Vascular Reconstruction and Major Resection for Malignancy

Christian Bianchi, MD; Jeffrey L. Ballard, MD; John H. Bergan, MD; J. David Killeen, MD

Hypothesis: Complications of vascular procedures performed for tumor infiltration of major vessels or for the rescue of complex tumor resections may significantly affect perioperative patient outcome and long-term patient survival rate.

Design and Patients: Retrospective review of 39 patients undergoing major resection for malignancy between April 1980 and April 1998; 35 patients underwent major-vessel reconstruction, 3 patients underwent extra-anatomic bypass, and 1 patient underwent major venous thrombectomy.

Setting: University hospital tertiary referral center.

Main Outcome Measures: Vascular complications and patient survival rate.

Results: Vascular complications included major stroke (3), carotid artery blowout (2), acute graft thrombosis (1), bowel infarction (1), and anastomotic disruption (1). Factors such as patient demographics, preoperative irradiation, tumor stage, resection for recurrent disease, and vessel or graft type had no bearing on the occurrence of a vascular complication ($P > 0.05$ in all cases). Eight patients (21%) died within 30 days of surgery, and 2 (5%) died after 30 days but before hospital discharge. Five of these deaths were directly related to vascular problems ($P < 0.001$). Cumulative patient survival rate was 44%, 26%, and 10% at 1, 3, and 5 years, respectively.

Conclusions: The long-term patient survival rate is poor when resections for carcinoma are associated with major-vessel infiltration or a complication that necessitates an emergent vascular procedure. In this setting, in-hospital mortality is negatively affected by the incidence of a major vascular complication.

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Tumor infiltration of major arteries or veins has traditionally been considered a contraindication to complete cancer resection. However, many authors have demonstrated that vascular reconstruction in conjunction with resective cancer therapy has value. This is particularly true in the management of carcinoma invading the carotid artery, the axial extremity vessels, the renal vein, and the vena cava. Reconstruction of the involved portal vein during pancreaticoduodenectomy has also been used selectively with some success. Nevertheless, there is a paucity of reports that address vascular complications associated with major arterial or venous procedures performed during resection for carcinoma or for rescue of a complicated tumor resection. Therefore, the purpose of this study is to detail these vascular complications and the long-term outcomes in research subjects who underwent complex major resection for malignancy.

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RESULTS

Vascular reconstruction procedures were electively performed in conjunction with tumor extirpation in 30 patients (77%) or emergently required as a consequence of a vascular complication that occurred during resective oncologic surgery in 9 patients (23%). Twenty-five patients (64%) had a primary tumor and 14 (36%) had recurrent disease. These procedures took place in a previously irradiated field for 6 patients (43%) with recurrent disease and 1 patient (4%) with primary disease. Curative oncologic surgery was accomplished in 35 patients (90%). Postoperative or post-mortem cancer staging demonstrated 3 stage I tumors (8%), 6 stage II tumors (15%), 12 stage III tumors (31%), and 14 stage IV tumors (36%). Four cases (10%) were not able to be staged.

Resective oncologic surgery was combined with elective vascular reconstruction for tumor invasion of the carotid artery (9), iliac artery (4), common or superficial femoral artery (2), hepatic artery (1), inferior vena cava (IVC) (10), femoral vein (2), or portal vein (2). Arterial continuity was restored directly with
PATIENTS AND METHODS

From April 1980 to April 1998, 39 patients underwent vascular reconstruction—35 major vessels, 3 extra-anatomic bypasses, and 1 major venous thrombectomy—as an integral part of an oncologic resection or for a vascular complication that was associated with surgical resection for malignancy. Patients were identified from a computer-generated list of patients who underwent oncologic procedures performed at Loma Linda University Medical Center, Loma Linda, Calif, and were matched with a prospective database from the Division of Vascular Surgery. There were 22 male (56%) and 17 female (44%) patients with a mean age of 59 years (age range, 2-86 years). Comorbid medical conditions included diabetes (3%), coronary artery disease (5%), hypercholesterolemia (8%), chronic obstructive pulmonary disease (10%), congestive heart failure (10%), hypertension (21%), and tobacco abuse (46%). Preoperative American Society of Anesthesiologists classes were 3 (67%) in 26 patients, 2 (28%) in 11 patients, and 1 (5%) in only 2 patients.

Neoplastic location and type, incidence of resection for recurrence of disease or preoperative irradiation, completeness of resection, nonvascular complications, and postoperative staging were recorded for each patient in conjunction with indication and type of vascular reconstruction, type of graft material used, and any complication of the vascular procedure. These variables are listed in Table 1 and Table 2.

