-institutional review of robotic nephrectomy with inferior vena cava tumor thrombectomy was performed with institutional review board approval.

Results: A total of 32 cases were performed among 9 surgeons at 9 institutions since the first known procedure in 2008. Of these cases 30 were level II and 2 were level III thrombi with no level I thrombi (renal vein only) included in the analysis. Each surgeon performed between 1 and 10 procedures. Mean patient age was 63 years (range 43 to 81) with a mean body mass index of 30 kg/m^2 (range 17 to 43) and mean maximal tumor diameter of 9.6 cm (range 5.4 to 20). The length of inferior vena cava tumor thrombi ranged from 1 to 11 cm (median 4.2) on preoperative imaging. The inferior vena cava required cross-clamping in 24 cases. One patient had 2 renal veins with 2 caval thrombi and 1 patient required synthetic patch cavoplasty. Mean operative time was 292 minutes (range 180 to 411) with a mean blood loss of 399 cc (range 25 to 2,000). There were no conversions to open surgery or aborted procedures and there were 3 transfusions of 1 to 3 units. All but 2 patients ambulated by postoperative day 1 and mean hospital stay was 3.2 days (range 1 to 7). Lymphadenectomy in 24 patients yielded a mean of 11 nodes and 8 patients had node positive disease. There were 7 patients who experienced distant recurrence at a mean followup of 15.4 months, including 4 who had node positive disease on postoperative pathological examination.

Conclusions: Robotic nephrectomy in the setting of inferior vena cava tumor thrombus is feasible and was performed safely in selected patients. Despite the complex and critical nature of these procedures, our series demonstrates favorable outcomes and reproducibility with adequate robotic experience.

Key Words: robotics; laparoscopy; nephrectomy; carcinoma, renal cell; vena cava, inferior

Abbreviations and Acronyms

IVC = inferior vena cava

RCC = renal cell carcinoma

RNIT = robotic nephrectomy with IVC thrombectomy

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Renal cell carcinoma can involve tumor thrombus into the renal vein or the inferior vena cava in 4% to 36% of cases.[1] While renal vein tumor thrombus can often be managed in a minimally invasive fashion, open surgery remains the standard surgical treatment for IVC thrombus as laparoscopy is considered contraindicated for this condition by most experts.[1–3]

The complexity of the operation and potentially fatal complications that can occur in the course of tumor thrombectomy and IVC reconstruction have limited the application of laparoscopy.[4] Minimally invasive nephrectomy for IVC thrombus requiring cross-clamping of the cava had not been reported until the first such robotic series published in 2011.[5] Before this time laparoscopy had only been used for short thrombi not requiring IVC clamping or before an open incision to manage the IVC.[6]

Since then, only 1 laparoscopic series[7] and individual cases or videos of robotic nephrectomy for RCC with IVC thrombi have been published.[8–12] The safety and reproducibility of minimally invasive surgery for such complex tumors remain uncertain due to the scarcity of cases reported. We report the first multi-institutional and the largest series to date to our knowledge of robotic nephrectomy with IVC thrombectomy.

METHODS

A multi-institutional database of RNIT procedures at 9 institutions was compiled with institutional review board approval and inter-institutional data sharing agreements as required. Each institution collected data prospectively while compilation of the data among institutions was done retrospectively in a de-identified fashion. Procedures were performed between 2008 and 2014. All patients who underwent RNIT at these institutions were elicited regardless of whether the procedure was completed robotically or whether open conversion was necessary. Given the retrospective nature of the study, inclusion criteria were at the discretion of the operating surgeon and were not uniform.

Demographic and perioperative data were reviewed, including patient age, gender, body mass index, operative time, estimated blood loss, conversion rate, transfusion requirements, tumor histology and stage, thrombus length, margin status, nodal status, length of stay, complications and cancer recurrence. Due to the small number of patients, descriptive statistics only were analyzed (eg medians, means etc).

RESULTS

A total of 32 cases were performed among 9 surgeons at 9 institutions since the first known procedure in 2008, with each surgeon having performed between 1 and 10 RNIT procedures. Among the 9 surgeons previous robotic surgery experience before performing RNIT averaged 1,100 robotic cases (range 600 to 2,500).

