Liver Resection Under Total Vascular Isolation

Variations on a Theme

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Total vascular isolation (TVI) of the liver was employed during parenchymal transection in 16 patients undergoing hepatic resection for large tumors (mean diameter, 10.7 cm) located near hilar structures, hepatic veins, or the inferior vena cava (IVC). In 14 cases, TVI was achieved by clamping the suprahepatic and infrahepatic IVC and the porta hepatis, with or without aortic occlusion; in two, selective hepatic vein clamping was possible, obviating IVC occlusion. Procedures included standard and extended right and left lobectomies and caudate lobe resections. Concomitant resection and reconstruction of the portal vein (one case), IVC (one case), and bile duct (three cases) was required. Postoperative hepatic and renal failure did not occur. Mean intensive care unit and hospital stays were 2.8 ± 1.9 and 12.5 ± 5.2 days, respectively. There were two perioperative deaths. Total vascular isolation permits safe resection of large, critically located tumors that would otherwise present prohibitive operative risks.

Although technical refinements in liver resection have led to lower mortality and morbidity rates, profuse hemorrhage and air embolism remain major risks during resection of large tumors, especially those located centrally or close to the hepatic veins or vena cava. Limiting blood loss while performing safe and expeditious resection are primary goals of the liver surgeon. In an effort to achieve these aims, we have explored the usefulness of total vascular isolation (TVI) of the liver during parenchymal transection. Isolation is carried out by completely mobilizing the liver and then occluding the inferior vena cava (IVC) above and below the liver and clamping the structures in the porta hepatis. This method, employed with concomitant occlusion of supraceliac aorta, was first described by Heaney and co-workers.[1] Since then, several groups have performed liver resection using TVI with or without supraceliac aortic occlusion.[2–5] Herein, we report our experience with liver resection using TVI, and describe useful modifications of this technique.

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PATIENTS AND METHODS

Between September 1987 and June 1991, 16 patients underwent elective major liver resection under total vascular isolation; in four of these, adjunctive supraceliac aortic occlusion was employed. Mean patient age was 55 years (range, 16 to 71); 12 were women or girls and four were men or boys. The indications for resection in these patients are presented in Table 1.

All patients considered for liver resection were studied with ultrasonography and computed tomography; magnetic resonance imaging and selective celiac and mesenteric angiography with late phase portography were done on a selective basis. If involvement of retrohepatic IVC was suspected, an inferior venacavagram was obtained. In patients with hepatocellular carcinoma, bone scan and chest computed tomography were done to rule out metastatic disease. For those with secondary liver tumors, the primary sites were studied to rule out local recurrence, and the appropriate metastatic workup was performed.

Tumors found on preoperative studies to be located centrally or close to the hepatic veins or IVC were considered for TVI, but the final decision to proceed was based

Table 1. PATIENT DEMOGRAPHICS, INDICATIONS FOR OPERATION, AND DETAILS OF SURGERY

Patient No.	Sex	Age	Diagnosis	Size of Tumor (cm)	Type of Resection	Duration of Total Vascular Isolation (min)	Aortic Occlusion	EBL (mL)	Intensive Care Unit Stay (days)	Hospital Stay (days)
1	M	59	Metastases from the neuroendocrine system	5 × 5	Right hepatectomy	35	Yes	1500	2	11
2	F	35	Metastases from the adrenal gland	4 × 3	Right hepatectomy, caudate lobe, retrohepatic inferior vena cava, diaphragm resection	48	No	7000	2	14
3	F	64	Simple cyst	20 × 20	Right hepatectomy	16	No	1250	2	12
4	M	65	Metastases from the colon	6 × 5	Segment 8 resection	14	No	500	—	8
5	F	54	Metastases from the salivary gland	15 × 12	Left hepatectomy	36	No	1000	—	12
6	F	68	Angiolipoma	15 × 13	Caudate lobe resection	15	No	400	3	12
7	M	60	Cholangiocarcinoma	8 × 8	Extended right lobectomy, caudate lobe resection, hepaticojejunostomy	45	Yes	3000	5	28
8*	F	57	Metastases from the colon	15 × 13	Extended right lobectomy, caudate lobe resection, hepaticojejunostomy	35	No	2000	3	19
9†	M	71	Metastases from the colon	14 × 13	Extended left lobectomy	25	No	1200	—	—
10	F	16	Adenoma	12 × 12	Segments 4 & 8 resection	35	No	100	3	12
11	F	57	Cystadenocarcinoma	12 × 9	Left hepatectomy, caudate lobe resection	39	Yes	1400	1	12
12	F	39	Metastases from the colon	5 × 6	Left hepatectomy	25	No	400	—	6
13	F	53	Metastases from the colon	7 × 6	Right hepatectomy	21	No	1100	1	7
14	F	69	Metastases from the colon	8 × 7	Left hepatectomy hepaticojejunostomy	37	No	4000	8	8
15	F	67	Hepatoma	13 × 10	Left hepatectomy	22	No	2000	2	15
16	F	53	Metastases from the lung	12 × 12	Extended right lobectomy	17	Yes	3000	2	12

