COLLECTIVE REVIEW

AN ANALYSIS OF THE PROBLEM OF BILIARY INJURY DURING LAPAROSCOPIC CHOLECYSTECTOMY

Steven M. Strasberg, M.D., F.R.C.S.(C), F.A.C.S., Martin Hertl, M.D., and Nathaniel J. Soper, M.D., F.A.C.S.

Laparoscopic cholecystectomy is a revolutionary change in the treatment of patients with gallstones. It rapidly replaced open cholecystectomy, the standard treatment for more than 100 years, as well as a number of newer medical therapies, such as extracorporeal shock wave lithotripsy and bile salt therapy. Laparoscopic cholecystectomy was quickly accepted because it permanently cures gallbladder stones, with a minimum of inconvenience, pain, and loss of activity for the patient. However, compared with open cholecystectomy, the incidence of injuries to the bile duct seems to be increased in laparoscopic cholecystectomy. Injuries to the bile duct are a serious problem, potentially life-threatening. They can cause major morbidity, prolonged hospitalization (1), high cost (2), and litigation (2). Much has been written about laparoscopic biliary injury recently. This study was done to synthesize available information and to introduce some new perspectives in classifying and preventing injury. We attempted to answer eight questions (Table I). For some of the questions there are answers, but for others the best that can be done at present is to emphasize needed areas of clinical research.

A COMPARISON OF THE INCIDENCE OF BILIARY INJURY IN LAPAROSCOPIC CHOLECYSTECTOMY AND OPEN CHOLECYSTECTOMY

Biliary injuries are major, such as occlusion of the common duct, or minor, such as bilomas or bile leaks resulting from injuries to smaller ducts, failure of occlusion of the cystic duct, or lateral injuries to major ducts. Often, the line separating the two types of injuries is unclear. In general, major injuries to the bile duct are more serious than minor injuries, but bile leaks are not innocuous and reoperation is sometimes required. Most studies on laparoscopic biliary injuries present both types of injuries (3-14) and we will discuss both.

There was no way to predict that bile duct injury would become the major negative outcome of laparoscopic cholecystectomy. Biliary injury during open cholecystectomy has been well recognized and surgical texts have devoted long sections to the cause, prevention, and treatment of this injury. The subject was recently reviewed (15). We have identified 16 case series of open cholecystectomy published from 1980 to 1993 that include at least 100 cases, for a total of 25,544 cholecystectomies performed (16-30, 54) (Table II). Most series quoted major bile duct injury rates of 0.50 percent or less, and several series reported no injuries to the bile duct (16, 19-24, 26, 29, 34). However, results of case series cannot be extrapolated to the general population of patients treated.

To obtain figures representative of large populations, regional or national data are required and the information should be collected on a database that assures complete collection. New York state has an information gathering system for reporting incidents contributing to patient death or impairment of body functions (50). In 1992, this Incident Reporting System detected three major injuries to the bile duct and two bile leaks requiring reoperation, for a total of
TABLE I.—PERTINENT QUESTIONS REGARDING BILE DUCT INJURY DURING LAPAROSCOPIC CHOLECYSTECTOMY

1. What is the incidence of biliary injury during laparoscopic cholecystectomy and how does it compare with open cholecystectomy?
2. What types of biliary injuries occur and how should they be classified?
3. What are the risk factors for the biliary injuries?
4. What are the direct causes of biliary injuries?
5. How may one prevent biliary injury during laparoscopic cholecystectomy?
6. How do biliary injuries present and how should they be investigated?
7. What is the correct management of biliary injuries recognized intraoperatively and postoperatively?
8. What is the long-term outcome of treatment?

Five biliary injuries in approximately 4,000 open cholecystectomies performed during a six month period, an incidence of 0.125 percent. If major bile duct injury only is considered, the incidence is 0.075 percent. The denominator in this estimate (4,000 open cholecystectomies) is a value calculated from information given by Bernard and Hartman (30). Case series of biliary injuries lack denominators. Case series of cholecystectomies do have denominators, but these may not be representative of the population. The denominator of 4,000 in the report of Bernard and Hartman (30) is so large that precision would add little to the estimate. If the denominator is allowed to fluctuate from 3,600 to 4,000, the estimate of injury ranges only from 0.113 to 0.158 percent. Inaccuracy could occur from an error of not detecting injuries, i.e., the true incidence could be higher but not lower. Therefore, 0.125 percent may be taken as a good estimate that exists for biliary injury, including clinically important bile leaks, during open cholecystectomy.

Three types of studies suggest that the incidence of biliary injury has increased since the introduction of laparoscopic cholecystectomy (Table III). The most conclusive information comes from two statewide evaluations. In one evaluation from New York (30), there were 45 injuries (32 major injuries to the bile duct and 13 bile leaks requiring operation) in approximately 8,000 laparoscopic cholecystectomies performed during a six month period in 1992, an incidence of 0.55 percent (0.40 percent for major bile duct injury). Orlando and co-workers reported on more than 4,000 cholecystectomies performed in Connecticut during a 15 month period (31). The incidence of major bile duct injury was 0.32 percent. They did not comment on bile leaks. From these two statewide series, one may estimate the injury rate to be 2.5 to 4 times higher than that with the open operation.

Institutional case series present variable rates of biliary injury ranging from zero to 2.4 percent (Table III). The case series are of three types: single institution, multi-institutional (usually involving 25 or fewer hospitals); and surveys encompassing hundreds or thousands of surgeons or hospitals (32, 51). We have differentiated "statewide database studies" from "surveys" because, in the former, reporting of negative events is obligatory, while in the latter, replies are vol-