Patient follow-up was obtained from the Loma Linda University Cancer Data and Vascular Registries. Notable end points studied included the incidence and type of vascular complication and patient survival rate. Data were evaluated by the life-table method, univariate and multivariate logistic regression, and cross tabulation with χ² test analysis. Statistical significance was inferred when P<.05.

Table 2

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct graft reconstruction</td>
<td>12</td>
<td>12 different arterial reconstructions performed for the patient's surgical repair.</td>
</tr>
<tr>
<td>Venorrhaphy</td>
<td>2</td>
<td>Performing venorrhaphy for the patient's surgical repair.</td>
</tr>
</tbody>
</table>

Emergent vascular surgery was required during or immediately after tumor resection for 3 research subjects with major arterial injuries (aorta, superior mesenteric artery [SMA], and carotid artery). 3 with major venous injuries (subclavian, portal, and axillary veins), 1 with aortic saddle embolism, 1 with iliofemoral artery thrombosis, and 1 with superior vena cava (SVC) thrombosis. The procedures used to restore vascular integrity in these complicated cases are also listed in Table 2. As a result, emergent vascular reconstruction procedures performed included primary repair of a major aortic laceration, SMA reconstruction, patch repair of a carotid artery laceration, patch repair of major rents in the portal and axillary veins, primary repair of a major rent in the subclavian vein, aortoiliacofemoral thrombectomy, unilateral axillofemoral bypass, and SVC thrombectomy.

Vascular interventions in this study were generally associated with elective cancer resection. However, 9 emergent vascular procedures (23%) were required for complications that occurred during or immediately after tumor resection. Three of these emergent procedures involved the following: a major injury of the internal carotid artery during radical neck dissection, an injury of the SMA during synchronous resection of duodenal and cecal carcinoma, and an injury of the aorta during retroperitoneal lymph node dissection. Two other emergent procedures involved acute thrombosis of the femoral artery after the patient underwent a low anterior resection and acute thrombosis of the distal aorta after the patient underwent an upper lobectomy. Major venous injuries occurred in 3 patients during radical thyroid and mediastinal node dissection (subclavian vein), modified radical mastectomy (axillary vein), and pancreaticoduodenectomy (portal vein), and 1 other patient acutely developed severe SVC syndrome after undergoing a total esophagectomy.

The occurrence of a major vascular complication in conjunction with resective oncologic surgery is decidedly uncommon and rarely detailed in the English-language literature. Pafalvi et al reported a 7% (13 cases) incidence of major vascular injuries in a series of 184 gynecological resections for malignancy. The injured vessels included the external iliac artery (4), the vena cava (3), the external iliac vein (5), and the femoral vein (1). All of these vessels were primarily repaired without a prosthesis or patch. In this study, postoperative complications directly related to the vascular injury occurred in 4 patients (2%). These complications included femoral vein thrombosis (2) and iliac artery occlusion (2), which resulted in permanent walking disabilities for both patients. In our study, complications following 2 of the described emergent vascular procedures— injury of the SMA and SVC thrombosis—lead directly to patient death from bowel infarction and stroke, respectively.

While the need for emergent vascular reconstruction during a resective oncologic procedure is distinctly unusual, there appears to be a continued role for elective vascular reconstruction during resective oncologic procedures for some carefully selected patients. For instance, recurrent head and neck cancer occurring with vessel invasion is a common indication for carotid resection-reconstruction. Eighty percent of the carotid reconstructions in this study were for recurrent disease.
Resective oncologic surgery in this setting is supported by an improvement in locoregional control without having an impact on the long-term survival rate. In addition, there is a decrease in perioperative stroke risk vs unselected carotid artery ligation (15%-30%). However, vascular complications do occur despite the elective nature of these cases.

Two (22%) of the 9 patients in this study who underwent elective procedures with carotid resection-reconstruction for head and neck malignancy had serious vascular complications as a result of postoperative wound infections. These infections lead directly to vein graft blowouts, which were both managed by acute graft ligation resulting in 1 minor and 1 major stroke. Wright et al reported 3 postoperative wound infections (15%) and 1 carotid blowout (5%) among 20 patients who underwent resection of the carotid artery and replacement with a vein graft. The blowout case was not complicated by stroke although it was similarly managed by acute graft ligation. The perioperative (30-day) mortality rate was zero for elective carotid artery resection-reconstruction, which is comparable to the Ohio State series. However, the patient in our study who sustained a major stroke after carotid blowout event eventually died on postoperative day 55, and another patient died on postoperative day 60 secondary to cardiac arrest. The late postoperative stroke rate of 11% (1 case) in patients who underwent elective procedures is comparable to that found in recently published literature.