Right side tumors accounted for 27 of the 32 procedures. All patients underwent preoperative cross-sectional imaging with computerized tomography or magnetic resonance imaging and 1 surgeon performed a vena cavogram before his first procedure (fig. 1). Mean patient age was 63 years (range 43 to 81) and mean body mass index was 30 kg/m^2 (range 17 to 43). Overall 30 IVC thrombi were level II (below hepatic veins) and 2 were level III (above hepatic veins but below diaphragm) according to the Novick classification with no level I thrombi (renal vein only) included in the series. The maximal tumor diameter was 9.6 cm (range 5.4 to 20) with IVC tumor thrombus length ranging from 1 to 11 cm (median 4.2) on preoperative imaging. No patient underwent preoperative renal artery angioembolization.

There were no conversions to open surgery or aborted procedures. Among the 24 (75%) procedures with tumor thrombus length requiring cross-clamping of the IVC, clamping was performed with bulldog clamps or modified Rommel tourniquets using vessel loops. Shorter IVC thrombi were managed with tangential clamping of the IVC using a laparoscopic Satinsky clamp. Procedures were performed using a maximum of 8 port sites (4 assistant ports) to as few as 3 ports with a stab incision for the Satinsky clamp in less complex procedures (no assistant port).

All procedures were performed transperitoneally as previously described with minor variations among surgeons.[5] Cross-clamping of the IVC was accomplished after ligating the arterial supply and circumferentially dissecting the cava above and below the thrombus, placing modified Rommel tourniquets in the form of vessel loops doubly wrapped around

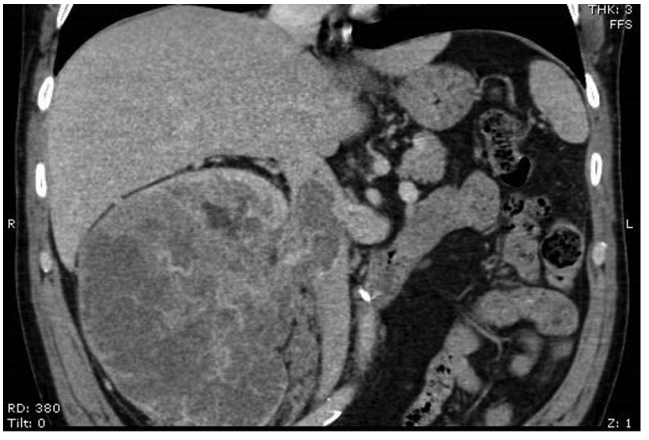

Figure 1. Representative preoperative computerized tomography of 20 cm primary right renal mass with level II IVC thrombus.

the IVC (fig. 2). Alternatively some surgeons selectively used bulldog clamps to replace 1 or more tourniquets. The left renal vein was controlled in a similar fashion, and all lumbar veins were clipped and divided or controlled with bipolar cautery when small (fig. 3). The cava was only opened once all inflow was controlled or clamped by cinching the vessel loops so that a bloodless field was maintained during thrombus extraction (fig. 4). The cava was suture reconstructed and flushed with heparinized saline before releasing tourniquets to reestablish blood flow (fig. 5).

Left side tumor thrombi were managed completely in the left flank position in 4 patients with short thrombi where adequate access to the IVC was possible without repositioning and 3 were managed with tangential IVC clamping only. One patient required repositioning from right flank for IVC management and tumor thrombus extraction to left flank position to complete the nephrectomy. In all procedures regardless of side the tumor thrombus was removed en bloc with the kidney and tumor. Level III intrahepatic, infradiaphragmatic thrombi required division of the short hepatic veins to allow control of the IVC above the thrombus (fig. 2). In these cases the short hepatic veins were clipped and divided before using laparoscopic ultrasound to identify the cranial-most extent of the tumor for placement of the tourniquet.

The mean operative time from incision to closure including console time was 292 minutes (range 180 to 411). Mean blood loss was 399 cc (range 25 to 2,000) with 3 patients (9%) receiving transfusions of 1 to 3 units of packed red blood cells. A closed suction drain was left in 2 cases. One patient had extensive tumor infiltration into the vena cava wall requiring wide excision and vena cavoplasty with a Dacron® patch. One patient had 2 renal veins, each with a caval thrombus, and 1 patient had a caval thrombus in the renal vein as well as 1 extending into the cava through the adrenal vein. The length of extraction incisions was recorded in only 15 patients and varied from 4 to 14 cm depending on the size of the specimen and patient body habitus.

