Surgical Approach to Abdominal Tumors Involving the Inferior Vena Cava

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ABSTRACT

Background: Abdominal tumors invading the inferior vena cava (IVC) present significant challenges to surgeons and oncologists.

Objectives: To describe a surgical approach and patient outcomes.

Methods: The authors conducted a retrospective analysis of surgically resected tumors with IVC involvement by direct tumor encasement or intravascular tumor growth. Patients were classified according to level of IVC involvement, presence of intravascular tumor thrombus, and presence of hepatic parenchymal involvement.

Results: Study patients presented with leiomyosarcomas (n=5), renal cell carcinoma (n=7), hepatocellular carcinoma (n=1), cholangiocarcinoma (n=2), Wilms tumor (n=1), neuroblastoma (n=1), endometrial leiomyomatosis (n=1), adrenocortical carcinoma (n=1), and paraganglioma (n=1). The surgeries were conducted between 2010 and 2019. Extension of tumor thrombus above the hepatic veins required a venovenous bypass (n=3) or a full cardiac bypass (n=1). Hepatic parenchymal involvement required total hepatic vascular isolation with in situ hepatic perfusion and cooling (n=3). Circular resection of IVC was performed in five cases. Six patients had early postoperative complications, and the 90-day mortality rate was 10%. Twelve patients were alive, and six were disease-free after a mean follow-up of 1.6 years.

Conclusions: Surgical resection of abdominal tumors with IVC involvement can be performed in selected patients with acceptable morbidity and mortality. Careful patient selection, and multidisciplinary involvement in preoperative planning are key for optimal outcome.

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KEY WORDS: abdominal tumors, inferior vena cava (IVC), surgical resection

Abdominal tumors rarely involve the inferior vena cava (IVC), and leiomyosarcomas seldom originate directly from the venous wall [1]. Alternatively, tumors originating from adjacent structures may directly invade the venous wall or they can grow into the lumen of the vein and grow within the vascular lumen. Such intravascular growth, which is typically seen in renal cell carcinoma (RCC) [2], adrenocortical carcinoma (ACC) [3], hepatocellular carcinoma (HCC) [4], and endometrial leiomyomatosis [5], can rapidly progress beyond the abdominal IVC and involve the right atrium, tricuspid valve, and right ventricle [6].

Although data on the management of tumors invading the IVC are lacking, surgery is considered the only modality that offers a chance for cure in most of these tumors. Surgery, however, may be complex and associated with significant morbidity and mortality [4,7-9]. The most important anatomical factors that determine the complexity of such an operation, and thereby the surgical approach, are the cephalic extent of IVC involvement and the presence of hepatic parenchymal involvement. Another major consideration when dealing with tumors with intravascular growth is the concern for tumor dislodgement during dissection [10]. Whereas small tumor particle dislodgement may result in metastatic spread, a larger tumor embolism may result in a life-threatening massive pulmonary embolism.

The aim of the current study was to describe our recent experience in the resection of tumors that involve the IVC. We described the diverse options for surgical approach, as determined according to the level of IVC cephalic invasion, hepatic parenchymal involvement, and risk for intraoperative tumor embolism, with emphasis on the use of available surgical techniques to improve the safety of these complex resections.

PATIENTS AND METHODS

All patients undergoing resection of abdominal tumors with either direct invasion to the wall of the IVC or intravascular growth within the lumen of the IVC between January 2010 and March 2019 were included. Data were extracted from the retrospective databases of retroperitoneal sarcomas, RCCs (database established by the urology department), and liver cancers. Electronic medical records for each study patient were reviewed, after approval by the institutional research ethics board had been obtained. A total of 20 resections of tumors with IVC involvement were performed during the study period. The demographic, radiological, operative details; peri-operative outcome; and pathological variables of these patients were analyzed.

INITIAL EVALUATION

All patients underwent dual-phase contrast-enhanced computed tomography (CT) of the chest and abdomen. A preoperative biopsy was taken at the discretion of the treating physicians. For tumors that exhibited intravascular growth, evaluation of the cephalic extent of the tumor growth was assessed with CT, magnetic resonance imaging (MRI), and transesophageal echo (TEE) when supra-diaphragmatic tumor extension was suspected. Tumor markers were taken when appropriate. A comprehensive evaluation of performance status and co-morbidities was performed to assess the patient's ability to withstand extensive surgery.