* Total vascular isolation via selective venous outflow occlusion.
† Intraoperative mortality rate. EBL, estimated blood loss.

on the operative findings. During the procedure, arterial blood pressure, central venous pressure, pulmonary wedge pressure, and cardiac output were monitored. Arterial blood gases and pH were recorded at fixed intervals before, during, and after TVI.

Our standard technique of resection with TVI is as follows: Abdominal exploration is done through a bilateral subcostal incision with an upper midline extension, without thoracotomy. The liver is completely mobilized by dividing the round and falciform ligaments, the right and left triangular ligaments, and the gastrohepatic omentum. When right hepatectomy or extended right hepatectomy is performed, if a left hepatic branch is noted to arise from the left gastric artery, this branch is preserved. The IVC is encircled above and below the liver. The entire retrohepatic IVC then is freed up; if the right adrenal vein enters this segment of the IVC, it is ligated and divided. The IVC and porta hepatis are then test-clamped for 3 to 5 minutes to assess whether arterial blood pressure and cardiac output will be well main-

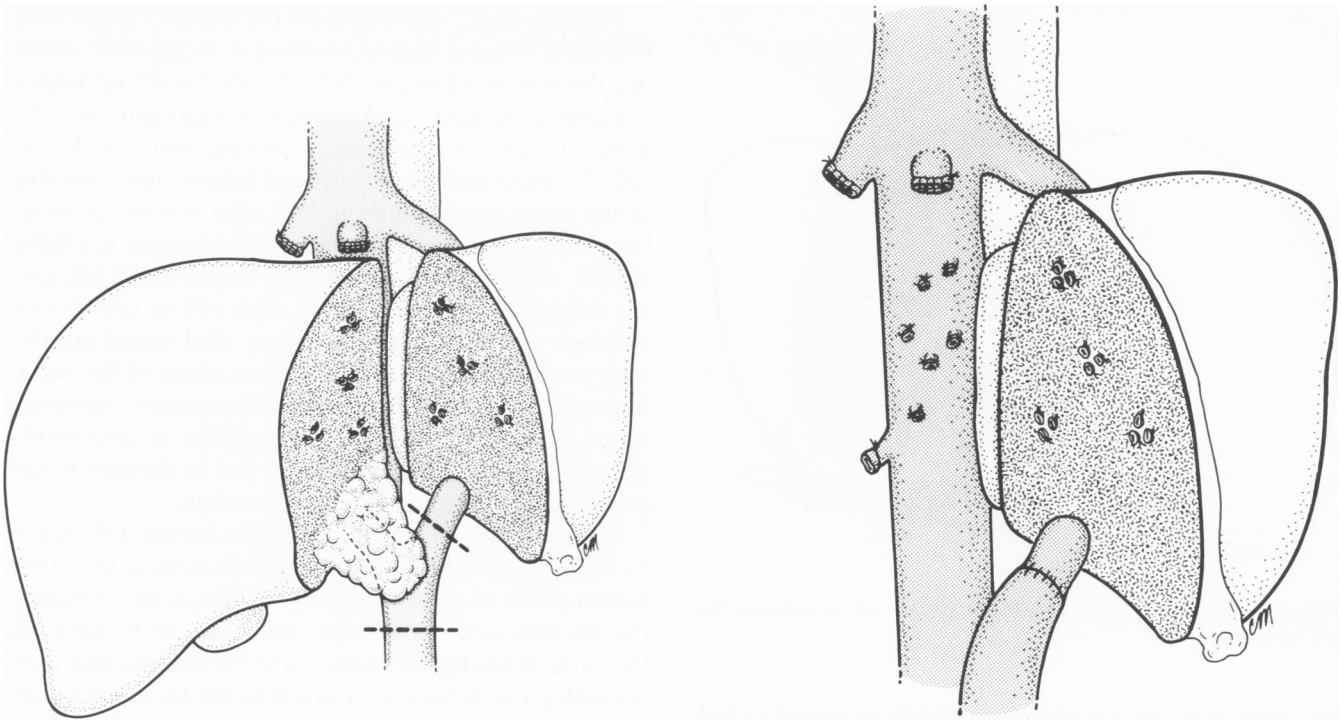

Figure 1. (A, left) Tumor involving the portal vein confluence. Dotted lines show margins of resection. (B, right) The main portal vein was anastomosed to the portal vein of the left lateral segment.

tained. In patients who, even with volume loading, do not tolerate test clamping, the supraceliac aorta is exposed through the crura of the diaphragm to permit concomitant aortic occlusion.

After outlining the margins of resection with the electrocautery, TVI is instituted and the hepatic parenchyma is transected using finger fracture or an unsheathed Poole-type suction tip. Blood vessels and bile ducts need be ligated only on the side of the liver that will remain in the patient. After transection, the infrahepatic IVC clamp is partially opened first to evacuate air and to check for caval integrity; the liver then is reperfused. Any significant bleeding points are controlled with fine silk sutures, and final hemostasis at the resection margin is assured with the aid of the Argon Beam Coagulator. Closed suction drains are routinely employed.