The rationale behind concomitant vascular resection-reconstruction in the management of retroperitoneal sarcomas is based on the fact that complete tumor resectability as well as tumor grade are the dominant predictors of both disease recurrence and survival rate. In this study, radical excision of 3 retroperitoneal soft tissue sarcomas was accompanied by elective iliac artery resection. Lower extremity vascular continuity was restored with a femorofemoral bypass in 2 patients and an aortoexternal iliac artery bypass in the other. Despite this aggressive tumor management and the absence of infections.

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**Table 1. Carcinoma Variables in Patients Undergoing Major Resection for Malignancy**

<table>
<thead>
<tr>
<th>Type of Carcinoma, No. of Patients</th>
<th>Recurrence, No. of Patients</th>
<th>Preoperative Irradiation, No. of Patients</th>
<th>Complete Resection, No. of Patients</th>
<th>Type of Nonvascular Complication, No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head/neck, 10</td>
<td>8</td>
<td>6</td>
<td>10</td>
<td>Pneumonia, 1</td>
</tr>
<tr>
<td>Gastrointestinal, 8</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>Coagulopathy, 2</td>
</tr>
<tr>
<td>Renal, 7</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>Coagulopathy; 2</td>
</tr>
<tr>
<td>Endocrine, 4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>GB/liver failure, 1</td>
</tr>
<tr>
<td>Sarcoma, 4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>None</td>
</tr>
<tr>
<td>Skin, 3</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>None</td>
</tr>
<tr>
<td>Breast, 1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>None</td>
</tr>
<tr>
<td>Lung, 1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>None</td>
</tr>
<tr>
<td>Testicular, 1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>None</td>
</tr>
</tbody>
</table>

*ATN indicates acute tubular necrosis; GB, gallbladder.

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**Table 2. Vascular Reconstruction Variables in Patients Undergoing Major Resection for Malignancy**

<table>
<thead>
<tr>
<th>Type of Vessel, No. of Patients</th>
<th>Type of Procedure,† No. of Patients</th>
<th>Type of Graft, No. of Patients</th>
<th>Complication, No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carotid artery, 10</td>
<td>Reconstruction, 9/1</td>
<td>Vein, 10</td>
<td>Carotid blowout; 2</td>
</tr>
<tr>
<td>Iliac artery, 5</td>
<td>Bypass, 2/0; extra-anatomic bypass, 2/1</td>
<td>PTFE, 5</td>
<td>None</td>
</tr>
<tr>
<td>Aorta, 2</td>
<td>Primary repair, 0/1; thrombectomy, 0/1</td>
<td>None, 2</td>
<td>None</td>
</tr>
<tr>
<td>SFA/CFA, 2</td>
<td>Reconstruction, 2/0</td>
<td>Vein, 2</td>
<td>Graft thrombosis, 1</td>
</tr>
<tr>
<td>Hepatic artery, 1</td>
<td>Bypass, 1/0</td>
<td>PTFE, 1</td>
<td>None</td>
</tr>
<tr>
<td>SMA, 1</td>
<td>Bypass, 0/1</td>
<td>Vein, 1</td>
<td>Bowel infarction, 1</td>
</tr>
<tr>
<td>Inferior vena cava, 10</td>
<td>Reconstruction, 8/0; venorrhaphy, 2/0</td>
<td>PTFE; 8, none, 2</td>
<td>None</td>
</tr>
<tr>
<td>Portal vein, 3</td>
<td>Reconstruction, 2/0; patch, 0/1</td>
<td>PTFE; 1, vein, 2</td>
<td>None</td>
</tr>
<tr>
<td>Subclavian/axillary vein, 2</td>
<td>Patch, 0/1; venorrhaphy, 0/1</td>
<td>Vein, 1; none, 1</td>
<td>None</td>
</tr>
<tr>
<td>Femoral vein, 2</td>
<td>Reconstruction, 2/0</td>
<td>PTFE; 1, vein, 1</td>
<td>None</td>
</tr>
<tr>
<td>Superior vena cava, 1</td>
<td>Thrombectomy, 0/1</td>
<td>None, 1</td>
<td>Stroke, 1</td>
</tr>
</tbody>
</table>

*SFA indicates superficial femoral artery; CFA, common femoral artery; SMA, superior mesenteric artery; and PTFE, polytet.
†Values are given as elective/emergent reconstructions.