SURGERY

Surgical planning was meticulous. Hepatobiliary transplant, urologic, cardiothoracic, and gynecologic surgeons participated in the preoperative workup. The most significant factors that determined the surgical approach were the extent of cephalic tumor growth, involvement of liver parenchyma, and intravascular tumor thrombus that raised concerns for intraoperative tumor embolism. The surgical procedures that were carried out according to these factors were:

- Group 1: Tumors with IVC involvement below the hepatic veins, liver parenchyma not involved (RCC n=5, Wilms tumor n=1, neuroblastoma n=1, paraganglioma n=1, sarcoma n=6) [Figure 1A]

  A midline laparotomy was performed, and IVC exposure was gained by mobilization of the ascending colon and duodenum and included control of both renal veins. The IVC above and below the tumor was taped. Dissection of the tumor and organ of origin were completed with minimal manipulation to avoid thrombus from tumor dislodgement. Resection of the tumor was completed with en-bloc resection of the organ of origin and the involved IVC. Finally, reconstruction of the IVC was completed by reconstruction of a circular IVC resection reconstructed by using a 20 mm ringed polytetrafluoroethylene (PTFE) graft. Tangential resections were reconstructed with a primary suture or a staple when there was no significant stenosis or with a pericardial patch when significant stenosis was a concern.

- Group 2: Tumors with IVC involvement above the hepatic veins due to intravascular tumor growth, liver parenchyma not involved (RCC, n=1; endometrial leiomyomatosis, n=1) [Figure 1B]

  Midline laparotomy and sternotomy were performed for optimal exposure. Full IVC and renal vein exposure were completed with minimal dissection and mobilization of the tumor, followed by early control of the atrial tumor via a right atriotomy. A veno-venous bypass was used when only minimal atrial involvement was observed on the preoperative TEE, and clearance of the atrial tumor was followed by IVC clamping above the tumor thrombus. When there was significant atrial tumor involvement, a full cardiac bypass was used for wide atriotomy and clearance of the atrial tumor, followed by IVC clamping. Finally, extraction of the intracaval tumor was completed through a venotomy in the abdominal IVC. IVC reconstruction was performed by primary suture with a 4-0 PROLENE® Polypropylene Suture (J&J Medical Devices, USA).

- Group 3: Tumors with IVC involvement above the hepatic veins, liver parenchyma involved, no intravascular tumor growth (intrahepatic cholangiocarcinoma, n=2) [Figure 1C]

  This group included patients with liver tumor with retrohepatic IVC encasement. Exposure was gained with a midline laparotomy and right subcostal extension. Mobilization of the liver was followed by extended right hepatectomy with en-bloc resection of the IVC and hepatic vein, reconstruction of the IVC using a PTFE graft, and reconstruction of the left hepatic veins (v2 and V3) to the PTFE graft. The resection was performed under total hepatic vascular isolation, in-situ hepatic perfusion, and in-situ cooling.

- Group 4: Tumors with IVC involvement above the hepatic veins due to intravascular tumor growth, liver parenchyma involved (HCC, n=1) [Figure 1D]

  Exposure was gained with a midline laparotomy and a midline sternotomy. Minimal mobilization of the liver was performed prior to control of the atrial involvement due to concerns for tumor embolism. Early clearance of the atrial tumor via right atriotomy was completed, followed by IVC clamping, and use of a veno-veno bypass. Hepatic parenchy-