Robotic retroperitoneal lymphadenectomy was performed in 24 patients. Mean lymph node yield was 11 (range 1 to 25) and 8 patients had involved nodes (range 1 to 20 positive nodes, median 3). Six tumors had sarcomatoid histology involving 5% to 90% of the tumor volume. Three tumors were Fuhrman grade II and all others were grade III or IV. Excluding the exposed IVC tumor thrombus 2 patients (6%) had positive surgical margins, including in 1 pT4 tumor.

Intraoperative complications occurred in only 1 patient who had a bowel injury during access that was repaired primarily. Postoperative complications occurred in 7 other patients, and included shortness of breath requiring Lasix (Clavien I), pneumonia, pulmonary embolism, ileus and emergency room visit for cardiac complaints in 1 patient each, as well as temporary renal impairment not requiring dialysis in 2 patients (Clavien II). No patients experienced Clavien III-V complications.

Ambulation on the day of surgery or by postoperative day 1 was achieved by 30 of the 32

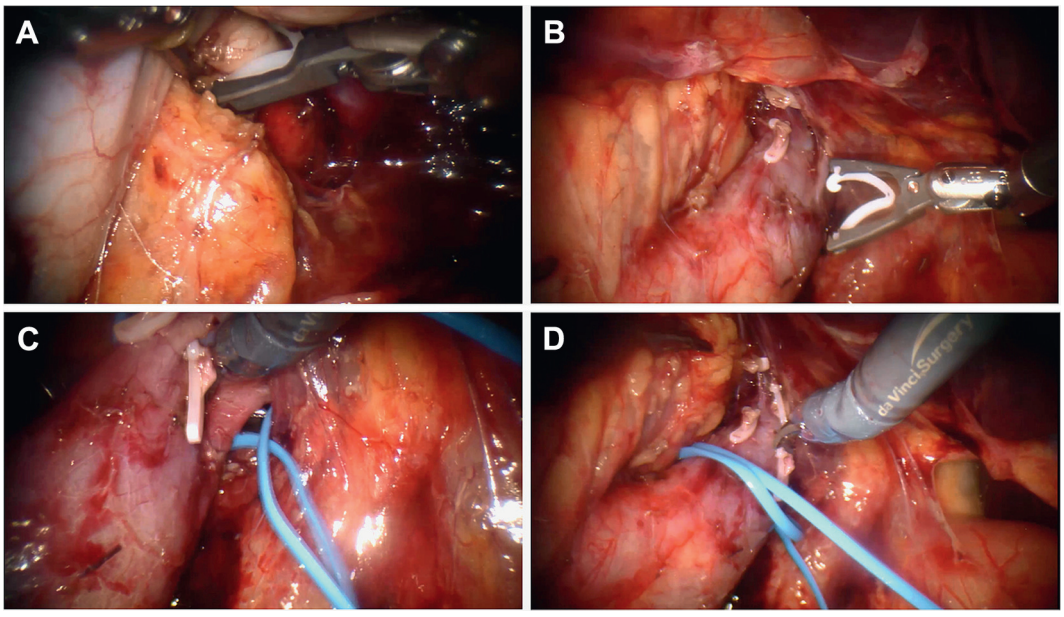

Figure 2. Interaortocaval clipping of right renal artery (*A*) followed by clipping and division of short hepatic veins (*B*) for maximal cranial control of IVC for placement of vessel loop just below liver edge (*C*) and repeated to encircle cava (*D*).

