Cavoatrial tumor thrombus: Single-stage surgical approach with profound hypothermia and circulatory arrest, including a review of the literature

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Background: In recent years, heart surgery has been used more frequently to treat diseases that are not primarily of cardiac origin. This is the case for intracardiac extension of infradiaphragmatic tumors, such as renal cell carcinoma, Wilms tumor, uterine tumors, and adrenal tumors, which require radical surgery associated with cavoatrial thrombectomy.

Methods: From April 1987 to April 2001, 13 patients with an infradiaphragmatic tumor with thrombosis of the vena cava, the right atrium, or both underwent surgical resection with cardiopulmonary bypass, arrested circulation, and profound hypothermia.

Results: The in-hospital mortality was 0%. The postoperative complications were respiratory failure (1 patient) and a redo operation for bleeding (1 patient). After a mean follow-up time of 33.9 months, 8 (61.5%) patients were alive.

Conclusions: The use of extracorporeal circulation and deep circulatory arrest provide an optimal technique for removing the tumor thrombus in a bloodless field, even in the presence of metastatic disease, and has good early and long-term results.

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Renal and adrenal tumors might involve the inferior vena cava (IVC), with an intraluminal thrombotic extension in 5% to 15% of all cases and with right atrium (RA) involvement in 1% of cases. Renal cell cancer (RCC) represents 1% to 3% of all visceral cancers and 85% to 90% of malignant kidney tumors and is most frequently responsible for this phenomenon (4%-10% of all patients).¹⁻³ In this kind of pathology, the only available therapy is surgical intervention because conventional antineoplastic therapy alone (radiotherapy and chemotherapy) is not useful. It is now accepted that neoplastic extension into the IVC is not a prognostically determining factor.⁴ With no perinephric fat or lymph nodal involvement, it has been observed that the patients who undergo tumor excision with a radical nephrectomy and IVC thrombectomy have an overall and cancer-specific

Figure 1. The 4 stages of cavoatrial tumor thrombus.

5-year survival of 30% to 72%, with an operative mortality of 2.7% to 13% and an immediate palliation of symptoms of obstructive tumors.⁵⁻¹³ The aim of surgical therapy is the radical removal of neoplastic tissue, including the thrombus in the IVC, the adjacent lymphatic structures, and, eventually, the involved caval wall, as well as caval wall reconstruction. There have been several surgical techniques proposed depending on the proximal extension of the tumor thrombus. Usually, in type I and II disease (Figure 1) the tumor excision can be safely achieved by means of simple proximal and distal control of the IVC. In type III and IV disease the exposure and isolation of the IVC are more extensive, requiring liver mobilization with or without the use of cardiopulmonary bypass (CPB) and, in some circumstances, deep hypothermic circulatory arrest (DHCA). We treated patients with type III and IV disease with CPB and DHCA.

Materials and Methods

From April 1987 to April 2001, 13 consecutive patients with IVC, RA, or both types of tumor extension were operated on at the Department of Cardiovascular Surgery of the University of Bologna. Seven of these patients had type IV disease, and 6 had type III disease. There were 9 (69%) male and 4 (31%) female patients. Mean age was 51.2 ± 21.2 years (minimum, 10 years; maximum, 74 years). Ten (76.9%) patients had RCC, 1 (7.7%) had Wilms tumor, and 2 (15.4%) had adrenal carcinoma. Distant metastases were identified preoperatively in 4 (30.7%) patients, and lymph node metastases were found in 5 (38.5%) patients. The first 5 patients were studied preoperatively by using total body computed tomography scanning and echocardiography; the other 8 patients were studied with echocardiography and magnetic resonance imaging, which is presently the diagnostic test of choice. Patient characteristics are shown in Table 1. Data are expressed as means with 1 SD.

All tumors were exposed through a median sternotomy by using a Chevron incision (Figure 2). After exploration of the abdomen, a nephrectomy or an adrenalectomy was performed, being careful not to manipulate the IVC or the RA. Then we

Figure 2. The Chevron incision and sternotomy exposing the IVC.

performed a division of the diaphragmatic suspensory ligaments of the liver, which allowed for increased mobility of the organ, to expose better the anterior wall of the IVC. After administration of heparin (3 mg/kg), CPB was instituted by means of aortic cannulation of the ascending aorta and a single short, basket-like venous cannula. Cooling was continued to maintain a nasopharyngeal temperature of 18°C. Before the beginning of circulatory arrest, thiopental (5 mg/kg), mannitol (250 mL at 18%), and methylprednisolone (1 g) were administered to protect the brain and vital organs during arrest. Immediately before circulatory arrest, the ascending aorta was crossclamped, and crystalloid cardioplegia was administered for myocardial protection. After removal of the atrial cannula, the RA was opened near the orifice of the IVC; attention was then directed to the IVC, which was entered near the orifice of the renal vein. The bloodless field allowed for complete intravascular thrombus extirpation. When the vena caval reconstruction was accomplished by means of direct suturing, the 2-stage venous cannula was reinserted into the RA, and the patient was rewarmed.

