Surgical Resection and Inferior Vena Cava Reconstruction for Treatment of the Malignant Tumor: Technical Success and Outcomes

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Objective: The purpose of this study was to review patients who underwent inferior vena cava (IVC) resection with concomitant malignant tumor resection and to consider the operative procedures and the outcomes.

Materials and Methods: Between 2000 and 2012, 41 patients underwent resection of malignant tumors concomitant with surgical resection of the IVC at our institute. The records of these patients were retrospectively reviewed.

Results: Primary tumor resections included nephrectomy, heptatectomy, retroperitoneal tumor extirpation, lymph node dissection, and pancreaticoduodenectomy. The IVC interventions were partial resection in 23 patients and total resection in 18 patients. Four patients underwent IVC replacement. Operation-related complications included pulmonary embolism, acute myocardial infarction, deep vein thrombosis, leg edema and temporary hemodialysis. There were no operative deaths. The mean follow-up period was 24.9 months (range: 2–98 months). The prognosis depended on the type and stage of the tumor.

Conclusion: Resection and reconstruction of the IVC can be performed safely if the preoperative evaluations and surgical procedures are performed properly. The IVC resection without reconstruction was permissible if the IVC was completely obstructed preoperatively, but it may also be considered in cases where the IVC is not completely obstructed.

Keywords: inferior vena cava, malignant tumor, inferior vena cava resection, inferior vena cava reconstruction, inferior vena cava replacement

Introduction

Resection and reconstruction of the inferior vena cava (IVC) to remove malignant tumors is an invasive procedure. Thus, such operations have rarely been performed. Often patients with malignant tumors invading the IVC have distant metastases at the time of the diagnosis or they are too ill for an operation to be considered. In general, there are not many therapeutic options besides surgical resection for such patients. The resection remains the only hope for cure or palliation of their symptoms. Therefore, the operative indication and procedure should be carefully considered.

Malignant tumors that involve the IVC are most often renal cell carcinomas (RCC). Resection of tumors invading the IVC can be accomplished without major IVC resection, removing the tumor within the vessel with limited exposure and thrombectomy techniques. But other tumors, such as leiomyosarcomas, adrenal cancers, testicular tumors, and other cancers, invade...
the wall of IVC, and tumor resection requires partial or complete IVC excision. Therefore, the operative procedures should differ by the type of tumor. In this study, we reviewed operations for malignant tumors that involved the IVC at our institute and considered the operative procedures and the outcomes.

Materials and Methods

Between 2000 and 2012, 41 patients underwent resection of malignant tumors concomitant with surgical resection of the IVC at our institute. The records of these patients were retrospectively reviewed. The patient's clinical presentation, the type of tumor, the operative procedure, postoperative complications, tumor recurrence, and survival were reviewed.

The average age of the patients was 60.4 years (range: 26–81 years). Fourteen of 41 patients were females. The primary neoplasms and patient characteristics are shown in Table 1. The neoplasms included RCC (29 patients), leiomyosarcomas originating from the IVC wall (4 patients), testicular tumors (2 patients), and 1 patient each with adrenal cancer, retroperitoneal fibrosarcoma, paraganglioma, metastatic liver tumor of colon cancer, pancreas head cancer, and uterine sarcoma.

The extent of the tumor and its involvement of the IVC were mainly assessed by computed tomography (CT). Ultrasonography and magnetic resonance imaging were also used for diagnosis. The precise extent of resection was finally determined by ultrasound during the operation. By definition, the infra-renal segment of the IVC extended from the confluence of the common iliac veins to the origin of the lower renal vein. The suprarenal segment extended from the lower renal vein to the hepatic vein, and the suprahepatic segment was between the hepatic vein and the origin of the right atrium.

Results

The preoperative and operative evaluation by CT and ultrasonography revealed severe stenosis (7 patients) and complete occlusion (7 patients) of the IVC by the tumor. We had planned the IVC resection without reconstruction for these 14 patients because the abundant collateral vein network was observed. In contrast, we had planned the IVC replacement for 4 patients who required resection of the IVC because the IVC was not occluded and collateral vein network development was poor. The other 23 patients were planned to undergo partial resection.