RESULTS

Anatomic extent of resection, tumor dimension, various modifications of TVI, and other details of surgery are shown in Table 1. In three cases, the tumor involved the confluence of the right and left hepatic ducts, necessitating bile duct resection and subsequent biliary reconstruction; in one of these cases, portal vein resection was also required because the tumor extended to the portal vein confluence (Fig. 1). One patient required retrohepatic IVC resection combined with right hepatectomy for metastatic adrenal carcinoma. In this patient, who also required resection of part of the right diaphragm, the IVC was reconstructed with autogenous superficial femoral vein.[6]

Supraceliac aortic occlusion was employed in four cases; resultant hypertension was readily controlled with vasodilators. In two patients who underwent extended hepatectomy (one right and one left) with caudate lobe resection, TVI of the liver was achieved by preliminary division of the hepatic veins draining the specimen and then clamping the only remaining major hepatic vein, thus avoiding the need for caval occlusion (Fig. 2). In the remaining ten cases, TVI was instituted using the standard technique described above.

The average duration of vascular isolation was 29.0 ± 10.7 minutes (range, 14 to 48 minutes). Mean operative blood loss was 1866 ± 1683 mL (range, 100 to 7000 mL). Mean intensive care unit and hospital stays were 2.8 ± 1.9 and 12.5 ± 2 days, respectively. Postoperative hepatic and renal failure did not occur. Preoperative and postoperative parameters of hepatic and renal function are shown in Table 2.

There were two perioperative deaths. One occurred intraoperatively, in a 71-year-old man who underwent extended left hepatectomy for metastatic colonic carcinoma and suffered cardiac arrest during a period of hypotension after hepatic reperfusion. A 69-year-old woman, who underwent extended left hepatectomy with