TABLE II.—BILIARY INJURIES IN OPEN CHOLECYSTECTOMY IN STATEWIDE DATABASE REPORTS AND INSTITUTIONAL SERIES SINCE 1980

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Statewide database study</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bernard (30)</td>
<td>4,000</td>
<td>3</td>
<td>0.075</td>
<td>2</td>
<td>0.50</td>
<td>5</td>
<td>0.15</td>
</tr>
<tr>
<td>Single institution studies</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corlette (16)</td>
<td>100</td>
<td>0</td>
<td>0.00</td>
<td>0</td>
<td>0.00</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td>Hoffmann (19)</td>
<td>430</td>
<td>0</td>
<td>0.00</td>
<td>0</td>
<td>0.00</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td>Van der Linden (20)</td>
<td>184</td>
<td>0</td>
<td>0.00</td>
<td>0</td>
<td>0.00</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td>Trowbridge (29)</td>
<td>100</td>
<td>0</td>
<td>0.00</td>
<td>0</td>
<td>0.00</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td>Smith (54)</td>
<td>124</td>
<td>0</td>
<td>0.00</td>
<td>0</td>
<td>0.00</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td>Konsten (26)</td>
<td>925</td>
<td>0</td>
<td>0.00</td>
<td>0</td>
<td>0.00</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td>Harris (23)</td>
<td>100</td>
<td>0</td>
<td>0.00</td>
<td>1</td>
<td>1.00</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td>Riggs (17)</td>
<td>941</td>
<td>1</td>
<td>0.11</td>
<td>0</td>
<td>0.00</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td>Mogenstern (25)</td>
<td>1,200</td>
<td>2</td>
<td>0.17</td>
<td>9</td>
<td>0.75</td>
<td>11</td>
<td>0.92</td>
</tr>
<tr>
<td>Girard (27)</td>
<td>10,501</td>
<td>90</td>
<td>0.29</td>
<td>80</td>
<td>0.76</td>
<td>110</td>
<td>1.05</td>
</tr>
<tr>
<td>Coelho (28)</td>
<td>705</td>
<td>5</td>
<td>0.71</td>
<td>6</td>
<td>0.85</td>
<td>11</td>
<td>1.56</td>
</tr>
<tr>
<td>Smith (18)</td>
<td>4,425</td>
<td>40</td>
<td>0.90</td>
<td>0</td>
<td>0.00</td>
<td>40</td>
<td>0.90</td>
</tr>
<tr>
<td>Multi-institutional studies</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ganev (22)</td>
<td>1,035</td>
<td>0</td>
<td>0.00</td>
<td>1</td>
<td>0.10</td>
<td>1</td>
<td>0.10</td>
</tr>
<tr>
<td>Clavien (24)</td>
<td>1,252</td>
<td>0</td>
<td>0.00</td>
<td>4</td>
<td>0.32</td>
<td>4</td>
<td>0.92</td>
</tr>
<tr>
<td>Farha (21)</td>
<td>122</td>
<td>0</td>
<td>0.00</td>
<td>3</td>
<td>2.46</td>
<td>5</td>
<td>2.46</td>
</tr>
<tr>
<td>Total</td>
<td>25,544</td>
<td>81</td>
<td>0.32</td>
<td>106</td>
<td>0.41</td>
<td>187</td>
<td>0.70</td>
</tr>
</tbody>
</table>

Numbers in parentheses are percentages.
No., Number; and pts., patients.
TABLE II.—LAPAROSCOPIC BILIARY INJURIES IN STATEWIDE DATABASE REPORTS, INSTITUTIONAL SERIES, AND SURVEYS

<table>
<thead>
<tr>
<th>Reference</th>
<th>No. of pts.</th>
<th>Major bile duct injury</th>
<th>Bile leak, biloma</th>
<th>Total biliary injuries</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>Percent</td>
<td>No.</td>
<td>Percent</td>
</tr>
<tr>
<td>Statewide database study</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bernard (20)</td>
<td>8,500</td>
<td>82</td>
<td>0.40</td>
<td>13</td>
</tr>
<tr>
<td>Orlando III (31)</td>
<td>4,640</td>
<td>15</td>
<td>0.32</td>
<td></td>
</tr>
<tr>
<td>Single institution studies</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Voiles (35)</td>
<td>500</td>
<td>0</td>
<td>0.00</td>
<td>1</td>
</tr>
<tr>
<td>Spaet (36)</td>
<td>500</td>
<td>0</td>
<td>0.00</td>
<td>1</td>
</tr>
<tr>
<td>Baird (37)</td>
<td>800</td>
<td>0</td>
<td>0.00</td>
<td>3</td>
</tr>
<tr>
<td>Brooks (8)</td>
<td>650</td>
<td>0</td>
<td>0.38</td>
<td>9</td>
</tr>
<tr>
<td>Soper (38)</td>
<td>618</td>
<td>1</td>
<td>0.16</td>
<td>1</td>
</tr>
<tr>
<td>Williams (59)</td>
<td>1,107</td>
<td>5</td>
<td>0.27</td>
<td>0</td>
</tr>
<tr>
<td>Frazee (40)</td>
<td>706</td>
<td>2</td>
<td>0.28</td>
<td>1</td>
</tr>
<tr>
<td>Periand (41)</td>
<td>704</td>
<td>3</td>
<td>0.43</td>
<td>6</td>
</tr>
<tr>
<td>Feusner (42)</td>
<td>500</td>
<td>4</td>
<td>0.80</td>
<td>13</td>
</tr>
<tr>
<td>Multi-institutional studies</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lane (43)</td>
<td>641</td>
<td>0</td>
<td>0.00</td>
<td>4</td>
</tr>
<tr>
<td>Larson (44)</td>
<td>1,628</td>
<td>5</td>
<td>0.28</td>
<td>3</td>
</tr>
<tr>
<td>Barkun (45)</td>
<td>1,300</td>
<td>0</td>
<td>0.00</td>
<td>2</td>
</tr>
<tr>
<td>Meyers (46)</td>
<td>1,518</td>
<td>7</td>
<td>0.46</td>
<td>5</td>
</tr>
<tr>
<td>Kozarek (9)</td>
<td>597</td>
<td>14</td>
<td>2.35</td>
<td></td>
</tr>
<tr>
<td>Surveys</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Litwin (47)</td>
<td>2,401</td>
<td>6</td>
<td>0.27</td>
<td>20</td>
</tr>
<tr>
<td>Devereux (48)</td>
<td>9,597</td>
<td>27</td>
<td>0.29</td>
<td>69</td>
</tr>
<tr>
<td>Cashner (49)</td>
<td>1,286</td>
<td>4</td>
<td>0.32</td>
<td>2</td>
</tr>
<tr>
<td>Collet (50)</td>
<td>2,955</td>
<td>11</td>
<td>0.37</td>
<td>16</td>
</tr>
<tr>
<td>Deciel (51)</td>
<td>77,604</td>
<td>459</td>
<td>0.59</td>
<td>198</td>
</tr>
<tr>
<td>Go (52)</td>
<td>6,076</td>
<td>52</td>
<td>0.86</td>
<td>49</td>
</tr>
<tr>
<td>Total</td>
<td>124,433</td>
<td>650</td>
<td>0.52</td>
<td>415</td>
</tr>
</tbody>
</table>

Numbers in parentheses are percentages.