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Cumulative patient survival curve. Standard error is less than 10% for all intervals.
However, considerable long-term survival is possible when vascular reconstruction is combined with limb-preserving resection of extremity sarcomas. This is true despite a relatively high incidence of systemic metastases. The estimated 3-year patient survival and local recurrence rates after en bloc tumor and axial vessel resection parallel those of patients not requiring major-vascular resection. Not unexpectedly, wound infection with graft exposure and acute graft thrombosis are the most common reported vascular complications in this group of patients in need of challenging procedures. One patient in this study underwent en bloc resection of thigh sarcoma with an interposition vein graft replacement of the superficial femoral artery. The procedure was complicated by acute graft thrombosis. However, performing an immediate graft thrombectomy salvaged both the conduit and the extremity.

In this study, 3 other elective major arterial reconstructions were performed as part of en bloc resection of ampullary carcinoma (pancreaticoduodenectomy), vulvar carcinoma (groin dissection), and cecal carcinoma (retroperitoneal lymph node dissection). These vascular procedures included an aortohepatic artery bypass, a femoral artery reconstruction, and an aortoiliac bypass, respectively. Two other patients underwent elective femoral vein reconstruction during groin dissections for primary carcinoma of the vulva and regional recurrent disease from carcinoma of the penis. Aggressive cancer management was the impetus for these vascular reconstructions. Arguably, except to prevent possible postoperative liver dysfunction in the case of aortohepatic bypass, the other vascular interventions are not associated with any survival advantage. Fortunately, there were no vascular complications in this group of 5 patients.

In contradistinction to the above scenarios, performing a resection of the portal vein in the course of treatment for locally advanced pancreatic adenocarcinoma generally affords patients considerably improved survival rates compared with performing palliative or no surgery. Harrison and Brennan have demonstrated that the survival rate is ultimately similar between patients with adenocarcinoma of the pancreas who undergo portal vein resection compared with patients who undergo standard pancreatic resection. This is predicated on the ability to perform the procedure safely. In this study, as part of pancreaticoduodenectomy, one patient underwent portal vein reconstruction with polytetrafluoroethylene (PTFE) while the second underwent vein graft reconstruction. The vein graft anastomosis disrupted on postoperative day 7, resulting in a massive hemorrhage and the patient’s death. The other patient died on postoperative day 25 from nonvascular complications related to multisystem organ failure that was initiated by the breakdown of the pancreaticojejunal anastomosis.

Similar to portal vein resection for locally advanced adenocarcinoma of the pancreas, IVC resection-reconstruction for locally advanced carcinoma of all types may offer some patients the only possible palliative intervention. Some authors have also noted an increase in the long-term survival rate in selected patients after undergoing IVC resection for tumor invasion. Postoperative vascular complications are more often due to coagulopathy and bleeding than to direct graft problems. In this study, 10 IVC reconstructions were performed in conjunction with en bloc tumor resection of renal carcinoma (7), adrenal carcinoma (2), and carcinoid (1). There were 2 wedge resections performed in conjunction with primary venorrhaphy and 8 total resections performed with polytetef reconstruction. Bypass assistance was needed in 3 of the latter procedures for suprahepatic tumor extension. No vascular complication or perioperative mortality occurred in this group of research subjects.

Overall, 3 of the 39 patients died within 30 days of surgery as a direct consequence of a vascular complication that occurred in conjunction with resective oncologic surgery. One research subject developed extensive small-bowel infarction after undergoing an SMA bypass, 1 developed massive brain edema after undergoing an SVC thrombectomy, and 1 died of hemorrhage after a disruption of the portal vein reconstruction. Two other patients died in the hospital of massive stroke 55 and 60 days after surgery. One of these deaths was associated with carotid artery blowout. In this diverse group of patients with cancer, even if the patient was able to be discharged from the hospital, the long-term survival rate was extremely poor. Cumulative patient survival rate was only 44%, 26%, and 10% at 1, 3, and 5 years, respectively; this was despite aggressive surgical management of primary or recurrent carcinoma of all types.