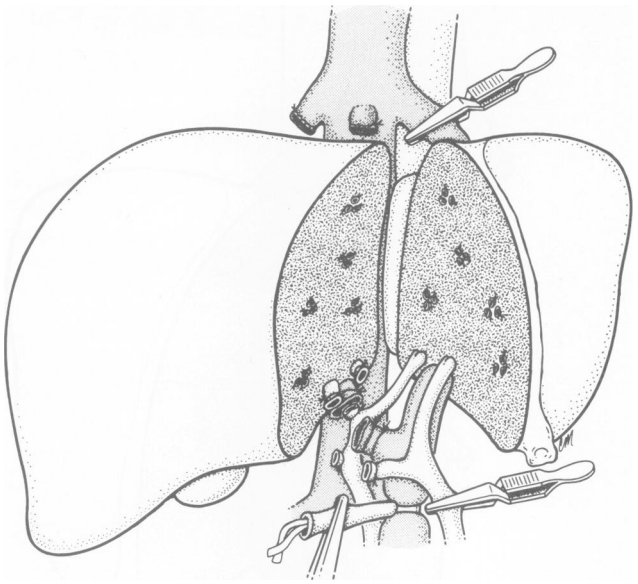

Figure 2. Modification of TVI. Only the left hepatic vein is occluded; the IVC is not clamped.

bile duct resection for metastatic colon carcinoma, died suddenly on the eighth postoperative day; hepatic and renal function were normal at the time of death, and permission for autopsy was not granted.

DISCUSSION

Profuse hemorrhage and air embolism have long been of concern during the resection of extensive liver tumors, particularly tumors located centrally or close to the hepatic veins or IVC. Total vascular isolation permits parenchymal transection in a bloodless field, facilitating precise identification and dissection of intrahepatic vessels and ducts without risk of air entry. When radical resection mandates extensive skeletonization of major hepatic veins to ensure tumor-free margins, TVI allows the fine suturing of multiple venous tributaries that would otherwise be virtually impossible to control. Lesions involving the IVC, hepatic veins, portal vein, or bile duct are readily resected *en bloc* along with the involved structures, with subsequent vascular or biliary reconstruction.[6,7]

Stephen et al.,[8] reporting on the use of TVI in liver resection, suggest that concomitant supraceliac aortic occlusion is beneficial in that it limits blood loss, hemodynamic instability, and splanchnic engorgement.[8] We prefer a selective approach, reserving aortic occlusion only for those patients who do not tolerate test clamping of the porta hepatis and the IVC after volume preloading. Although isolation of the supraceliac aorta is usually simple, in the patient with a large tumor in the left lobe the dissection may be difficult. The risk of spinal cord ischemia is another consideration: vital spinal arteries may uncommonly arise from this segment of the aorta. Moreover, especially in elderly atherosclerotic patients, aortic cross-clamping can cause embolic or thrombotic ischemic injury at distant sites as well as damage to the aorta itself at the site of clamp placement.

Venous outflow can be controlled during TVI either by clamping the suprahepatic and infrahepatic IVC after assuring that all retrohepatic caval tributaries (including the adrenal vein) have been controlled, or by dividing the veins draining the segments to be resected and then occluding the hepatic vein draining the remaining lobe. This technique was proposed by Raia et al.,[9] but was abandoned by Huguet et al.[10] because of difficulties experienced during the dissection of hepatic veins. Although not universally applicable, if the hepatic veins can be easily dissected, this method enables TVI without interruption of IVC and thus simplifies the anesthetic management of the patient.

Regardless of the technique of vascular isolation, complete interruption of vascular inflow and outflow must be assured; imperfect application of TVI may result in bleeding equal to or exceeding that seen with standard nonisolation methods. Early in our series, the portal vein and hepatic artery were dissected and clamped individually (Fig. 3). Although all named vessels were occluded, inflow to the liver through small hilar collaterals produced significant bleeding during the parenchymal transection. In our more recent experience, we have used a broad atraumatic vascular clamp with DeBakey teeth to accomplish inflow occlusion (Fig. 4). There have been no arterial injuries, and the vascular isolation has been complete.