Results

Either a radical nephrectomy or an adrenalectomy with a tumor thrombectomy was performed in all patients. There were no in-hospital deaths. The mean stay in the intensive care unit was 2.1 ± 2 days (minimum, 1 day; maximum, 7

TABLE 1. Patient characteristics

Patient no.	Age (y)	Sex	Symptoms	Histology	Lymph node	Metastases	Thrombosis site
1	74	M	Hematuria	RCC	—	—	IVC+RA
2	18	F	Hematuria	RCC	—	Lung	IVC+RA
3	59	M	Flank pain	RCC	—	—	IVC+RA
4	10	M	Abdominal mass	Wilms	—	—	IVC
5	37	M	Peripheral edema	Adrenal	—	—	IVC
6	58	M	Peripheral edema	RCC	Yes	—	IVC
7	56	M	Hematuria	RCC	—	—	IVC
8	63	F	Hematuria	RCC	Yes	—	IVC
9	68	F	Dyspnea	RCC	Yes	Brain, lung	IVC+RA
10	26	F	Dyspnea	Adrenal	—	Lung	IVC+RA
11	71	M	Hematuria	RCC	Yes	Liver	IVC+RA
12	60	M	Flank pain	RCC	Yes	—	IVC
13	66	M	Peripheral edema	RCC	—	—	IVC+RA

days). Five thousand international units of nadroparin was administered to all patients. Two patients experienced perioperative complications: respiratory failure in 1 patient (requiring ventilatory support for 6 days) and a redo operation for bleeding in 1 patient. Hospital stay averaged 16 ± 2.5 days (range, 14-19 days). The mean follow-up time was 33.9 months (minimum, 4 months; maximum 120 months). There were 5 (38.5%) late deaths: 4 were caused by rapid progression of the disease (1 patient who had brain metastasis at the time of the operation died 6 months after the operation, 1 patient died 5 months later, 1 patient who had lymph node metastases at the time of the operation died 10 months later, and the fourth patient died 2 years after the operation), and 1 patient died because of a stroke 2 months after the surgical treatment. Eight (61.5%) patients are still alive, with an average postoperative time of 33.9 months; 3 have metastases (lung, $n = 2$; liver, $n = 1$), and 1 one patient had a rethrombosis of the IVC (type I) 3 months after the operation, without surgical indication. The latter patient had a complete resection of tumor; at follow-up he was asymptomatic, and the IVC was thrombosed by blood clots rather than tumor thrombus. All patients underwent chemotherapy or radiation therapy combined with the surgical intervention, and the patient with Wilms tumor underwent preoperative chemotherapy to shrink the tumor.

Discussion

The most frequent causes of cavoatrial tumor thrombus are RCC, adrenal carcinoma, liver carcinoma, uterine carcinoma, and Wilms tumor.³ In 1913, Berg⁴ described nephrectomy and vena caval thrombectomy for RCC that extended into the IVC. Since this report, radical tumorectomy with vena caval thrombectomy has become a safe treatment in cases of cavoatrial tumor thrombosis, with operative mortality rates ranging from 2.7% to 13% and an expected 5-year survival ranging from 30% to 72%.⁵⁻¹³ According to Flocks and Robson,¹⁴ in stage III of RCC and

adrenal carcinoma, local node involvement is more likely to occur. According to these considerations, Skinner and co-workers¹⁵ and Libertino and associates³ reported that tumor thrombus, to whatever degree of extension, without metastasized local nodes or perinephric fat involvement has a 5-year survival rate similar to that for a tumor that remains inside the renal capsule. Moreover, these tumors (excluding Wilms tumor) are not responsive to conventional chemotherapy or radiotherapy, and therefore surgical treatment provides the safest and most effective technique for removing these tumors.

We reviewed the literature of the last 15 years and found that management consists primarily of resection and that several different operations have been advocated, depending on the proximal extent of the tumor thrombus.