No. Number, and pts., patients.

untary. Single institutional series often report a low incidence of biliary injury, sometimes as low as no major injuries to the bile duct in 800 laparoscopic cholecystectomies (37). While the results are commendable, they are not representative.

The first multi-institutional series in the literature reported seven major injuries to the bile duct and three bile leaks in 1,518 patients, an incidence of 0.5 percent for major duct injury and 0.7 percent overall (46). This study is notable for taking special steps to ensure that data were gathered from every case during the study period. Such procedures are essential. An injury rate of 0.7 percent represents injury to only ten of 1,518 patients. The numerator is extremely important and omission of only a few patients causes a large change in results. There is probably a strong tendency to underreport injuries. Since the numerator is so critical to the data, one must cautiously interpret reports or surveys that do not use specific safeguards to collect all negative events. One multi-institutional report originating from three centers suggested that the peak of the problem has lapsed (52). This conclusion is based on the number of patients referred to these particular centers over several years. While encouraging, the result might be explained by other factors, such as increased reliance on local treatment.

Several large mail surveys have been done. These are also subject to the criticism of undetected negative events. Of particular concern to those commenting on this problem (53), are surveys in which a substantial percent of surgeons fail to respond (54). In an Australian survey, the major bile duct injury rate was 0.2 percent (12 of 5,927) (54), while in a Dutch survey (52), the biliary injury rate was 1.3 percent (81 of 6,076), of which major duct injury was 0.55 percent (32 of 6,076 patients). In the latter report, the questionnaire compliance rate was 100 percent, while in the former, 26 percent of questionnaires were not returned (53, 54). In a recent survey of French surgeons, the major duct injury rate was 0.30 percent (11 of 3,679) and the overall rate 1.1 percent (42 of 3,679), but no information was given regarding compliance with the survey (50). In another survey consisting of more than 75,000 cases, the overall incidence of major bile duct and minor injuries was 0.6 percent (51). A second Dutch survey compared recent injury rates in open and laparoscopic cholecystectomy. In 1991, only 25 percent of cholecystectomies were being done laparoscopically (53). The response rate in the survey was 88 percent. The
major and total (including bilomas) injury rates for laparoscopic cholecystectomy were 0.51 percent (15 of 2,932 patients) and 1.3 percent (32 of 2,392), respectively. The corresponding values in the open procedure were 0.20 percent (18 of 8,790) and 0.51 percent (45 of 8,790).

The third and final evidence supporting an increased incidence of biliary injury is the accumulating case series of laparoscopic biliary injuries in the surgical (2, 6, 8, 11-13, 52, 55-60), medical (9, 61, 62), and radiologic (4, 5, 7, 14, 63) literature. As in other referral centers specializing in hepatobiliary surgery, we have noted an increase in referrals for biliary injuries, which now exceed 35 cases in the laparoscopic era.

Another way of gauging the incidence of injury was used in a Canadian surgeon-based (rather than patient-based) survey in which 710 of 1,400 questionnaires were returned (64). In 1992, 30 percent of surgeons less than 60 years of age had learned laparoscopic cholecystectomy and 76 percent had begun doing the procedure. Of these individuals, almost 10 percent had experienced a biliary injury with laparoscopic cholecystectomy and 25 percent had experienced a bile leak.

How many injuries to the bile duct are occurring yearly in this country if the incidence in laparoscopic cholecystectomy is 0.3 to 0.4 percent? About 500,000 cholecystectomies were performed in the United States of America (U.S.A.) in 1990, but the number of cholecystectomies performed seems to be increasing since laparoscopic cholecystectomy was introduced (30, 65). In 1992, 67 percent of procedures were performed laparoscopically in New York state, while in a large Pennsylvania-based health maintenance organization more than 83 percent of cholecystectomies were laparoscopic, an increase from zero percent in 1988 and 25 percent in 1990 (65). From these figures, and the estimate of injury rates in New York and Connecticut, one may conservatively estimate that 1,500 to 2,500 laparoscopic biliary injuries are now occurring annually in the U.S.A.

It may also be instructive to relate biliary injury to a temporal scale of surgical practice. How often will an injury occur in a surgical practice at the increased (and unacceptable) rate of 0.4 percent (four of 1,000 operations) seen in laparoscopic cholecystectomy? There are approximately 39,000 general surgeons in this country, including vascular and pediatric surgeons (66). An exact tally of the number of surgeons performing cholecystectomies is not available, but 600,000 cholecystectomies could be performed by only 12,000 surgeons doing 50 operations per year. This must mean that on average, general surgeons are performing fewer than 50 cholecystectomies per year. Nevertheless, even if one assumes a mean annual rate of 50 cholecystectomies and a major duct injury rate of four of 1,000 (0.4 percent), then surgeons on average would injure a major bile duct only once every five years. Note that although the national incidence of bile duct injury is presently unacceptably high, injury is very infrequent in each individual surgeon's practice. This demonstrates well the vigilance required in every case over prolonged periods of surgical practice, to reduce the injury rate to acceptable levels.

**WHAT TYPES OF BILIARY INJURIES OCCUR AND HOW SHOULD THEY BE CLASSIFIED?**

There is overlap in cause, presentation, diagnosis and management of postoperative bile leaks and major injuries to the bile duct. As a result, most reports include both bile leaks and major ductal injuries (5-5, 7, 9-14, 52, 67). Unfortunately, there is no accepted classification that includes bilomas and bile leaks in the spectrum of biliary injuries. Even within the biloma category, there are different grades of injury. For instance, the seriousness of a lateral injury to the common bile duct and a leak from the gallbladder bed are quite different, but both produce bilomas. Neither is included in the Bismuth classification of major injuries to the bile duct (68). Isolated occlusion of the right bile duct is also not found in the present classification. We believe a classification that includes both types of injuries is needed, and therefore, we propose one herein (Fig. 1). In this terminology, proximal and distal refer respectively to points higher (closer to the liver) and lower (closer to the ampulla of Vater) in the biliary tree.

