Management and Outcome of Patients With Combined Bile Duct and Hepatic Artery Injuries

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Background: Major bile duct injury is an important therapeutic problem that can be associated with simultaneous injury to the hepatic artery. Limited information exists regarding the course of patients who have combined bile duct and arterial injuries.

Objective: To compare the management and outcome of isolated bile duct injuries with bile duct and hepatic artery injuries.

Patients and Methods: Since 1991, 13 patients have undergone reconstruction of right and left hepatic confluence or proximal bile duct injuries. At the time of bile duct injury, 4 of these patients had simultaneous occlusion or extirpation of the right hepatic or common hepatic artery. All patients underwent reconstruction of the biliary tract with hepaticojejunostomies. The immediate and long-term outcomes of the patients with and without hepatic artery injury were compared.

Results: In the immediate postoperative period, 3 of 4 patients with combined injuries had hepatic necrosis and/or abscesses with 2 patients requiring transcutaneous or operative drainage. This problem was not diagnosed in patients with isolated bile duct injuries. None of the biliary anastomoses have failed in the patients with isolated bile duct injuries while 50% of the anastomoses in patients with combined injuries have caused recurrent problems following reconstruction.

Conclusion: Patients with major bile duct injuries should be evaluated for concomitant hepatic arterial injury as management and outcome may be influenced by the absence of arterial blood flow to the injured bile ducts and to the liver.

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Acute bile duct injury and subsequent strictures occur most commonly following trauma and cholecystectomy. Hepatic duct injury occurring proximal to the cystic duct is primarily an iatrogenic problem associated with cholecystectomy. The incidence of bile duct injury currently associated with open, laparoscopic, or "mini" cholecystectomy is unknown. Irrespective of technique, there has always been a finite incidence associated with innumerable factors. Recent information suggests that the estimated incidence in population studies of iatrogenic bile duct injuries has been relatively stable at 1.4 per 1000 cholecystectomies for the past 5 years.

The difficulties associated with ascertaining the incidence of bile duct injuries is mirrored by any attempt to ascertain the incidence of simultaneous bile duct and hepatic artery injury. The article by Davidoff et al described a series of patients undergoing bile duct repairs, some with simultaneous injury to the hepatic artery; however, the frequency of the combined injury and the significance of the hepatic artery injury were not presented. In a series of 130 postcholecystectomy biliary strictures from the prelaparoscopic era, angiography was performed in 41 patients because of a history of vascular damage at the operation during which the injury occurred. Prior to reconstruction, 17 (13%) of the 130 patients were found to have hepatic arterial damage. No specific information was produced regarding the significance of the associated vascular injury.

The importance of hepatic arterial blood supply to the short- and long-term outcome of bile duct reconstructions has been suggested by studies that demonstrated the arterial blood supply to the extrhepatic bile duct and pointed out that some biliary strictures may be produced or exacerbated by bile duct ischemia. The experience produced by hepatic transplantation has demonstrated that hepatic artery thrombosis following engraftment is associated with early focal necrosis and subsequent ischemic intrahepatic bile duct strictures and extrahepatic bile duct strictures.

We have recently treated 4 patients with simultaneous major bile duct and hepatic artery injuries. The immediate and continuing course of these patients is reviewed and presented to relate our experience with this problem and to attempt to develop some clinical guidelines to direct the management of patients with this serious problem.
PATIENTS AND METHODS

During the past 4 years, 13 patients with major bile duct injuries have undergone reconstruction by a relatively uniform method of preoperative and postoperative management regarding the technique of reconstruction. Four of these patients had various hepatic arterial injuries that occurred at the time of the bile duct injury. It was intended to compare the course of the patients with and without hepatic arterial injury to ascertain the differences between the immediate and late results that occurred in the presence and absence of hepatic arterial injury.

Major bile duct injury was defined as a bile duct injury requiring reconstruction above the level of the cystic duct. These injuries would be categorized as Bismuth type 2 through 4 injuries. All reconstructions were performed when the patient was encountered and no planned delay in reconstruction was involved. Patients presented with various T tubes and endoscopically or transcutaneously placed biliary stents; however, if the patient did not have biliary stents in place, none were attempted to be placed preoperatively. All bile duct reconstructions were performed employing standard Roux-en-Y reconstructions with anastomoses performed with 5-0 or 6-0 suture placed in a running fashion using magnification. A form of Hepp-Couinaud technique was performed for Bismuth type 2 and Bismuth type 3 bile duct injuries. Bilateral right and left hepaticojejunostomies were performed for Bismuth type 4 injuries. If a patient had a transhepatic stent in place, it was left in place postoperatively. Otherwise, stents were not routinely applied to the anastomoses postoperatively. Transhepatic stents were removed as soon as it was safe to do so. Anastomotic leaks were identified as bile drainage from drains placed at the area of the anastomoses.