The operations were performed mainly by oncologic surgeons who specialized in each type of neoplasm, such as urologists, gynecologists, orthopedists, and digestive surgeons (Table 1). Vascular surgeons participated for the IVC intervention. Primary tumor resections included right nephrectomy (25 patients), left nephrectomy (4 patients), hepatectomy (4 patients), retroperitoneal tumor extirpation (3 patients), lymph node dissection (2 patients), and pancreaticoduodenectomy (1 patient). The average operation time was 513 min (166–857 min) and the average amount of blood loss was 3569 ml (305–16990 ml).

The type of laparotomy procedures included midline incision (13 patients), right subcostal incision (12 patients), midline and right flank incision (7 patients), and subcostal and midline incision (4 patients). Proximal and distal exposure for control of the IVC was performed in advance. Mobilization of the right lobe of the liver was performed when retrohepatic IVC resection was needed. An infradiaphragmatic approach by transection of the falciform ligament of the liver was used for exposure and clamping of the suprahepatic IVC between the hepatic vein and the right atrium. None of the patients needed thoracoabdominal incision for the suprahepatic IVC clamp.

The IVC clamp level and the number of patients for each clamp level are shown in Fig. 1A. Suprahepatic clamping was required in 9 patients (RCC: 8; leiomyosarcoma: 1), suprarenal in 22 patients (RCC: 17; leiomyosarcoma: 1; adrenal cancer: 1; testicular cancer: 1; paraganglioma: 1; metastatic liver tumor: 1), and infrarenal in 6 patients (RCC: 2; leiomyosarcoma: 2; uterine sarcoma: 1; pancreas head cancer: 1), and the other patients underwent resection by partial clamping of the IVC.

Two patients required cardiopulmonary bypass (CPB) for removal of a tumor thrombus in the right atrium. None of the other patients required CPB or venovenous bypass to maintain blood pressure. During the IVC clamping, rapid transfusion loading into the superior vena cava system and the use of vasopressor drugs prevented excessive hypotension. If the tumor thrombus was mobile within the IVC at the hepatic vein level, suprahepatic IVC clamping and the hepatic pedicle clamping (Pringle maneuver) were performed.
from 138.3 ± 13.4 mmHg before clamping to 101.7 ± 16.5 mmHg during clamping (the mean decrease was 36.6 mmHg). As a reference, in 9 patients who required the suprarenal IVC clamp, the mean systolic blood pressure decreased from 126.1 ± 20.0 mmHg before clamping to 103.9 ± 17.1 mmHg during clamping (the mean decrease was 18.9 mmHg).

The IVC interventions were partial resection and closure in 23 patients, resection and left renal vein stump closure in 8 patients, infrarenal resection in 6 patients, and suprarenal resection in 4 patients (Fig. 2). One of infrarenal resection patients and 3 of suprarenal resection patients needed graft replacement (Fig. 3). A ringed reinforced polytetrafluoroethylene (PTFE) graft with a diameter of 20 mm was chosen for the patient who underwent infrarenal resection (right RCC) and 2 patients who underwent suprarenal resection (both with leiomyosarcoma of the IVC) (Fig. 4A). A reversed superficial femoral vein (rSFV) graft was used for 1 patient who

first and the suprarenal or infrarenal IVC was incised to evulse the tumor thrombus; the clamp site was shifted to below the hepatic vein level immediately, and the hepatic pedicle clamp was released. In most patients who needed this procedure, the suprarenal clamping time was less than 10 min and excess hypotension during clamping was not observed. When retrohepatic IVC replacement was required for the patient, with limited distance between the tumor and the hepatic vein, infrarenal clamping, hepatic pedicle clamping, and hepatic vein clamping were required during replacement. We endeavored to finish the IVC and graft proximal anastomosis within 15 minutes to avoid hepatic ischemia and congestion, and then shifted the clamp site to the graft and released the hepatic vascular clamp. The changes in systolic blood pressure during the IVC clamping are shown in Fig. 1B. In 7 of 9 patients (the records of 2 patients were lost) who required the suprarenal IVC clamp, the mean systolic blood pressure decreased from 138.3 ± 13.4 mmHg before clamping to 101.7 ± 16.5 mmHg during clamping (the mean decrease was 36.6 mmHg). As a reference, in 9 patients who required the suprarenal IVC clamp, the mean systolic blood pressure decreased from 126.1 ± 20.0 mmHg before clamping to 103.9 ± 17.1 mmHg during clamping (the mean decrease was 18.9 mmHg).