*Type A injury: bile leak from a minor duct still in continuity with the common bile duct.* For practical purposes, these leaks occur at the cystic duct or from the liver bed. The two injuries are combined because their presentation and management are almost identical. They may be thought of as lateral injuries to the biliary tract in which biliary communication between hepatic parenchyma and the major bile ducts and duodenum remains intact (Fig. 1).

Cystic duct leaks usually occur as a result of failure of clip occlusion. Sometimes they occur in association with retained common bile duct
stones (8), which raise intrabiliary pressure and increase the rate of leakage. Bile leaks from the liver bed are usually caused by dissection in too deep a plane, resulting in injury to a normal small peripheral right hepatic duct (Fig. 2). Less commonly, injury occurs to an accessory bile duct i.e., a duct communicating both with the gallbladder and the main intrahepatic bile ducts, such as a Luschka’s duct, or another accessory duct running between the cystic duct and an intrahepatic bile duct. Accessory ducts provide a second route of bile drainage from a part of the liver, as opposed to aberrant ducts, which are the only route of drainage, but lie in an unusual position. Ligating an accessory duct does not deprive any part of the liver of bile drainage as does ligation of an aberrant duct. The common feature of these injuries is that the problem can usually be resolved by decompression of the biliary tree by endoscopic sphincterotomy and stenting or stenting alone. This reduces intrabiliary pressure and results in drainage of bile into the duodenum rather than from the site of injury.

Type B injury: occlusion of part of biliary tree. This injury is almost always the result of an injury to an aberrant right hepatic duct (Fig. 1). In about 2 percent of patients, the cystic duct enters a right hepatic duct rather than the common bile duct-common hepatic duct junction (69, 70). The right duct then joins the main ductal system. Such an aberrant duct has a similar appearance to a cystic duct at the point where it joins the main duct and is in danger of being mistaken for the cystic duct and divided. The aberrant duct may be a segmental duct, a sectoral duct (the right anterior or posterior duct), or even the main right duct. When one of these ducts is occluded, we have designated the injury type B (Fig. 3). When it is transected without occlusion, it is termed type C. The reason for the difference in classification is that presentation and management are usually quite different. Type B injuries are often asymptomatic or the patients present later with pain or cholangitis in the occluded segment. The liver behind a type B injury normally atrophies and the remaining liver undergoes compensatory hyperplasia. Type C injuries result in intraperitoneal bile collections.

Type C injury: bile leak from duct not in communication with common bile duct. As noted, this injury is almost always the result of transection of an aberrant right hepatic duct with drainage of bile into the peritoneal cavity. Both types B and C injuries, as opposed to type A injuries, result in disconnection of a part of the hepatic parenchyma from the main biliary tree. Type C injuries are usually diagnosed in the early postoperative period (Fig. 4).

Type D injury: lateral injury to extrahepatic bile ducts. Like type A injuries, all hepatic parenchyma remains in communication with the distal end of the biliary tree and duodenum (Fig. 1). The separate classification is justified because the con-
duct are very similar, but there are major therapeutic implications to complete transection (type C) versus lateral injury (type D). Type D injuries may involve the common bile duct, common hepatic duct, or the right or left bile duct; they could be subclassified on this basis. We have not found a report of an isolated left ductal injury of this type, but injuries to the right bile duct have been reported (7, 13).

There is a question as to whether or not an opening made in the common bile duct while performing operative cholangiography should be considered an injury. If so, it would be a type D injury. The circumstance of this event is that the surgeon is unsure whether or not the structure being dissected is the cystic duct. A cholangiogram is done, realizing that the duct may be the common bile duct or common hepatic duct. Upon seeing on the cholangiogram that the common duct has been cannulated, the operation is converted and completed by putting a T-tube in the duct. Does this constitute a ductal injury?

There is a long history of cannulating the bile duct during biliary and other operations of the upper intestinal tract in order to protect the duct. This step is completed by suturing the duct or inserting a T-tube and one would not consider that a biliary injury had occurred. If the duct is injured while performing the cholangiogram and requires repair other than insertion of a T-tube, this would be considered a ductal injury. Since opening the duct to protect it has not previously been considered a ductal injury, we believe it should not be considered so in the context of laparoscopic cholecystectomy. The criteria for injury would be whether any signs of ductal injury occur after simple closure over a T-tube or whether techniques other than simple closure over a T-tube had to be used. For instance, in some cases in which the common bile duct is cannulated, it may have been dissected circumferentially, and thereby devascularized, resulting in later development of stricture. This would certainly be considered to be a biliary injury. In our recent report, balloon dilation was needed postoperatively after a cholangiogram had been done and the event was reported as an injury (10).

Type E injury: circumferential injury of major bile ducts (Bismuth class 1 to 5). These injuries involve circumferential injury of one or more main bile ducts as described by Bismuth and illustrated in Figure 1. Subclassification in the first four Bis-

Fig. 2. A postoperative endoscopic retrograde cholangiopancreatogram in a patient who had a biloma. Note that the injury is to a small tributary of the right hepatic duct. The arrow points to the beginning of the contrast leak from the small duct.