All patients underwent nuclear biliary imaging during the past 6 months and have had clinical evaluation and liver function studies performed during the past 6 months.

REPORT OF CASES

CASE 1

A 44-year-old woman (patient 11) underwent laparoscopic cholecystectomy followed by laparotomy because the specimen appeared to include the common bile duct. The surgeon identified the injury and placed drains into the area and transferred the patient the next day. The surgeon did not describe bleeding during the procedure, did not mention hepatic artery injury, and an operative cholangiogram or videotape of the operation was not performed. The patient underwent an endoscopic retrograde cholangiopancreatography that demonstrated discontinuity of the common bile duct. The next day the patient underwent an operation during which the bile duct was found resected to the bifurcation as was a segment of the right hepatic artery that apparently had crossed over the proximal common bile duct (Figure 1). Metallic clips were found on the proximal end of the bile duct and on both ends of the hepatic artery. No attempts were made to further evaluate the arterial injury. Both ends of the vessel were secured and bilateral hepaticojejunostomies were performed.

In the postoperative period, the patient had sepsis associated with multiple hepatic abscesses in the right lobe of the liver (Figure 2). The patient had a severe iodinated contrast allergy that restricted diagnostic studies. The patient underwent a technetium Tc 99m sulfur colloid liver scan that demonstrated the perfusion defect seen in Figure 2. Two separate percutaneous drains and a posterior rib resection and open drainage were required to eradicate the patient’s hepatic abscesses. During the subsequent 2 years, the patient had marked atrophy of the right lobe and hypertrophy of the left lobe of the liver (Figure 2).

The patient has no identifiable drainage from the right ductal system and a patent left ductal system when evaluated by biliary scintigraphy. The patient’s serum bilirubin level is normal; however, her alkaline phosphatase and other liver enzyme levels remain elevated.

CASE 2

A 40-year-old woman (patient 9) underwent a laparoscopic cholecystectomy associated with an operative cholangiogram that demonstrated no proximal flow of contrast material. Exploratory surgery was performed and the patient was reported to have had several metallic clips on
the common bile duct. The clips were removed and a T tube was inserted. The T tube was left in place for 3 weeks during which the patient was doing satisfactorily as an outpatient. The T tube was removed followed by the progressive development of jaundice. The patient underwent endoscopic retrograde cholangiopancreatography 3 weeks following removal of the T tube that showed a bile duct obstruction. The patient was referred for bile duct reconstruction. At the time of exploratory surgery, the patient was found to have bile duct stricture compatible with a Bismuth type 2 injury. She also had metallic clips occluding the right hepatic artery (Figure 1). There was no flow in the distal right hepatic artery and the artery was thrombosed when opened. The patient underwent a hepaticojejunostomy. The patient did well postoperatively, had no hepatic necrosis evident on a computed tomographic scan of the liver, and has had normal results on liver function studies and a patent anastomosis with good drainage from both right and left ductal systems, as evaluated by biliary scintigraphy.

**CASE 3**

A 48-year-old woman (patient 7) underwent laparoscopic cholecystectomy associated with intraoperative bleeding requiring a laparotomy to control the hemorrhage. A cholangiogram was not performed and bile duct or hepatic artery injury were not described in the operative note. With serum bilirubin levels progressively increasing, the patient was transferred to our institution 4 days later. Endoscopic retrograde cholangiopancreatography findings showed an obstruction of the common bile duct. The next day the patient underwent bilateral hepaticojejunostomies to treat a Bismuth type 4 bile duct injury. At the time of reconstruction, the patient was found to have the hepatic artery resected up to the level of the bifurcation of the right and left hepatic arteries. The ends of the arteries were occluded with metallic clips. There was no discernible flow in the distal hepatic artery system as seen by Doppler ultrasonographic evaluation, and the right and left hepatic arteries were believed to be thrombosed. The patient postoperatively had abscesses in the right and left lobes of the liver that were treated with transcutaneous drainage and antibiotics (Figure 3). One year following this operation the patient’s serum bilirubin and liver enzyme levels increased. Right and left transhepatic cholangiograms revealed several areas of intrahepatic bile duct strictures and a long stricture of the left hepatic duct to the anastomosis with the jejunum. The left-sided primary strictures were dilated and a transhepatic stent was left through the left hepaticojejunostomy for 1 month. The right-sided bile duct strictures (Figure 3) have not been treated. A celiac arteriogram was performed to evaluate the patient’s condition for potential hepatic transplantation. As seen in Figure 3, there is evident development of collateral blood flow to the right and left hepatic arteries. Six months following management of bile duct strictures the patient has a normal serum bilirubin level with elevated liver enzyme levels, with alkaline phosphatase levels higher than 1000 U/L, and with intermittent episodes of cholangitis.