Figure 1. Examples of tumor classification

Tumor classification figures are correlated with group description in the method section. **[A]** Group 1: adrenocortical carcinoma, reconstruction with GORE-TEX® Stretch Vascular Graft (Gore Medical, USA). **[B]** Group 2: renal cell carcinoma. **[C]** Group 3: cholangiocarcinoma. **[D]** Group 4: hepatocellular carcinoma
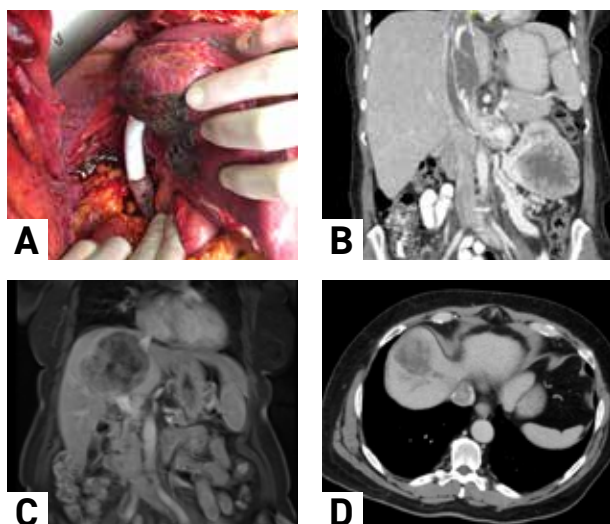
mal dissection was performed under total hepatic vascular isolation, in-situ hepatic perfusion, and in-situ hepatic cooling. Reconstruction of the IVC was completed using an autologous pericardial patch.

Heparin was not used during the clamping time or when a venovenous bypass was performed, but full-dose heparinization was administered when a complete cardiac bypass was performed. When PTFE grafts were used, patients were placed on a low-dose heparin drip (500 IU/hour) postoperatively, and switched to full-dose enoxaparin which was initiated on postoperative day 2–3 and continued for 1 year.

Complications were graded according to the Clavien-Dindo classification [11]. Operative mortality was defined as mortality during the hospital stay or within 90 days of the operation.

FOLLOW-UP

Patients were followed at our outpatient clinics. Follow-up protocol was not uniform for all patients and depended on the type of tumor and the discretion of the treating oncologist and surgeon. Most patients underwent abdominal and chest CT studies every 4 months for the initial 2 years, and every 6 months thereafter. Data on disease progression and survival were collected from reports at follow-up visits and direct patient contact.

STATISTICAL ANALYSIS

Demographic, surgical and clinical data were retrieved from the medical records. Descriptive statistics and Kaplan-Meier survival curves were processed with the statistical package SPSS release 24 (SPSS Inc., Chicago, IL, USA).

RESULTS

A total of 20 patients with tumors involving the IVC were included in our analysis. Tumor types included leiomyosarcomas (n=5), renal cell carcinoma (n=7), hepatocellular carcinoma (n=1), cholangiocarcinoma (n=2), Wilms tumor (n=1), neuroblastoma (n=1), endometrial leiomyomatosis (n=1), paraganglioma (n=1), adrenocortical carcinoma (n=1) [Table 1].

Patient demographics and clinical data are summarized in Table 2. The mean age of the cohort was 50.9 ± 23.6 years, and there were 9 females and 11 males. Neoadjuvant treatment was administered to four patients with metastatic Wilms tumor, metastatic neuroblastoma, and leiomyosarcoma. Surgery was planned only after good response to treatment was demonstrated. Intravascular growth was detected in patients with HCC, ACC, endometrial leiomyomatosis, and RCC. Adjuvant treatment was administered in six cases (30%).

Patients were categorized into four groups according to level of IVC involvement, the presence of intravascular growth, and whether the hepatic parenchyma was involved. The mean operative time was 5.1 hours (range 1.5–9 hours).

Table 1. Summary of cases

Pathology	Cases, n	Age, years, mean	Gender	
			Female	Male
Total	20	50.9	9	11
Cholangiocarcinoma	2	53.4	2	0
Endometrial leiomyomatosis	1	33.8	1	0
Hepatocellular carcinoma	1	61.9	1	0
Leiomyosarcoma	5	51.2	1	4
Neuroblastoma	1	3.0	0	1
Paraganglioma	1	19.2	0	1
Renal cell carcinoma	7	66.3	3	4
Wilms tumor	1	9.8	0	1
Adrenocortical carcinoma	1	64	1	0

Resection of IVC was circular in five cases, and by patch in 14 cases. Reconstruction was completed by primary repair in most cases, while alternative reconstruction methods were required in other cases, including a pericardial patch (n=2) and a Dacron graft (n=3). Exposure required laparotomy in 17 cases, and both laparotomy and sternotomy in three cases. Nine patients (45%) required intraoperative blood product transfusion of varying amounts (range 3 to 10 units of packed cells). A veno-venous bypass was used in three patients, and a full cardiac bypass in one patient. Hepatic total vascular isolation, in situ cooling, and perfusion were performed in three patients. Three patients sustained clinically significant complications (Clavien-Dindo 3 or more). Peri-operative 90-day mortality was recorded for two patients with RCC, including a single case of intraoperative mortality.