Fig. 3. A postoperative endoscopic retrograde cholangiopancreatogram demonstrating a type B injury. Note absence of right posterior sectoral ducts (segments 6 and 7).

sequences of type D injuries are potentially greater than type A injuries. Type D injuries often require laparotomy for repair and may later result in stenosis of the bile duct. However, a type D injury is usually less serious than other biliary injuries to the main bile ducts (type E). Type C and type D injuries involving the right bile

muth while duct injury beca
patic "seps"
for o
be b
of ce
or al
This
ne
mu
i
site
be tr
ow
i
muth classes relates to the upper level of injury, while class 5 is a combined common hepatic duct and aberrant right duct injury. Type E injury is not the same as a type B or C injury because, in these latter lesions, the common hepatic duct is not injured. Type E injuries cause "separation" of hepatic parenchyma from the lower ducts and duodenum. The separation may be because of a stenosis in the duct, because of complete occlusion of the duct, or because of loss of ductal tissue as a result of resection or ablation with cautery. The Bismuth classification does not stipulate the length of the injury. This information is useful for nonoperative treatment, such as percutaneous or endoscopic techniques, which may be used when the injury is a stenosis. Sometimes, even clip occlusion may be treated nonoperatively (14). Therefore, it may now be useful to subclassify these lesions according to whether they involve the loss of a ductal segment or are stenoses, and to state the length of stenosis.

INCIDENCE OF REPORTED BILIARY INJURIES ACCORDING TO THE PROPOSED CLASSIFICATION

We found 24 reports in the world literature specifically on the problem of laparoscopic biliary injury that provide details of four or more biliary injuries, for a total of approximately 300 injuries (1-14, 52, 55-57, 59-63, 67). The exact number in these reports is unclear because several institutions have more than one publication. Thus, all of our knowledge of the type of injury, risk factors for injury, mode of presentation, management, and outcome is based on a tiny sample (300 injuries) of the actual event (an estimated 1,500 to 4,000 biliary injuries per year in this country alone). Biliary injuries are also noted in reports on complications of laparoscopic cholecystectomy and in case series of laparoscopic chol-
cystectomy. These divide injuries into bile leaks or major ductal injury as previously noted, but rarely indicate details of the injuries. Even within the group of reports that examine specifically injury to the bile duct, there is considerable variability in the completeness of the data, and the type of data presented depends on whether the reports originate primarily from surgical, radiologic, or medical services. Most reports come from tertiary care centers and cases are therefore selected on the basis of need for referral to an hepatobiliary unit. The individual reports usually contain fewer than 20 patients. Therefore, although there are now many reports on this subject, the total sample is a small proportion of the event and may not be representative of the injured population. Clearly, one must be cautious in interpreting available results. The foregoing does not negate the importance of these publications. They have alerted the medical community to the seriousness of the problem and therefore have been important and influential.

The type of injury described depends on the nature of the report. Type E injuries predominate in surgical series and type A injuries are more prominent in the radiologic and endoscopic literature. Almost all reports giving details of injury are from referral centers, and as indicated previously, are concerned with the more severe levels of injury. Of 270 patients who could be classified from these series (1–3, 6–14, 56, 59, 60, 62, 63, 67), 62 had type A injuries, one had a type B injury, eight had type C injuries, 24 had type D injuries, and 175 had type E injuries. About 85 percent of type A injuries were cystic duct leaks. The 97 type E injuries that could be subclassified (2, 10–14, 55, 56, 59, 62, 67) were fairly evenly distributed among the first four Bismuth types (22, 27, 21, 26 for type E1 to E4, respectively). There were two type E5 injuries (13). The most that one can say on this subject from the literature is that the main injuries being seen at tertiary centers are cystic duct leaks and high major ductal injuries.

The most common injury may be the type A injury, because, in broader surveys, it seems to account for 33 to 65 percent of biliary injuries (30, 32, 50). Type D injuries are probably also more common than indicated from tertiary care center data. In a recent survey from France of 3,000 laparoscopic cholecystectomies, "lateral injuries" to the duct accounted for 77 percent (seven of 11 injuries) of injuries to the main bile duct (50). Most of the type A and D injuries are apparently treated in the local setting and are thus underrepresented in the tertiary center data. It is not surprising that few type B injuries were reported because, as previously noted, these characteristically present late or are asymptomatic (71).

**WHAT ARE THE RISK FACTORS FOR BILIARY INJURY?**

*Training and experience.* An early case series of 1,518 laparoscopic cholecystectomies (46) suggested that the high rate of injury (0.5 percent) was mainly the result of the "learning curve" effect (46, 55). Most injuries occurred within the first 13 procedures performed by a surgeon. If data from the learning period were excluded, the incidence of major bile duct injury was 0.1 percent. The injury rate for this group of surgeons decreased to 0.2 percent (major duct injuries only) by the time 9,000 procedures had been done (72). A similar learning curve effect was reported by Kozarek and co-workers (9). Furthermore, as previously noted, there has been a decreased incidence of these problems at some referral centers (52). It is too early to determine whether or not the biliary injury rate will subside to acceptable levels once the learning period has passed because, even in 1992, many surgeons had not done 25 laparoscopic cholecystectomies. However, there are reasons to doubt that the learning curve is the whole explanation. In a later report from the Duke University group, many injuries occurred during operations by surgeons who had done more than 25 laparoscopic cholecystectomies (5). Similarly, the mean number of laparoscopic cholecystectomies performed by surgeons was 75 in a recent report of 18 injuries by Adams and co-workers (6). In one Canadian series (64), there was a direct relationship between the chance of having had a major bile duct injury and number of procedures performed; the rate reached 20 percent when more than 50 laparoscopic cholecystectomies had been performed. It is possible that early reports on the "learning curve" effect, and accompanying editorial comment (73–75), resulted in a change in the pattern of injury. It is also possible that differences among series and current referral rates indicate selection biases, as discussed previously. To determine if experience is the main risk factor, we require more regional data obtained during a period in which the surgical community is in the same steady state in respect to learning that existed during the open cholecystectomy era. Until that time, it seems wise to...
assume that the problem still exists and to take all measures to discover how to eradicate the problem.