When the thrombus is localized within the infrahepatic IVC, tumor extraction is usually accomplished after proximal and distal control of the IVC. When the thrombus extends into the intrahepatic IVC or higher, isolation of the IVC requires mobilization of the liver with or without the use of CPB and, in some circumstances, must be accompanied by DHCA (Table 2).¹⁵⁻²² In stage III and IV disease various surgical approaches have been described. Control of the IVC must be achieved by clamping, but several problems must be resolved, such as the abrupt reduction of the venous return, which could cause severe hypotension, bleeding from the uncontrolled suprahepatic veins, and venous hepatic congestion. When using CPB only, it is necessary to clamp the hepatic artery and the porta hepatis, but these procedures are limited to the period during which the liver and the kidneys undergo warm ischemia, thus increasing the surgical risk. Skinner and coworkers¹⁵ reported an average warm liver and kidney ischemia time of 14 minutes with a range from 8 to 20 minutes. Postoperative complications occurred in 41% to 60% of the patients and included transient hyperbilirubinemia, renal dysfunction, and respiratory failure. There were also intraoperative complications

TABLE 2. Management of cavoatrial tumor thrombus

Authors	No. of patients	Operative technique	In-hospital mortality	Postoperative complications	5-year survival
Skinner and coworkers, 1989 ¹⁵	8	CPB	—	—	57%
Tsuji and coworkers, 2001 ¹⁶	33	CPB	6%	Pulmonary embolism	52.9%
Langenburg and coworkers, 1994 ¹⁷	3	CPB+DHCA	0%	—	100%
Glazer and Novick, 1996 ¹⁸	18	CPB+DHCA	5%	Myocardial failure	56.6%
Staehler and Brkovic, 2000 ¹⁹	9	CPB+DHCA	44%	Sepsis, renal failure	39%
Stewart et al, 1991 ²⁰	8	CPB	0%	Transient dementia, bleeding	37%
	4	No CPB	0%		
Yamashita and coworkers, 1999 ²¹	12	CPB	8.3%	Pulmonary embolization	18.8%
Welz and coworkers, 1997 ²²	19	CPB+DHCA	5.2%	Respiratory failure, cardiac failure	38%
	25	No CPB	16%		18%

with 3 deaths: 2 were due to exsanguination and 1 to a massive pulmonary tumor embolization. There were 4 other perioperative deaths caused by sepsis and multiorgan system failure, resulting in an operative mortality rate of 13%.

Other authors²³ treated this disease with CPB without DHCA, which allows for a shorter bypass time and a reduced risk of bleeding but has several disadvantages: reduced visualization and exposure because of blood and hepatic congestion; higher risk of embolization; higher risk of warm hepatic and renal ischemia; hypoxic liver impairment; and acute tubular necrosis. In the study of Tsuji and coworkers,¹⁶ 2 patients died during the early postoperative period because of retrohepatic caval injury and intraoperative pulmonary embolism. In the study of Stewart and colleagues,²⁰ all patients received blood transfusions (average of 10 units of blood, 6 units of platelets, and 2 units of fresh frozen plasma). Serious perioperative morbidity occurred in 3 patients, transient dementia occurred in 2 patients, and 1 patient required mediastinal reexploration for postoperative bleeding. In addition, 3 patients had transient elevation of serum transaminase and bilirubin levels postoperatively.

Compared with the results of Glazer and Novick¹⁸ and Welz and associates,²² we think that CPB with DHCA has several advantages. There is a bloodless surgical field with reduced risk of cellular spreading, pulmonary embolization, and fatal hemorrhage. There is also reduced risk of warm renal and hepatic ischemia, reduced risk of incomplete tumor excision, and optimal visualization of the IVC lumen and of the RA, and extended retroperitoneal dissection is unnecessary. Reported disadvantages of DHCA are extended bypass time as a result of rewarming, postoperative bleeding and coagulopathy, and increased neurologic risk. In our study in-hospital mortality was 0%, and postoperative complications appeared in 3 cases: 1 patient underwent a relaparotomy for major bleeding, and 2 patients required blood transfusions (3 and 4 units) early in the postoperative period. There were no neurologic events.

In conclusion, we believe that when there is a renal or adrenal tumor that interests the IVC, the RA, or both, the surgical approach is justified because it allows for the immediate palliation of symptoms, removal of a life-threatening focus of disease, tumoral burden reduction before biologic therapy, and lower risk of coagulopathies or hepatic dysfunction. Keep in mind that postoperative survival is closely related to the stage of the disease (but not to the stage of caval tumor thrombus) at the time of the operation rather than the operative approach. Our experience suggests that CPB with DHCA has improved the safety and the technical efficacy of a difficult procedure, even in cases of metastasis providing good perioperative results in terms of complications, and early and long-term survival.

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