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Table 1 Variation of disease and patient characteristics

<table>
<thead>
<tr>
<th>Primary neoplasm</th>
<th>No. of patients (Female)</th>
<th>Mean age</th>
<th>Cooperation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Renal cell carcinoma</td>
<td>29 (9)</td>
<td>64.6</td>
<td>Urology</td>
</tr>
<tr>
<td>Leiomyosarcoma</td>
<td>4 (3)</td>
<td>55</td>
<td>Urology, Digestive surgery</td>
</tr>
<tr>
<td>Testicular cancer</td>
<td>2 (0)</td>
<td>30.5</td>
<td>Urology</td>
</tr>
<tr>
<td>Adrenal cancer</td>
<td>1 (0)</td>
<td>50</td>
<td>Urology</td>
</tr>
<tr>
<td>Fibrosarcoma</td>
<td>1 (1)</td>
<td>45</td>
<td>Urology</td>
</tr>
<tr>
<td>Paraganglioma</td>
<td>1 (0)</td>
<td>52</td>
<td>Orthopedics</td>
</tr>
<tr>
<td>Metastatic liver tumor</td>
<td>1 (0)</td>
<td>61</td>
<td>Digestive surgery</td>
</tr>
<tr>
<td>Pancreas head cancer</td>
<td>1 (0)</td>
<td>67</td>
<td>Digestive surgery</td>
</tr>
<tr>
<td>Uterine sarcoma</td>
<td>1 (1)</td>
<td>48</td>
<td>Obstetrics</td>
</tr>
</tbody>
</table>

Fig. 1 Inferior vena cava (IVC) clamp level and the changes in blood pressure. (A) The IVC clamp level and the number of patients. SH: suprahepatic clamp; SR: suprarenal clamp; IR: infrarenal clamp; HV: hepatic vein; RV: renal vein. (B) The changes in systolic blood pressure before and during clamping. The filled circle is the mean systolic blood pressure.
underwent suprarenal resection (metastatic liver tumor). The reason for choosing the rSFV graft was the possibility of digestive tract resection during the operation. Oral anticoagulant medication (warfarin) was started after the operation for all graft replacement cases. No other patients except for these four cases were administered anticoagulant if they did not develop deep vein thrombosis before or after the operation.

Eight patients underwent left renal vein stump closure in connection with the IVC resection, and all patients underwent concomitant right nephrectomy. The serum creatinine level increased from 1.49 ± 0.44 mg/dL (preoperation) to 1.66 ± 0.81 mg/dL (postoperation); this difference was not statistically significant (Mann–Whitney U test).

Operation-related complications included pulmonary embolism during the operation in 1 patient, acute myocardial infarction during the operation in 1 patient, deep vein thrombosis in 2 patients, severe edema of the bilateral lower extremities in 1 patient, and temporary hemodialysis in 1 patient. All patients who experienced these complications had adequate treatment and recovered. There were no operative deaths. The mean follow-up period was 24.9 months (range: 2–98 months). The prognosis depended on the type and stage of the tumor. In the RCC group, 2-year survival was 61%. In the leiomyosarcoma group, the mean follow-up period was 20.8 months (range: 10–29 months), 2 patients died, and 2 patients had recurrence of the tumor. Two testicular cancer patients were alive and disease-free for 72 and 65 months after the operation, respectively. The retroperitoneal fibrosarcoma patient was alive for 98 months after the operation, without recurrence. All other patients had died or had recurrence of the neoplasm.

### Discussion

The resection and reconstruction of the IVC to remove malignant tumors is a formidable procedure. Thus, these procedures have rarely been performed. Since most of the tumors invading into the IVC are at advanced stages, the prognosis is poor even after a successful operation. In addition, there are not many decision branches of effective treatment for tumors invading into the IVC. En bloc resection offers the only chance of cure or at least provides prolonged palliation of symptoms. For this reason, the indication of operation and operative procedure should be discussed and decided carefully.

The evaluation of tumor invasion into the IVC is important. Traditionally, the gold standard in the detection of tumor invasion into the IVC was DSA cavography. But a newly developed imaging method, multidetector computed tomography (MDCT), has become known as one of the most reliable diagnostic methods. Johnson, et al. reported a sensitivity of 78% and a specificity of 96% for determining venous invasion using MDCT. Triphasic MDCT protocol provides adequate information about tumor invasion, and this is often the only diagnostic method necessary for deciding the extent of resection. We also used MDCT to map out the extent of tumor invasion into the IVC preoperatively, and used the ultrasound imaging during the operation to make the final decision for resection.