Local operative risk factors. In open cholecystectomies, biliary injuries are more likely to occur when the procedure is difficult, although, of course, injury may occur during the "easy" cholecystectomy because of lack of care. Laparoscopic biliary injuries are also associated with difficult procedures. Six operative series reporting 70 biliary injuries comment on one or more factors (2, 10, 11, 13, 55, 56). Chronic inflammation with dense scarring, operative bleeding obscuring the field, or fat in the portal area, are mentioned in a number of reports as possible contributing factors (2, 6, 7, 10, 11, 13, 55, 56, 60). They seem to be present in 15 to 35 percent of injuries, but since there are no comparable estimates in cases without biliary injuries, conclusions based on statistical comparisons are not available. Exact numbers may be less important than the repeated association of these factors with biliary injury in the laparoscopic cholecystectomy literature and prior information on these risk factors in open cholecystectomy. The association of bile duct injury during operation for acute cholecystitis is mentioned in several series (2, 10, 11, 13, 60). Acute cholecystitis was the indication for operation in about 20 percent of cases in which injury occurred. However, as it seems that about 15 percent of patients are having laparoscopic cholecystectomy for this indication (31), no conclusion as to the effect of acute inflammation on injury rate is possible. Several authors have commented that oozing of blood hampers dissection much more in laparoscopic than in open cholecystectomy and have emphasized the need for gentle dissection in the face of inflammation to avoid bleeding that then obscures vision (2, 57, 76, 77). The role of obesity is difficult to evaluate (2, 13, 56) because it is so often present in patients with cholelithiasis.

Aberrant anatomy. Aberrant anatomy is a common and well-recognized danger in biliary operations (69, 71, 78–80). The biliary anomaly most likely to be involved in ductal injury is the right ductal anomaly, referred to previously in type B and type C injuries. Aberrant anatomy was clearly present in nine patients in three reports (1, 2, 11). In three other reports, an isolated injury to the right hepatic duct was treated (7, 13, 55) and these injuries may have been associated with anomalous position of ducts. We believe these injuries are underreported because type B injuries may be asymptomatic or not appear with symptoms until years after the injury (69, 70). No aberrant duct injuries were present in our own initial report, but during the past year, we have seen four such injuries.

Equipment. A number of early injuries occurred during laser dissection. There is no evidence that the number of injuries was disproportional to the frequency of use of laser for dissection (2, 72). Few surgeons use the laser during laparoscopic cholecystectomy today. Any thermal source can cause damage to the portal structures when used incorrectly. In our report, there was one major injury (type E5) caused by application of monopolar current to the lateral surface of the bile duct (10). We have subsequently treated a type E5 injury caused in the same way (Fig. 5).

WHAT ARE THE DIRECT CAUSES OF LAPAROSCOPIC BILIARY INJURY?

The immediate causes of biliary injury may be classified as either misidentification of an anatomic structure or technical (Table IV). Misidentification of the bile duct as the cystic duct results in type D or E injuries. Misidentification
TABLE IV.—CLASSIFICATION OF CAUSES OF LAPAROSCOPIC BILIARY INJURIES

<table>
<thead>
<tr>
<th>Common Causes of Injury in Laparoscopic Cholecystectomy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Misidentification of bile ducts as the cystic duct</td>
</tr>
<tr>
<td>Misidentification of common bile duct as cystic duct*</td>
</tr>
<tr>
<td>Misidentification of aberrant right duct as cystic duct*</td>
</tr>
<tr>
<td>Technical causes</td>
</tr>
<tr>
<td>Failure to securely occlude cystic duct*</td>
</tr>
<tr>
<td>Too deep plane of dissection on liver bed*</td>
</tr>
<tr>
<td>Injudicious use of thermal energy* to dissect, control bleeding, or divide duct</td>
</tr>
<tr>
<td>Tenting injury of cystic duct</td>
</tr>
<tr>
<td>Injudicious use of clips to control bleeding</td>
</tr>
<tr>
<td>Injuries due to improper techniques of ductal exploration</td>
</tr>
</tbody>
</table>

*Common causes of injury in laparoscopic cholecystectomy.

may also occur when there is an aberrant right duct leading to type B and C injuries. The segment of aberrant duct lying between the point that the cystic duct joins it and the point where it joins the main ductal system is mistaken to be the cystic duct.

The exact events that occur after misidentification of the common duct are variable. At least one clip is placed on the common duct, in the belief that it is being placed on the distal end of the cystic duct. The clip that the surgeon believes is being applied to the proximal end of the cystic duct may also be placed on the misidentified common duct or on the cystic duct.

In a common scenario described by Davidoff and co-workers as the "classical" injury (55), the common duct is mistaken to be the cystic duct, receives all three clips (one proximal and two distal), and is divided (Fig. 6a, point X). Then, to excise the gallbladder, the common hepatic duct must be divided (Fig. 6a, point Y), producing E1 or E2 injuries. This is often associated with injury to the right hepatic artery. The common hepatic duct may either be clipped or divided, which results in complete obstruction or bile leak. Often, the second transaction point is above the bifurcation (Fig. 6a, line Y2), which produces E3 or E4 injuries. In operative notes, this stage is often described as encountering a "second cystic duct" or "accessory duct." When reoperating upon patients with this injury, there is frequently evidence of extensive dissection on the left side of the common duct, even to the point of exposure of the portal vein (13). In another less common injury pattern, the proximal clip is placed on the cystic duct (Fig. 6b and c) and the point of division will then be either the common duct (Fig. 6b) or cystic duct (Fig. 6c). If the common duct is incised, bile will drain out of the cut end of the duct. Sometimes this results in immediate recognition of injury. However, equally often, the appearance of bile has not resulted in conversion because of the rationalization that a second cystic duct has been encountered. As a result, the full-blown injury illustrated in Figure 6b evolves. Potentially, the least harmful event is when the cystic duct is divided (Fig. 6c) because, if the injury is recognized by bile leaking into the field, the clip on the common bile duct may simply be removed. A bile leak will not occur if cystic and common duct run in a common sheath and the clip is placed across both (Fig. 6c, inset). Sometimes clip removal (55), balloon dilatation (14), or stenting (81) of the clipped duct may treat the injury successfully, even when the injury is recognized postoperatively, while in other patients, late stricture occurs after removal of the clip (13, 82).

