Atrial Caval Shunting in Blunt Hepatic Vascular Injury

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Of 51 patients with major blunt hepatic trauma treated at a Level I trauma center, 29 patients (56.8%) survived. Nine of the 51 patients required insertion of the atrial caval shunt, as indicated by uncontrollable hemorrhage due to disruption of the perihepatic veins. Eight of these nine patients sustained injury to the hepatic veins or the retrohepatic vena cava. Of the eight patients with hepatic vascular injury, four (50.0%) were long-term survivors. In hepatic trauma patients with suspected hepatic vascular injury, aggressive use of the shunt can control hemorrhage before the onset of coagulopathy or hypothermia.

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BLUNT TRAUMA TO THE LIVER carries a high mortality; in severe cases such as those associated with multiple trauma, the patient can exsanguinate in the field. Concomitant injury to the hepatic veins or retrohepatic vena cava is almost always fatal. Should the patient survive enroute to the hospital, the inaccessibility of the hepatic veins and retrohepatic vena cava renders their surgical isolation and control extremely difficult. Vascular isolation of the liver has been achieved with the atrial caval shunt together with the Pringle[1] maneuver. The shunt permits continuous venous return sufficient to maintain the ventricular filling pressures necessary to sustain cardiac output while simultaneously providing a "bloodless" field for repair of traumatized vascular structure. The experience of a Level I trauma center's use of the atrial caval shunt is reviewed here, together with a brief history of hepatic vascular isolation and a potential alternative method.

Materials and Methods

The Lehigh Valley Hospital Center (LVHC), Allentown, Lehigh County, Pennsylvania, is a Level I trauma center whose MedEvac program serves 1.5 million people in eight counties in Southeastern Pennsylvania plus two counties in New Jersey. From November 1979 through February 1985, over 7000 trauma patients had been treated. All cases of major hepatic trauma were reviewed with attention directed toward hepatic vein or retrohepatic vena cava injury requiring insertion of the atrial caval shunt. Major hepatic trauma was defined as (1) a laceration with significant hepatic parenchymal disruption, *i.e.*, at least 10 cm in length and 3 cm deep; (2) multiple moderate lacerations with or without hematoma; or (3) stellate lacerations.

Results

Of 51 cases of major hepatic trauma reviewed, nine involved the use of the atrial caval shunt. Seven of these nine patients were male, two were female, and eight of the nine were between 20 and 29 years of age. All nine patients were in shock on admission, with systolic blood pressure of 80 or less. All nine patients had major liver injury in addition to multiple trauma (Table 1). Four patients had major hepatic vein injury, four patients had hepatic vein and retrohepatic vena cava injury, and one patient had strictly hepatic trauma with no involvement of these vessels.

Eight of the 51 patients (15.7%, SEM: 5.1%) had major hepatic vascular trauma. Of the eight patients, four (50.0%, SEM: 17.7%) survived. The sternal split approach, using an endotrachial tube with a hole cut at the appropriate level as the shunt, was used in seven patients, three of whom survived. In the remaining patient who survived, an infrarenal approach was used, employing a large chest

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TABLE 1. *Patient Demographics with Use of the Atrial Caval Shunt*