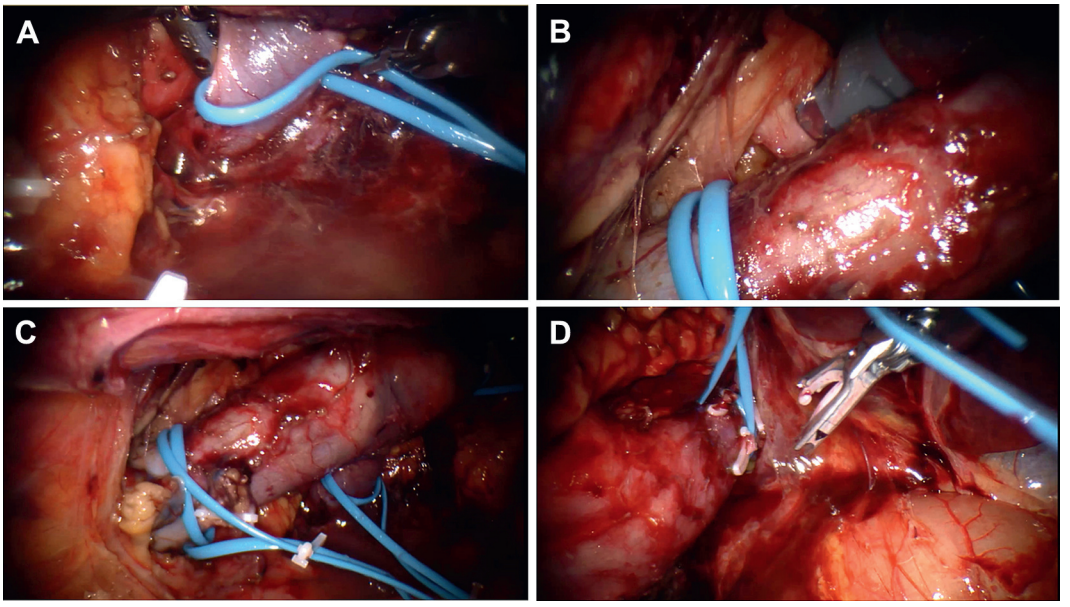

Figure 3. Modified Rommel tourniquet placed around left renal vein (*A*) and dissection of all lumbar vessels (*B*) as well as control of caudal IVC (*C*) before cinching tourniquets and placing clip to initiate complete IVC clamping (*D*).

patients. Intravenous narcotics were not needed for pain control in 24 patients (75%) during the postoperative period after leaving the recovery room until discharge home, while 8 patients did receive intravenous narcotics. Resumption of regular diet occurred on average on postoperative day 1.1 (range 0 to 4) with 21 patients on regular diets by postoperative day 1. Median hospital stay was 3 days (mean 3.2, range 1 to 7) with 22 patients (69%) discharged home on or before postoperative day 3.

One patient had known metastatic disease at surgery and underwent cytoreductive RNIT, and 4 others had suspected metastasis in the form of retroperitoneal lymphadenopathy on preoperative imaging. Mean followup was 15 months (range 1 to 50). There were no 90-day mortalities. Adjuvant systemic therapy was not used in patients with no evidence of disease postoperatively. There were 7 patients who experienced distant recurrence, of whom 3 died of the disease. Of these 7 patients 4

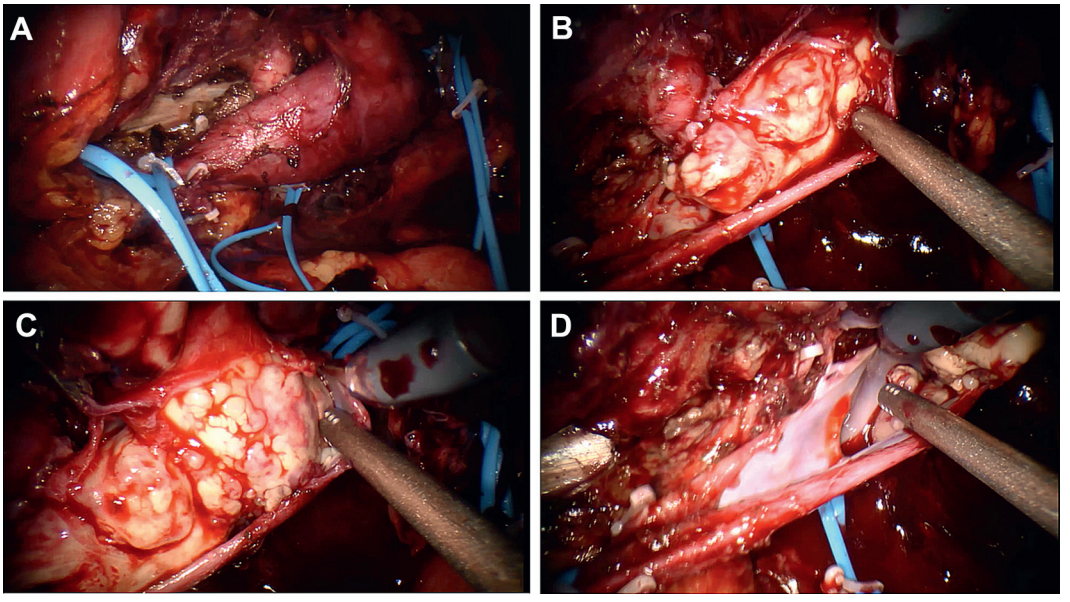

Figure 4. Completely clamped IVC with all 3 tourniquets cinched (*A*) before incision of IVC under complete hemostatic control (*B*), and visualizing upper extent of tumor thrombus (*C*) and os of left renal vein (*D*).