Injuries to the aberrant right duct occur in a similar sequence; here, the misidentification is that the distal segment of the right hepatic duct, between the point where the cystic duct enters it and the point at which the right duct joins the common bile duct, is thought to be the cystic duct. At least one clip is placed across the misidentified distal segment and the other on the proximal right duct or cystic duct (Fig. 6d, e, and f). In the former case, the right duct is transected and must be transected again higher up to get the gallbladder out. A type B injury (occlusion of part or all of the right lobe) occurs when the duct is clipped at this second point (Fig. 6d) and a type C injury (bile leak) when it is cut without clipping. Again, when the proximal limb of the aberrant duct is discovered during the later part of the dissection, it is usually described as a second cystic or accessory duct. If one of the clips is placed on the cystic duct rather than the aberrant duct and the aberrant duct (Fig. 6e) or cystic duct (Fig. 6f) is cut, a bile leak will occur through the cut end of the cystic duct or aberrant duct. In the former case, depending on whether or not the injury is recognized at this point, the injury will continue to evolve (Fig. 6e).

Several authors attribute misidentification to the direction of traction of the gallbladder, which by the "American" technique, pulls the common bile duct and cystic duct into alignment, making them appear to be one. This alignment is created by pushing the gallbladder superiorly rather than laterally, as in the open technique. Perissat has commented that the "European" technique does not align the ducts because the liver is lifted by
an instrument inserted from the left side (82). Nonetheless, injury rates in Europe are similar to those in the U.S.A. (82). Other contributing factors to misidentification are a short cystic duct, and a large stone in Hartmann's pouch, which makes retraction and display of the cystic duct difficult. In fact, stones may efface the cystic duct so that the gallbladder communicates directly with the common bile duct and Mirizzi's syndrome is the end stage of this process. Misidentification also seems to be more common when the gallbladder is tethered to the common bile duct by bands (83). It is likely that the risk factors of inflammation and bleeding referred to previously increase the chance of injury through misidentification. The small caliber common bile duct is also in danger of being misidentified. Bile ducts may normally be as narrow as 3 mm in the adult.

Misidentification may sometimes result in injury without actual division or clipping. Extensive dissection of the common bile duct by a surgeon who has misidentified it as the cystic duct (13) may result in devascularization of the duct. This is especially true if ductal arteries, thought to be the cystic artery, are divided (55). This type of injury may present at a later time as a stricture (56).

Technical errors may also cause biliary injury. Three technical problems, namely failure to securely occlude the cystic duct, too deep a plane of dissection of the gallbladder off the liver bed, and thermal injuries to the bile duct, seem to be the most frequent technical causes of ductal problems in the laparoscopic era. In laparoscopic cholecystectomy, the cystic duct is usually occluded with clips; failure of this closure is more common than during open cholecystectomy. Clip failure may result, in part, from untreated cholelithiasis with increased biliary pressure (8), but most cases occur without cholelithiasis. There is no single explanation for clip failure. Clips are inherently less secure than ligatures, especially suture ligatures. Thus, two clips are usually used on the distal cystic duct. Common causes of clip failure are loosening of the clips by subsequent dissection close to the clip and attempting to clip a thick rigid cystic duct. In
the latter case, clips may appear secure, but the tips may not meet and the lumen will not remain occluded. Inclusion of tissue other than the cystic duct may also result in improper closure of the clip on the duct. Occasionally, clips will "scissor" during application, resulting in faulty closure. Clips may also be able to cut ductal structures made weak by disease or by medication, such as steroids. Application of monopolar cautery to divide the clipped cystic duct may result in delayed thermal necrosis of the cystic duct stump or bile duct (84).

Injury to ducts in the liver bed may occur by entering too deep a plane when excising the gallbladder. Removal of the gallbladder from the liver bed is usually easy in laparoscopic cholecystectomy, but may be difficult in the presence of acute or chronic inflammation or in patients with an intrahepatic gallbladder. In a difficult open cholecystectomy, one can insert a finger into the gallbladder to help define the plane. Staying on the gallbladder may be more difficult laparoscopically, and if the liver bed is entered, a small duct in a normal position may be injured. Bleeding from the liver bed may contribute to this injury. When a duct is entered, a type A injury results. When bile is noted coming from the liver bed, it is an indication for drainage or conversion, depending on the size of the injury.

Injudicious use of the cautery has resulted in serious injuries to the bile duct. Such an injury, in which the common hepatic duct was destroyed, is illustrated in Figure 5. The cautery was said to have arced to the common hepatic duct during dissection of the cystic duct. Injuries induced by cautery are also related to the risk factors of intraoperative bleeding and inflammation. Both may result in the use of excessively high cautery settings to control hemorrhage or to application of the cautery without being sure of the position of the duct (55, 85).

The well described "tenting" injury, in which the common bile duct is pulled up at the time of occlusion of the cystic duct and caught in the clip or ligation, does not seem to be a common cause of injury during laparoscopic operation (5). Injuries to the bile duct can also occur in association with transcystic or direct common duct explorations, as in open cholecystectomy. We have not identified such an injury in the literature, but they may become more common as laparoscopic ductal exploration becomes more prevalent.

Misidentification of the common bile duct, cautery injuries to the bile duct and improper or failed application of clips to the cystic duct are the major causes of ductal injury (2, 6, 11, 53, 55, 57, 61, 67, 85). However, the injuries are not usually described in enough detail to provide a quantitative evaluation. In the series by Davidoff and co-workers (55), eight of the 12 injuries were the result of misidentification, three were attributed to cautery, and one could not be assigned. Another indication that misidentification is the paramount problem, is that of 149 injuries in the literature whose presentation we could characterize, only 32 were recognized as injuries during the original operation (2, 6–10, 11, 13, 14, 55, 56, 59, 60, 63).

**HOW MAY ONE PREVENT BILIARY INJURIES DURING LAPAROSCOPIC CHOLECYSTECTOMY?**

**General.** Laparoscopic cholecystectomy should be performed only by trained surgeons who have received adequate instruction and are operating with appropriate equipment. Difficult cases should be avoided early in one's experience. There may be a particular risk of operating upon patients with cholecystitis. Without question, laparoscopic cholecystectomy should not be attempted in this condition until the surgeon is very experienced in elective laparoscopic cholecystectomy. Surgeons should also be aware of which patients are likely to be difficult cases. We (86) and others (45) have shown that laparoscopic cholecystectomy is more likely to be difficult because of scarring or inflammation when the patients are males, elderly, and when there have been repeated attacks of pain. These factors are additive. A previous bona fide attack of acute cholecystitis also is a statistically significant contributing factor to operative difficulty (45, 86). Surgeons who perform laparoscopic cholecystectomy infrequently or who have performed few cholecystectomies laparoscopically should be aware of these predictive factors and take appropriate measures to ensure adequate assistance in the operating room or refer the patient to a more experienced colleague.