Table 2. PRE- AND POSTOPERATIVE PARAMETERS OF HEPATIC AND RENAL FUNCTION

		Postoperative Day		
	Preoperative	1	3	7
ALT (U/L)	59.4 ± 41.9	395 ± 234	237 ± 126	83.6 ± 41.7
Bilirubin level (mg/dL)	2.0 ± 3.7	4.5 ± 5.8	3.9 ± 6.1	3.7 ± 6.0
Prothrombin time (sec)	12.0 ± 0.6	14.2 ± 1.1	12.6 ± 0.9	12.3 ± 0.6
Serum creatinine (mg/dL)	1.0 ± 0.4	1.0 ± 0.4	1.1 ± 0.6	0.9 ± 0.2

It is unknown how long hepatic vascular inflow may be safely occluded. Out of fear of normothermic ischemic injury, Fortner[11] combined *in situ* core cooling of the liver with TVI. Huguet et al.[12] have demonstrated that the human liver can tolerate warm ischemia for at least 60 minutes, and probably as long as 90 minutes (personal communication). In our experience, even with concurrent portal vein resection and reanastomosis, the period of warm ischemia did not exceed 48 minutes, rendering hypothermic protection unnecessary. Within this range, we have not seen clinically significant ischemic liver injury. Although there has been a recent resurgence of interest in performing bench-top hepatic resections under hypothermic preservation, we agree with others who find such methods unwarranted.[11]

We have learned from this series that optimal application of TVI requires (1) assurance of complete vascular isolation, and (2) transection of the parenchyma in an unhurried, meticulous fashion. In this way, the bloodless field provided by TVI is used to its greatest advantage, and bleeding after reperfusion is minimized, without compromise of hepatic function.

Total vascular isolation simplifies surgery and provides a margin of safety in the resection of hepatic tumors located centrally or close to the hepatic veins and vena cava. Using TVI, direct tumor involvement of the portal vein, hepatic veins, or IVC is readily managed. With the appropriate application of selective outflow occlusion and supraceliac aortic clamping, TVI may be employed without major hemodynamic consequences.

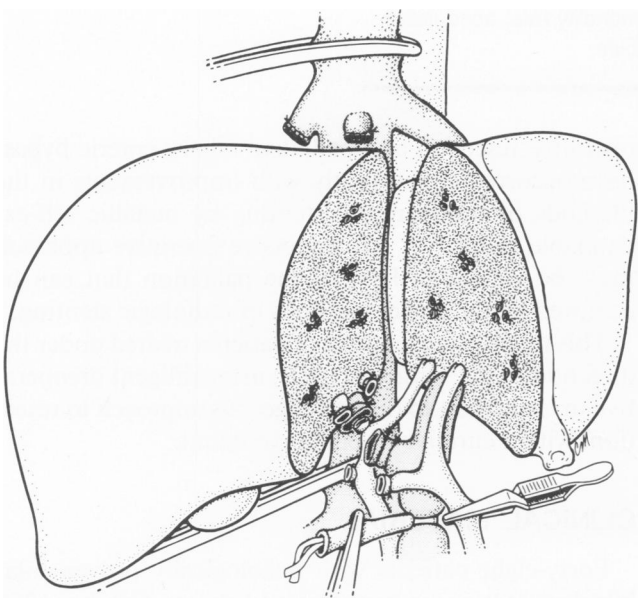

Figure 3. The portal vein and hepatic artery are occluded separately on the porta hepatis.

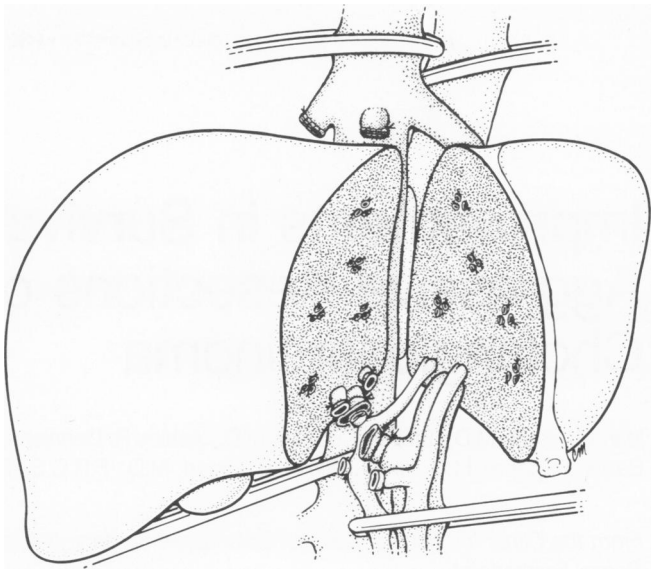

Figure 4. En bloc occlusion of the porta hepatis.

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