The mean follow-up duration was 1.6 years. All-cause mortality was 40% at a median of 23.6 months [Figure 1A]. Thirteen patients (65%) had disease recurrence, with mean disease-free survival of 6.5 ± 7.9 months and a median overall survival of 13.9 months [Figure 2].

DISCUSSION

A variety of abdominal and retroperitoneal tumors can involve the IVC, either in the form of direct tumor invasion and encasement of the vessel wall, as seen in intrahepatic cholangiocarcinoma, retroperitoneal sarcoma, adrenocortical carcinoma, paraganglioma, and neuroblastoma, or when the tumor originates from the wall of the IVC, most commonly in leiomyosarcoma. A different form of IVC involvement is seen in tumors that grow within the venous lumen from the organ of origin

Table 2. Perioperative data

|	Group 1	Group 2	Group 3	Group 4
Exposure	Laparotomy n=15	Laparotomy + sternotomy n=2	Laparotomy n=2	Laparotomy + sternotomy n=1
Operative time	4:10 ± 2:00	7:29 ± 0:54	7:16 ± 0:45	8:59
Packed red blood cells transfusion (mean units)	3	4	0	9
Use of bypass	None	Venous bypass n=1 Full bypass n=1	Venous bypass n=1	Venous bypass n=1
Inferior vena cava reconstruction	Primary/stapler n=12 Pericardial patch n=1 PTFE graft n=1 Dacron graft n=1	Primary/stapler n=1 No- reconstruction n=1	Primary/stapler n=1 PTFE graft n=1	Pericardial patch n=1
Clavien-Dindo score ⩾ 3	2	1	0	0
Perioperative mortality	1	1	0	0

Group 1: Sarcoma (n=5), renal cell carcinoma (n=6), neuroblastoma (n=1), paraganglioma (n=1), Wilms tumor (n=1), adrenocortical carcinoma (n=1)
Group 2: Renal cell carcinoma (n=1), endometrial leiomyomatosis (n=1)
Group 3: Cholangiocarcinoma (n=2)
Group 4: Hepatocellular carcinoma (n=1)

Figure 2. Survival curves (Kaplan-Meier) for overall and disease-free survival
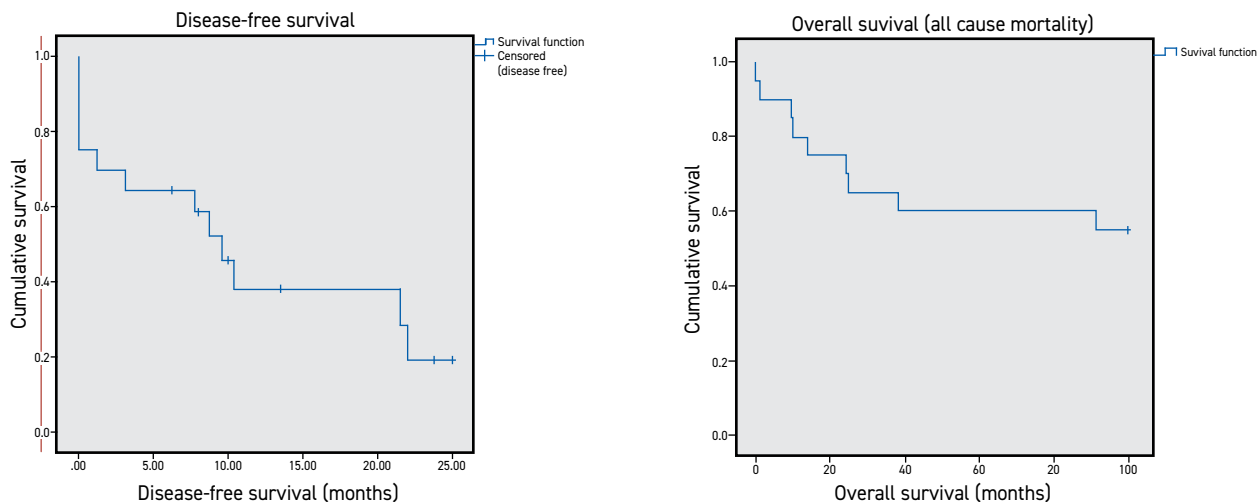
into the IVC, as seen in HCC, RCC, ACC, and endometrial leiomyomatosis. Intravascular tumor growth adds significant complexities to surgical resection since it is not always limited to the abdominal cavity and can extend into the right cardiac chambers. Moreover, the presence of an intravascular tumor thrombus adds the risk for intraoperative tumor emboli during tumor manipulation and dissection, which can result in massive pulmonary embolism and life-threatening hemodynamic instability or, alternatively, in smaller tumor emboli that may result in metastatic spread.