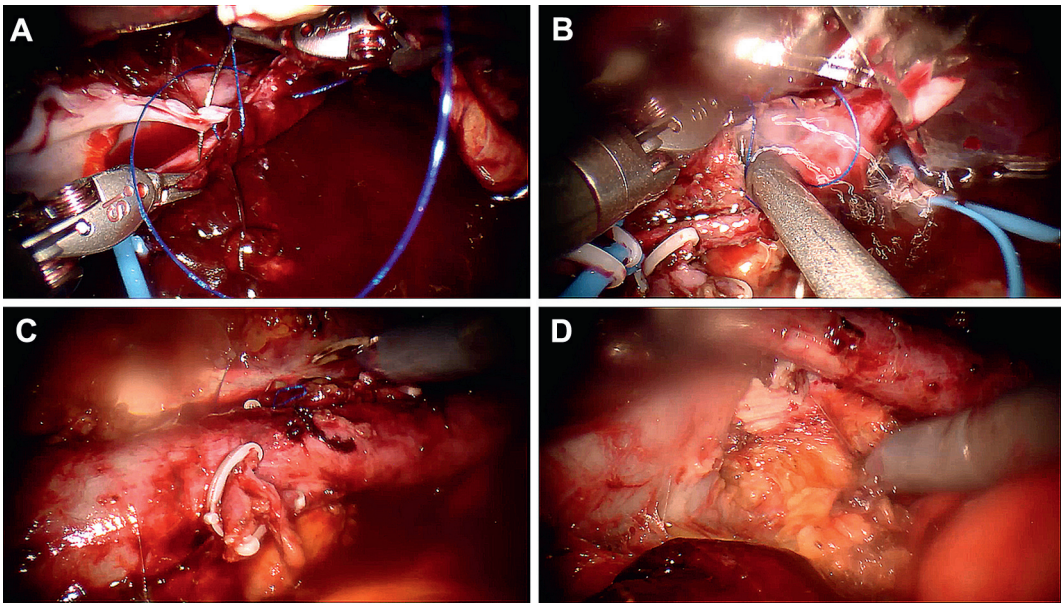

Figure 5. Sutured reconstruction of IVC (*A*) with flush using heparinized saline through laparoscopic suction irrigator (*B*) before completing IVC closure (*C*) followed by node dissection including anterior retraction of already mobilized IVC to access retrocaval nodes (*D*).

had positive lymph nodes identified on postoperative pathological examination.

DISCUSSION

Since the introduction of laparoscopic nephrectomy, this minimally invasive procedure has demonstrated benefits compared to open surgery that include reduced blood loss and pain, and shorter hospitalization and recovery time. These findings have persisted even as laparoscopy has been applied to increasingly large and more complex tumors.[13,14] Nephrectomy for tumors with IVC thrombi is among the most challenging scenario in RCC. However, the ability to manage such tumors in a minimally invasive fashion could confer a significant advantage to patients if it can be performed safely and reproducibly.

The first attempt at minimally invasive management of an IVC tumor thrombus was reported in 2002 when hand assisted laparoscopy was used for a short thrombus that could be excluded from the cava by a Satinsky clamp.[15] Porcine and bovine models for larger laparoscopic IVC tumor thrombectomy were developed in 2002 and 2003.[16,17] Pure laparoscopy in a human patient was reported in 2006, again for a short thrombus not requiring IVC cross-clamping.[18]

Completely intracorporeal management of larger IVC thrombi requiring IVC cross-clamping was not reported until the first successful procedures were completed in robotic fashion.[5] Since then, pure laparoscopic procedures duplicating the technique have been successfully performed in China.[7] Whether pure laparoscopic management can be widely replicated by other groups remains to be seen, but our series indicated that the robotic technique is feasible among experienced robotic surgeons with some limitations that continue to be explored. Several groups are working on adjustments to allow even more extensive caval thrombi to be managed robotically,[9] and it is likely only a matter of time before complex variations are no longer considered obstacles, such as circumcaval caudate lobes of the liver, accessory hepatic veins or invasion of the caval wall, among others.

While our series supports a role for robotics in the minimally invasive management of IVC tumor thrombi, open surgery remains the standard therapy. It should also be emphasized that the robotic surgeons who embarked on this procedure did so after extensive experience with other robotic procedures, including kidney surgery. Given the complexity of the procedure and potential major intraoperative complications, including death, the procedure should be approached cautiously. Also, surgeons should have a low threshold for conversion to open surgery if thrombus length or oncologic principles are in question, and the surgeon and team should be prepared for the potential need for open surgery. In addition, the fact that no open conversions occurred in this series and that the 9 surgeons represented had no such cases during this period likely reflect not only surgeon preparation

and experience before attempting RNIT but also equally or potentially more judicious patient selection.