**CASE 4**

A 54-year-old man (patient 13) was seen at another hospital with acute onset of severe chest pain, abdominal pain, and lower extremity weakness. Chest x-ray films showed a thoracic aneurysm and the patient was transferred to our institution. An aortogram showed a dissecting thoracic aneurysm (type 3) with distal flow to only his right kidney. He underwent a femorofemoral cardiopulmonary bypass and the placement of a 34-mm interposition tube graft to reconstruct his descending aorta and produce reentry (performed by the cardiothoracic surgery service). Because of
his abdominal pain, surgical exploration of his abdomen was performed following the closure of the thoracic incision. He was found to have patchy gangrene of his stomach and a gangrenous gallbladder. He underwent cholecystectomy and was returned to the operating room 24 hours later. At that time, the patient's stomach, spleen, pancreas, duodenum, and distal bile duct were gangrenous. He had patchy necrosis of the right lobe of the liver; however, the remainder of the abdominal viscera were viable. He had satisfactory renal function with palpable pulses in both renal arteries. He underwent a splenectomy, total gastrectomy, total pancreatectomy, and resection of his distal common bile duct to 1 cm below the bifurcation. He had a right hepatic artery originating from his superior mesenteric artery that was a 2- to 3-cm thrombotic mass throughout its length. The artery was opened and contained only extraintimal thrombus with no clot in the lumen. Throm-
bectomies at risk with bile duct reconstruction without hepatic artery injury compared with anastomotic failure of 3 of 6 of the anastomoses at risk in the presence of both hepatic artery and bile duct injury. Liver function study results are presently normal in the 9 patients with isolated bile duct injuries. Three of 4 patients with combined hepatic artery and bile duct injury have abnormal liver function study results manifested primarily by alkaline phosphatase levels ranging from 333 to 1427 U/L and normal serum bilirubin levels.

The clinical course of the patients with combined hepatic arterial and bile duct injuries was associated with several differences when compared with the course of patients with isolated bile duct injuries. These differences are primarily hepatic necrosis and anastomotic or bile duct strictures. Many questions remain concerning the most appropriate management of such problems.

Hepatic artery thrombosis following liver transplantation is continuously being watched for and, if identified early, can be managed with thrombolytic therapy or operative revision with the potential of salvaging the transplanted liver. Although defined ischemia time is not uniformly agreed on which is associated with possible revascularization, the general time limit in these patients associated with successful revascularization seems to be measured in days. When patients have immediate identification of an isolated right hepatic artery injury during the performance of a cholecystectomy, the results of ligation have been satisfactory and recommendations are generally not to attempt to reconstruct the injured artery. Based on our experience, if a patient has immediate recognition of a combined hepatic artery and proximal bile duct injury, reconstruction of both the patient’s arterial and bile duct injuries may prevent hepatic necrosis, choledochojugal anastomotic leakage and late anastomotic and bile duct stricture. The technique of hepatic artery recon-

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**RESULTS**

The demographic and clinical characteristics of the patients are outlined in the Table. Most bile duct injuries occurred during laparoscopic cholecystectomy. Patients also experienced bile duct injuries during open cholecystectomy and 1 patient had necrosis of the distal bile duct associated with a dissecting thoracic aneurysm. The only anastomotic leak occurred in patient 13 (case 4) who had concomitant bile duct and hepatic artery injury. Three of the 4 patients with combined bile duct and hepatic artery injury had evident hepatic necrosis, abscess formation in the area of liver devoid of arterial blood supply, or both. The fourth patient who had the combined vascular and bile duct injury did not have any diagnostic studies to identify areas of hepatic necrosis in the immediate postinjury period. A computed tomographic scan or ultrasonographic scan of the liver was performed in 5 of 9 patients with isolated bile duct injuries in the immediate postinjury period; none of the patients with bile duct injuries without hepatic artery injury had evidence of hepatic necrosis.

Anastomotic patency was evaluated primarily by biliary nucleotide scintigraphy and, where indicated, by transhepatic cholangiography. A total of 18 anastomoses were at risk. There has been no anastomotic failure in the 13 anastomoses at risk with bile duct reconstruction without hepatic artery injury compared with anastomotic failure of 3 of 6 of the anastomoses at risk in the presence of both hepatic artery and bile duct injury. Liver function study results are presently normal in the 9 patients with isolated bile duct injuries. Three of 4 patients with combined hepatic artery and bile duct injury have abnormal liver function study results manifested primarily by alkaline phosphatase levels ranging from 333 to 1427 U/L and normal serum bilirubin levels.