Patient No.	Sex	Age (yrs)	Cause of Injury	Hepatic Vein	Infrahepatic Vena Cava	Assessment of Injuries	Blood	Hypothermic	DIC	Survival
1	F	21	MVA	Yes (Multiple)	Yes	Liver: large stellate lacerations; hepatocaval disruption	PRBC-6 FFP-6 Plates-4	?	No	No (in OR)
2	M	29	MC	Yes	No	Liver: extensive lacerations of right lobe, splenic rupture; contusions of pancreas, stomach, small and large bowel, kidney; fractured tibia; fractured mandible; right hemopneumothorax	PRBC-59 FFP-30 Cryo-10 Plates-36	Yes	Yes	Yes
3	M	20	MVA	Yes	Yes	Liver: transection of liver at falciform ligament with free floating left lobe; laceration of spleen; fractured femur	PRBC-22 FFP-10 Cryo-0 Plates-10	Yes	Yes	Yes
4	M	24	MVA	Yes (Multiple)	Yes	Liver: fracture along falciform lig; fracture along right triangular and coronary lig, avulsing and wedge from right lobe; right hemopneumothorax	PRBC-50 FFP-16 Cryo-10 Plates-38	Yes	Yes	Yes
5	M	20	MVA	Yes	Yes	Liver: complete transection at infrahepatic vena cava; hepatocaval disruption; portal vein laceration; fractured right forearm, right tibia	PRBC-34 FFP-4 Cryo-10	?	Yes	No (in OR)
6	F	25	MVA	Yes	No	Liver: multiple fractures, shattered right lobe, lacerated small bowel, lacerated appendix	PRBC-30 FFP-10 Plates-10	Yes	Yes	No (in OR)
7	M	24	MVA	Yes	No	Liver: transection left hemopneumothorax	PRBC-30 FFP-2	Yes	Yes	No (in OR)
8	M	22	MVA	Yes	No	Liver: fractured right lobe; renal contusion; multiple fractures of pelvis; right hemopneumothorax; edemetous small bowel preventing closure; prolene mesh used; cardiac arrest twice; temporary pacemaker	PRBC-54 FFP-32 Cryo-40 Plates-30	Yes	Yes	Yes

MC = motorcycle.
MVA = motor vehicle accident.

tube as the shunt. Blood was replaced mainly *via* components: packed cells ranged from 5–59 units; other components are listed in Table 1. All patients developed disseminated intravascular coagulation (DIC) or a "washout" coagulopathy despite meticulous replacement of coagulation factors. All patients in our study who survived were hypothermic (less than 92 F) with an average temperature of 83 F at start of surgery and were still hypothermic on return to the Shock Trauma Intensive Care Unit.

Discussion

In 1966, Heany et al.[2] devised a method of hepatic vascular isolation clamping the porta hepatis a la Pringle, the suprahepatic and infrahepatic vena cava, and the aorta, but complications included cardiac arrhythmias and arrest due to decreased venous return. Buchberg et al.[3] in 1967 pioneered the use of an intracaval catheter, thereby permitting venous return, by introducing a chest tube through the suprarenal vena cava and threading it proximally toward the right atrium, a technically difficult and time-consuming procedure. In 1968, Schrock et al.[4] introduced a right thoracoabdominal approach to insert an intracaval catheter through the right atrial appendage. A side hole was cut in the proximal end of the catheter, which would lie in the right atrium, and the distal end was threaded to just above the renal veins, thus allowing caval blood to return to the heart. Fullen et al.[5] began the median sternotomy approach, which allowed better access to the heart, liver, and vena cava. Later refinements included

TABLE 2. *Survival with the Atrial Cava Shunt: Hepatic Vein/Retrohepatic Vena Cava Injury Due to Blunt Trauma*

	No. of Patients	No. of Survivors	No. of Deaths
Shrock et al.[4] 1968	2	0	2
Yellin et al.[7] 1971	1	0	1
Kudsk et al.[10] 1982	6	0	6
Misra et al.[9] 1983	3	2	1
Current study	8	4	4

using a cuffed endotrachial tube as the shunt, obviating the need to secure it. Aaron and Mays[6] designed a catheter with a long cylindrical balloon that completely isolates the retrohepatic vena cava.

Although the use of the atrial caval shunt had been proven successful in managing penetrating hepatic trauma,[7] before 1976, the use of the atrial caval shunt in injuries of the hepatic vein or retrohepatic vena cava due to blunt trauma remained unsuccessful and uniformly fatal. After 1976,[8] a few cases of survivors of hepatic vein and retrohepatic vena cava injury secondary to blunt trauma with the use of the atrial caval shunt were reported[9] (Table 2).