Particular attention should be paid to the size and length of tumor thrombi attempted robotically. Even experienced surgeons are encouraged to begin their approach to IVC thrombi with shorter thrombi requiring less extensive mobilization of the IVC, with the eventual ability to manage level III thrombi robotically. Control of the suprahepatic, infradiaphragmatic IVC was not performed in this series as it was not necessitated by the length of thrombi, but even this step has recently been described in a cadaver model robotically.[19] Also, 2 groups separate from our multi-institutional cohort recently described a case report and small series of specifically level III robotic thrombus management, further indicating the potential for future evolution and adoption.[20,21]

Our study was limited by a lack of inclusion criteria such that patient selection was not standardized across sites. The mean tumor size of 9.6 cm compares similarly with historical open series of RCC with IVC thrombi including 109 such patients reported by Kim et al who had a mean tumor size of 10.3 cm[22] and 49 patients (7 renal vein thrombi) reported by Parekh et al with a median tumor size of 10 cm.[23] This suggests that primary tumor size may not have been a selection factor, particularly since our range included tumors as large as 20 cm. With only 2 level III thrombi in our series, the uppermost extension of the thrombus may have been a selection criterion for surgeons, which is reasonable and reflects a likely preference for beginning with shorter thrombi. Surgeons should also be prepared for the possibility of caval wall invasion, which can occur in approximately 3% of caval thrombi and requires patch or graft reconstruction as in 1 of our cases.[24]

The benefits of minimally invasive surgical management of any condition are mostly short-term. Oncologic control remains a priority over the temporary benefits of avoiding large, open incisions. The oncologic outcomes observed in our series compare well with historical series given that the 5-year disease specific survival for nonmetastatic RCC with IVC thrombus is only 40% to 65%, and is only 6% to 28% for those presenting with metastasis.[1] While recurrences in 7 of 32 patients (22%) with a mean followup of only 15 months may initially seem high to those unfamiliar with T3b RCC, such a rate is not unexpected for T3b RCC and does not suggest an unfavorable oncologic impact of performing these surgeries minimally invasively.

In 111 patients undergoing open surgery for RCC with IVC thrombus with a median followup of 16.8 months Haferkamp et al reported recurrence in 54% of patients, even among those without metastatic disease.[25] In addition, several cytoreductive nephrectomies were performed in our patients with known or suspected metastatic disease. Still, longer term followup will be necessary to confirm the ability of the robotic approach to duplicate historical open oncologic results and to determine whether the selection criteria for a robotic approach in these cases may have favorably biased oncologic outcomes.

If oncologic outcomes can be confirmed, the true benefit of a minimally invasive approach would be in the potential to reduce convalescence and complications. Due to the complexity of the condition and the operation, the complication rate with open surgery is 12% to 47%, depending on the thrombus level, with a mortality rate of 5% to 10%.[26] Our complication rate and lack of mortalities compare reasonably with open series with no Clavien III-V complications in any patient, including no deaths. While complications were relatively minor in our series, it is evident that complications are not entirely avoidable. Even with a minimally invasive approach, the surgical management of severe cancers in mostly elderly patients will likely involve complications, although the type may vary as with other open procedures that have transitioned to less invasive surgery.

Further experience with RNIT, performed in more patients and by additional surgeons, will be necessary to clarify whether the benefits of other minimally invasive surgeries like reduced blood loss, pain and hospitalization apply to this complex procedure and patient population. In addition, future studies comparing matched patient populations undergoing open surgery vs RNIT will be beneficial as more patients undergoing RNIT become available. While our study suggests reproducibility among experienced robotic surgeons, this initial experience likely represents a carefully selected group of patients such that extension of this series and others will allow additional definition of the potential role for RNIT.

CONCLUSIONS

RNIT is a feasible and reproducible procedure for the management of RCC with IVC tumor thrombus by experienced robotic surgeons. Continued exploration will help identify ideal candidates for RNIT and possible exclusions as well as confirm the potential benefits of a completely intracorporeal approach to these tumors.

ADDENDUM

Subsequent to our study, one of our surgeons performed RNIT on a patient who died of respiratory failure postoperatively, reflecting the complex and serious nature of these surgeries.

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