Indication for the IVC replacement remains controversial. In a patient with complete IVC obstruction, collateral circulation usually provides sufficient venous drainage; therefore, obstructive symptoms such as edema of the lower extremity are uncommon. In the present study, because the abundant collateral vein network was observed, IVC resection...
without replacement was indicated for the patients with severe stenosis (7 patients) or complete obstruction (7 patients) of the IVC. Two patients in the severe stenosis group developed deep vein thrombosis after the operation. These 2 patients had RCC and had undergone retroperitoneal lymph node dissection. One cause of the deep vein thrombosis was thought to be the overestimation of the collateral vein development. The other cause of the venous sequelae was thought to be that the wide retroperitoneal resection for lymph node dissection concomitant with resection of a segment of the IVC disrupted preexisting venous channels and reduced the collateral venous return. It was reported that deep vein thrombosis occurred after radical resection of the IVC in leiomyosarcoma without replacement in 22 of 82 patients, and in one study, 2 of 8 patients who had the IVC resection for malignant tumors without replacement developed late venous complications, such as edema in the extremities. These results suggest that replacement of the IVC may be beneficial to patients who undergo extensive retroperitoneal dissection and at least
administration of the anticoagulant may be necessary if the IVC reconstruction cannot be performed for some reasons. Several studies have demonstrated that IVC replacement may be performed with limited morbidity.\(^1,12,13\) These studies reported a total of 43 patients that had undergone the IVC replacement. Follow-up ranged from 19 to 34 months with a mean of 24 months. All except 1 of the replaced grafts were ringed ePTFE grafts, and they were patent in 91% of patients without complications. The most common cause of graft failure was tumor recurrence.

We prefer the use of the ringed ePTFE graft for replacement of the IVC. It was reported that the ringed ePTFE graft was preferable to the Dacron graft based on patency.\(^4,14\) As for the diameter of the graft, it has been reported that a ringed ePTFE graft of more than 14 mm in a diameter is suitable for replacement of the IVC.\(^1\) In contrast, there are studies that report\(^2,15\) that the smaller graft (12–14 mm) is preferable because it promotes faster flow velocities throughout the graft segment and avoids graft thrombosis. We prefer the use of grafts with a diameter of 20 mm because the diameter of the IVC usually extends to over 15 mm and the ePTFE graft tends to form a thick pseudointima or thrombus (Fig. 4B). In the present study, the ePTFE graft patency was also good. In these 3 cases, the grafts did not become obstructed and did not result in pulmonary embolism in the 31 months average follow up after the operation. There was only 1 patient in the present study who needed autovein graft replacement because of the possibility of digestive tract resection during the operation. We chose an rSFV for the replacement of the IVC because its diameter is larger than with the saphenous vein graft. The graft had been patent for 33 months after the operation until the patient died from the primary disease.

The left renal vein can be divided without reconstruction if it is transected proximal to the ascending lumbar vein and adrenal vein. It has been reported that left renal vein stump closure rarely induces renal insufficiency even if concomitant right nephrectomy is performed.\(^16,17\) In the present study, 8 patients underwent left renal vein closure and concomitant right nephrectomy, and postoperative renal function was preserved.

We did not require CPB or venovenous bypass during IVC clamping. Rapid transfusion loading into the SVC system and the use of vasopressor agents reduce excessive hypotension, and the operation can be carried out safely even in the case of suprahepatic IVC clamping. Only 2 patients required CPB for the extirpation of a tumor in the right atrium. Cardiopulmonary bypass and venovenous bypass use during IVC clamping is controversial. Although many surgeons believe that these are important to maintain blood pressure during IVC clamping, several reports mentioned that CPB and venovenous bypass had not been needed during IVC clamping.\(^15,16\) It is important to be aware that CPB or venovenous bypass are sometimes important tools, but they are more invasive procedures.

**Conclusion**

Although resection and reconstruction of the IVC is an invasive procedure, it can be performed safely if the preoperative evaluation and surgical procedure are performed properly. These surgical procedures are worth performing for the cure and palliative relief of symptoms, because there are few treatment options for malignant tumors invading the IVC. Inferior vena cava clamping can be performed safely without using a CPB or venovenous bypass. The IVC resection without reconstruction can be performed if the IVC is completely obstructed preoperatively, but performing reconstruction in cases where the IVC is not completely obstructed and wide retroperitoneal resection is planned, should also be considered.

**Disclosure Statement**

The authors have declared no conflicts of interest.

**References**