Our results apply to the sternal split and infrarenal approaches. The median sternotomy approach, in which the shunt is threaded through the atrial appendage into the cava, is currently preferred (Fig. 1). The advantages of this over the infrarenal approach are: (1) exposure from the incision of the area of injury; (2) improved control

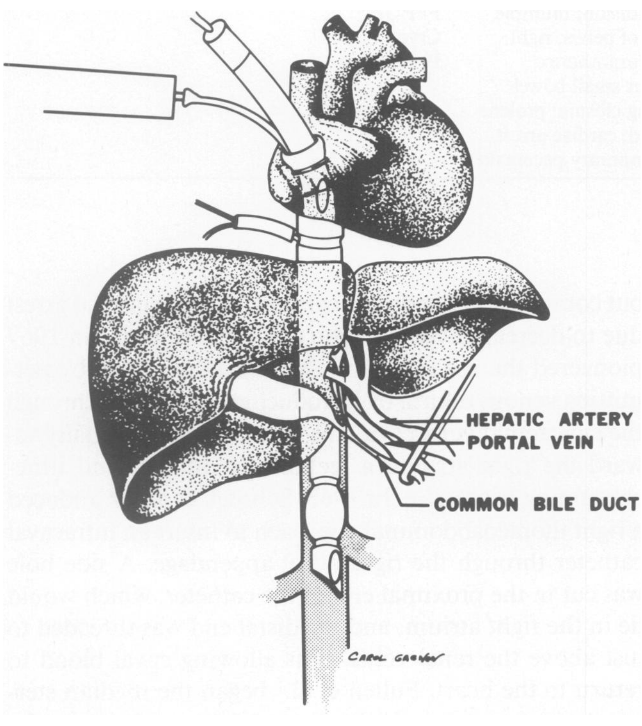

FIG. 1. Atrial caval shunt using endotracheal tube as the shunt.

and rapidity of insertion; (3) potential for direct intracardial transfusion; and (4) if necessary, open cardiac massage and warm saline lavage of the heart.[10]

Complications of the shunt insertion are few but serious. Air embolism is but one, thus demanding extreme care in inserting the catheter. Additional complications include perforation of vascular structures on insertion, pulmonary embolization of the catheter itself, and thrombosis within the catheter.[11]

The hypothermia experienced by our patients is believed to convey a protective effect to the viscera in general and the liver in particular. The slowing of the patient's metabolism as a result of the lower temperature improves the tolerance of ischemia. Normothermic ischemia time for the liver is 15–20 minutes,[4,6,7] but in the hypothermic liver up to 60 minutes of clamp time has been tolerated in animals without adverse effects.[12]

Hypothermia is a double-edged sword. It can cause myocardial depression with decreased cardiac output and predisposition to arrhythmias. Coupled with an already hypovolemic heart manipulated for shunt insertion, hypothermia can cause a tendency toward dysrrhythmias, including ventricular fibrillation and cardiac arrest. Continuous lavage of the heart (and other organs) with warmed saline has been helpful in dealing with hypothermia once control has been achieved.

An alternative to the atrial caval shunt is currently being explored at LVHC. Percutaneous catheters placed in the left subclavian and femoral veins and connected to a rapid transfusion device will allow massive fluid resuscitation in a matter of seconds. Immediate laparotomy and diagnosis of hepatic vein and retrohepatic vena cava injury is followed by application of a series of clamps to the suprahepatic and infrahepatic vena cava and the porta hepatis. A Y connector is placed on the subclavian catheter, and the femoral vein line is attached to an arm of the Y. The other is still connected to the rapid transfusion device. In addition, a catheter may be placed in the portal vein and connected to the femoral vein catheter. This arrangement of clamps and catheters effectively isolates the liver from circulation while still allowing venous return to the heart from the extremities and viscera *via* the femoral catheter connected to the subclavian catheter. Animal experiments are currently being conducted, thus far yielding encouraging results.

Vascular isolation of the liver and retrohepatic vena cava for hemorrhage control remains a technical challenge. Exposure of the retrohepatic area is a time-consuming and difficult process, and attempts at direct visualization are often met with torrential hemorrhage. Patients with this injury secondary to blunt trauma usually die in the field, but with improved advanced life support (ALS) and MedEvac capabilities, more of these patients are arriving at trauma centers: in shock, but alive. In hepatic trauma patients with suspected hepatic vascular injury, aggressive use of the shunt can control hemorrhage before the onset of coagulopathy or hypothermia.

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