**COMMENT**

The clinical course of the patients with combined hepatic arterial and bile duct injuries was associated with several differences when compared with the course of patients with isolated bile duct injuries. These differences are primarily hepatic necrosis and anastomotic or bile duct strictures. Many questions remain concerning the most appropriate management of such problems.

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**Comparison of the Results of Reconstruction of Major Bile Duct Injuries With and Without Associated Hepatic Artery Injuries**

<table>
<thead>
<tr>
<th>Patient No./ Sex/Age, y</th>
<th>Interval Between Injury and Reconstruction</th>
<th>Bismuth Type Injury</th>
<th>Hepatic Artery Injury</th>
<th>Mechanism of Injury</th>
<th>Hepatic Necrosis/ Abscess</th>
<th>Length of Follow-up, mo</th>
<th>Current Status of Bile Duct Reconstruction</th>
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<td>+</td>
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<td>+</td>
<td>4</td>
<td>Patent</td>
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*Minus sign indicates absent; plus sign, present. Patient 13 was the only one to have an anastomotic leak.†Major bile duct injury was categorized by using Bismuth’s classification.‡LC indicates laparoscopic cholecystectomy; OC, open cholecystectomy; MC, minicholecystectomy; and AD, aortic dissection.
struction would depend on the nature of the hepatic artery injury. Should hepatic artery injuries associated with major bile duct injuries be revascularized when identified later? Should the hepatic artery injuries described in this report have been revascularized when encountered? It seems unlikely that revascularization would prevent hepatic necrosis. The possible benefits associated with revascularization would seem to be related to the long-term potential problems of bile duct and anastomotic strictures. It is possible that anastomoses using ischemic bile ducts are destined to long-term failure. Also, the collateralization that develops will potentially make reoperation more difficult (Figure 3). Contrariwise, the placement of an arterial anastomosis under a bile duct–jejunal anastomosis could result in false aneurysm formation and hemorrhage if the bile duct–jejunal anastomosis leaks. Similarly, some patients will do well in the presence of an occluded right hepatic artery (patient 7).

As 30% of right hepatic arteries cross anterior to the common duct it would seem appropriate to evaluate the integrity of the hepatic artery whenever a proximal bile duct injury is being reconstructed. This is readily done by operative dissection and by use of intraoperative ultrasonographic Doppler evaluation. If a patient is going to undergo a bile duct reconstruction, preoperative arteriography would seem to have a limited role in providing information as the arterial anatomy distal to the injury is unlikely to be seen. If a patient is suspected of having an arterial injury and there is planned delay in reconstruction of the bile duct, the arterial injury could be confirmed arteriographically.

Hepatic necrosis and subsequent hepatic abscesses were a notable problem in 3 of 4 patients with hepatic arterial and bile duct injuries. It is well recognized that most of the blood supply to the hepatic parenchyma is supplied by the portal vein. Hepatic artery ligation in managing traumatic liver injuries and hepatic malignant neoplasm has been described and relegated to being safe to perform if liver function is otherwise normal as extensive collateral arterial blood flow develops in addition to portal blood flow. The patients described in this article had intact portal veins as evaluated intraoperatively and intact hepatic ligaments, yet developed hepatic necrosis in the presence of a hepatic artery injury. Patients undergoing liver transplantation have a high probability of developing focal areas of hepatic necrosis and abscess formation in the presence of hepatic artery thrombosis. In such patients, the liver experienced an ischemic event associated with harvest and storage and the process may not be comparable to the situation described here. Hepatic abscess has occurred following elective hepatic artery ligation for tumor; however, it may be primarily related to tumor necrosis. In our article, 75% of the patients with bile duct injuries and hepatic artery injuries had hepatic necrosis.

Patient 13 in this series had a clinically evident bile duct leak. While bile duct anastomotic leaks have a high probability of closing spontaneously, it was unclear whether such an anastomotic leak would close in the presence of a hepatic artery injury. This anastomotic leak healed in a short time. An anastomotic leak proved fatal in a patient described by Brittain et al, who had a combined hepatic artery and bile duct injury. Majno et al have described a series of patients undergoing complex pancreatic resections who sustained hepatic artery injuries and bile duct–jejunal anastomoses that leaked and they have recommended that the anastomosis be revised involving more proximal bile duct.

It is evident that bile duct reconstructions can fail following long periods of patency. The patients in our series have been followed up for a short period and it is possible that these patients with or without associated hepatic arterial injuries may eventually have anastomotic strictures. Based on the available information, short- and long-term patency of bile duct reconstructions in the presence of hepatic arterial injuries will be notably less than reconstructions of bile duct injuries with an intact arterial blood supply.

References