Tumor involvement of the IVC can cause debilitating symptoms and pose immediate threat of acute obstruction of the IVC or hepatic veins, as well as tumor particle dislodgement and life-threatening pulmonary embolism. Surgical resection remains the only chance for cure or at least symptom palliation and prolongation of life for many of these tumors. These procedures are rarely performed due to their complexity and the perioperative risk.

Meticulous preoperative multidisciplinary surgical planning is essential. Surgical teams should include cardiothoracic surgeons and transplant/hepatobiliary surgeons. The most important factors

that determine the surgical approach are the extent of cephalic tumor growth within the IVC, and the presence of hepatic parenchymal involvement. Another major consideration is intravascular tumor growth and the assessed risk for tumor embolism during surgery, which would require minimal dissection and tumor manipulation before gaining vascular control proximal to the tumor thrombus. Whether or not the intravascular growth involves the caval intima, is difficult to assess before the operation, but has a significant impact on the ability to pull the tumor out and preserve most of the vein. These "floating" tumors can sometimes be seen to freely move inside the vein in an US-Doppler study, or be completely surrounded by contrast in a CT scan, but this is oftentimes difficult to assess. When the intravascular part is adherent to the intima, replacement of the vein by a graft may be easier and oncologically safer. Moreover, "bland" thrombosis may develop below the tumoral obstruction. This DVT may need to be carefully removed, often with the aid of a Fogarty catheter, to avoid massive PE or propagation of the thrombus in the post-operative course.

Patient selection for these extensive operations is key, and includes patient and tumor factors. Patient age, performance status, and co-morbidities determine their ability to withstand such major operations with the associated hemodynamic shifts that result from prolonged IVC clamping. Assessment of tumor biology is central: high-grade aggressive tumors are usually not controlled with surgery alone, and other modalities, such as external beam radiation and systemic chemotherapy need to be included in the treatment plan. Low-grade, slow-growing tumors, or tumors that are at least partially controlled with chemo/radiation may benefit from surgical resection

The currently available surgical approaches and variety of modalities are described in detail in the Methods section, and they include veno-venous bypass, full cardiac bypass, hepatic vascular isolation, and in-situ hepatic cooling. Continuity of the IVC should always be maintained by primary suture, the use of a patch, or replacement with a tube prosthesis. Primary suture is adequate for minimal patch venous resections that do not result in significant narrowing or distortion of the vascular lumen. Whenever feasible, patch repair by means of an autologous vein or a bovine pericardial patch is preferable to the use of a tube prosthesis. The advantages of the patch repair are that they do not require full clamping of the IVC [1], where the risk for graft thrombosis and infection are probably lower. When reconstruction with a full tube graft is required, a synthetic PTFE (or Dacron) can be used with a low complication rate [12]. Our experience with the 20 mm ringed PTFE graft was excellent, with no cases of graft thrombosis or infection.

The main limitations of this study are the retrospective retrieval of the data and the limited number of patients. Nevertheless, the study included a wide variety of tumors with different levels of IVC and hepatic parenchymal involvement. As such, this is a representative summary of the surgical approaches and the different modalities that are available when planning surgery for these tumors.

CONCLUSIONS

Surgical resection of abdominal tumors with IVC involvement can be performed in selected patients with acceptable morbidity and mortality. The long-term survival of our patient cohort was reasonable, with a mean survival of 23.7 months. Careful patient selection and multidisciplinary involvement in preoperative planning are crucial for optimal outcome. The cephalic level of IVC involvement, hepatic parenchymal involvement, and the risk for intraoperative tumor embolism are major considerations. Venovenous bypass, cardiopulmonary bypass, hepatic vascular isolation, and in situ hepatic cooling are useful in selected cases.

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