These data demonstrate that the indications for vascular intervention in the surgical treatment of malignancy are 2-fold: one is rescue therapy for the unusual intraoperative or immediate postoperative vascular complication, and the other is concomitant resection-reconstruction of major vessels infiltrated by locally advanced cancer. While appropriate treatment is obviously required for the occasional vascular emergency that occurs in this setting, associated SMA or celiac artery involvement should still be considered an absolute contraindication to tumor resection. Similarly, aggressive resection of major arteries in conjunction with locally advanced retroperitoneal sarcoma, gastrointestinal, or gynecologic and penile regional recurrent disease does not appear to confer a significant long-term survival advantage. However, carotid resection-reconstruction, portal vein reconstruction, and IVC reconstruction are all acceptable options for treating locally advanced carcinoma. In these cases, vascular reconstruction performed in conjunction with resective oncologic surgery may offer the only possibility for tumor control without having a significant impact on the long-term survival rate. However, a reasonable long-term survival rate is possible after a limb-preserving resection of a sarcoma of the lower extremity. Thus, invasion of major axial vessels does not constitute an indication for amputation, and limb preservation should be the standard goal of therapy for extremity sarcomas.
DISCUSSION

Gregory L. Moneta, MD, Portland, Ore: At first consideration it is difficult to imagine what we can learn from Dr Bianchi's paper. After all, one could hardly dream up a greater hodgepodge of patients, operations, complications, and surgical techniques than that which Dr Bianchi has presented. The only unifying factor as far as I can discern is that a blood vessel operation of some sort, artery or vein, repair or bypass, abdomen, arm, neck, or leg was performed in the setting of a cancer resection, primary or recurrent. The authors' enthusiasm is admirable. They optimistically plunged into this pile confident they would discover a pony. Have they succeeded? Yes and no. First of all, it is important to recognize that investigations of certain topics by the very nature of the subject will never be able to sustain the rigors of level 1 evidence. Dr Bianchi's subject of blood vessel surgery is frequently the product of poor outcomes. I am always grateful for the opportunity to acquire experience at the expense of others.

Today we have learned that patients undergoing oncologic surgery and requiring a blood vessel resection, even as part of a theoretically curative resection, have only an expected 5-year survival of 10%. In addition, complications associated with the vascular reconstruction are devastating and not infrequent. I will appreciate this information the next time I contemplate such a procedure. Given the poor survival rate and the potential severity of the complications associated with arterial reconstructions in these patients, can the authors speculate on the true utility of total resection vs leaving a bit of tumor behind in order to avoid blood vessel reconstruction? It seems to me this is the main question this paper raises. When should the vessel be resected and when should we concede victory to the tumor?

Finally, a few technical questions. How do the authors suggest planning such procedures? Under what circumstances is preoperative angiography recommended? Should suprarenal caval filters be placed prior to reconstruction of the IVC? Why did carotid blowouts occur in the absence of infection? If postoperative radiation is contemplated, should patients in whom arterial resection is planned undergo in-line reconstruction or remote bypass?

Dr Ballard: Dr Moneta asked when should the vessel be resected and when should we concede victory to the tumor. Based on this review, it looks as though the best circumstance for vascular reconstruction in the setting of tumor invasion is when the internal carotid artery or the inferior vena cava is involved. This subset had the best surgical outcome though it didn't significantly impact survival. The cases that had the poorest outcome and probably where we might want to concede victory earlier than later would be the other infra-abdominal carcinomas and those that involve the groin. For instance, patients who had recurrent skin or GYN [gynecologic] tumors that metastasized to the groin and then required a resection did particularly poorly.

Dr Moneta asked how do we plan for these procedures and in what circumstances might angiography be recommended. We don't see all of these patients prior to surgery, and I am not advocating necessarily that we should. However, when surgical oncologists recognize significant vessel invasion based on preoperative imaging studies, then either arteriography or venography may be helpful to plan the appropriate concomitant vascular reconstruction. The worst scenario is to be called into the operating room after the disaster has occurred. Interestingly enough, we experienced 2 of these patients just last week. I originally thought this was an infrequent problem, but we had 2 iliac vein injuries and a thrombosed iliac artery with pelvic resections, one on the OB-GYN Service and the other on the Urology Service.

What about suprarenal caval filters? I don't think these are indicated because the tumor can tail up beyond the renal veins and you don't necessarily know this until you are resecting the IVC. The filter would just get in the way and probably make the situation worse. No patient in the series had PE [pulmonary embolism] associated with IVC reconstruction.

Regarding carotid blowout, I suspect that those patients probably did have subclinical infection. It is unusual to have carotid blowout without an obvious infection.

The last question was about postoperative radiation, that is, if this is to be contemplated, should you just do a direct in-line arterial or venous reconstruction or potentially do an extra-anatomic reconstruction? If I know the patient is going to have postoperative radiation, particularly after arterial reconstruction, I will figure out a route for reconstruction that potentially keeps the graft out of the radiation field. I don't have any hard and fast data regarding that, but it bothers me a little bit to irradiate these synthetic conduits.

REFERENCES


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