**Avoidance of misidentification of ducts.** Many guidelines have been suggested to avoid misidentification of ducts, including instructions on direction of traction on the gallbladder, use of operative cholangiography, and the need to identify (55) or not to identify (11) the common bile duct-cystic duct junction. These are helpful and will be discussed, but in our opinion, do
not emphasize the key issue, which is that misidentification is the result of failure to conclusively identify the cystic structures before clipping or division. We believe that injury can be avoided by adhering to certain principles.

Because the cystic duct and artery are the structures to be divided, it is these structures and these structures only that must be conclusively identified in every laparoscopic cholecystectomy. Accordingly, the cystic duct and artery should not be clipped or cut until conclusively identified. To achieve conclusive identification, Calot's triangle must be dissected free of fat, fibrous, and areolar tissue and the lower end of the gallbladder dissected off the liver bed (Fig. 7) (the latter is an essential measure that precludes the possibility of injury to an aberrant duct). At the completed dissection, there should only be two structures seen to be entering the gallbladder, and the bottom of the liver bed should be visible. Note that it is not necessary to see the common duct (Fig. 7). It is at this point that the surgeon has achieved the critical view of safety and the cystic structures may be occluded because they have been conclusively identified. Failure to achieve the critical view of safety because of difficulty of dissection as a result of inflammation or any other cause is an absolute indication for cholangiography or conversion to open cholecystectomy to define ductal anatomy.

Only the conclusive identification of structures before division can prevent injury because of misidentification. The only exception to this principle of the critical view as shown in the figure that we allow ourselves, is that identification of the cystic artery is considered to be secure when a clearly pulsatile structure of appropriate size is seen to enter the gallbladder. The magnification available by laparoscopy sometimes permits unquestionable identification of pulsation, if traction on the gallbladder is slightly relaxed. A structure so identified may be divided before achieving the critical view. In this case, only one structure, the cystic duct, will be left entering the gallbladder at the conclusion of the dissection. Division of the cystic artery in this manner is rarely necessary, but may be helpful when the artery is short and enters higher on the gallbladder than usual, thus, making exposure of Calot's triangle very difficult.

These principles are similar in rationale to those enunciated for years by expert biliary surgeons for open cholecystectomy (87), the difference being that they advocated freeing the entire gallbladder from the liver bed from above after identifying, but before dividing, the cystic structures. Doing that during laparoscopic cholecystectomy is sometimes difficult and the same objective can be achieved by freeing the base of the gallbladder off the liver bed, which is actually much easier to do laparoscopically than during open operation. To achieve complete clearance of Calot's triangle laparoscopically, it is helpful to dissect Calot's triangle from both its dorsal and ventral aspects (2, 11). The surgeon should be proficient in a variety of dissection techniques, including pulling techniques, gentle spreading with forceps, hook cautery, and blunt dissection with a nonactivated spatula cautery tip or anchored pledgets. In the American technique, Hartmann's pouch should be pulled laterally and inferiorly to open the anterior-left side of Calot's triangle and to create an angle between the cystic duct and common bile duct (11). Additionally, the posterior-right side of Calot's triangle is exposed and dissected while applying superior and medial traction to the gallbladder infundibulum (88). The plane of dissection should always be maintained on the gallbladder (2) or cystic duct. This is of critical importance. To achieve this goal, the gallbladder should be traced down to the presumed point of the infundibulum-cystic duct junction and dissection begun there and not at the presumed location of the middle of the cystic duct. Staying on, or close to, the gallbladder during clearance of Calot's triangle is a key feature of safe dissection. The triangle will

Fig. 7. Critical view. Calot's triangle is dissected free of all tissue except for the cystic duct and artery and the base of the liver bed is exposed. When this view is achieved, the two structures entering the gallbladder can only be the cystic duct and artery.
open as divided structures fall away from the gallbladder, which is maintained on traction. Other hints to avoid misidentification are no different from the practice in open cholecystectomy. The normal common bile duct can be a structure of very small caliber; therefore, small-diameter should never be used as a reason to divide a bile duct that has not been identified. However, a duct of large diameter should alert one to the possibility that it is the common duct. If a duct with visible vessels on the surface is seen, or if the dissection is somewhat more bloody than expected, one must be aware of the likelihood that the common bile duct is being dissected.

Routine operative cholangiography has been recommended to avoid ductal injury (2, 73, 89). However, there are no decisive data to support this view. In three of the earlier surgical reports (2, 55, 56), only five of 29 patients had cholangiograms attempted. The four successful cholangiograms were misinterpreted as normal. In our later report, eight of 15 patients had cholangiography and three were incorrectly interpreted. Thus, in about 50 percent of the cases, an abnormal cholangiogram failed to prevent injury. Misinterpretation of abnormal cholangiograms has also been noted by others describing laparoscopic biliary injuries (1, 6, 14, 53, 67).

The usual misinterpretation of normal is that there is visualization of only the lower part of the biliary tree without filling of the hepatic ducts. In reality, this often means that the common bile duct has been cannulated and a clip has been placed across it so contrast cannot flow proximally into the hepatic ducts. The reason for confusion is that nonfilling of hepatic ducts may also occur when the cystic duct has been cannulated. This cholangiographic appearance can be seen when there is little resistance at Oddi’s sphincter, for example after endoscopic retrograde cholangiopancreatography (ERCP) and endoscopic sphincterotomy, or if the catheter tip is threaded too far down the duct. When only the lower part of the duct is seen, one may reposition the catheter or administer morphine to increase sphincter tone and allow cholangiographic visualization of the intrahepatic bile ducts. Failure to fill the proximal ducts must be interpreted as abnormal until proved otherwise and is a reason to convert to an open procedure. There is one reported instance of a bile duct injury occurring when a normal cholangiogram was interpreted as abnormal and as a result

"Led to attempted duct reconstruction" (1). In summary, there are no hard data that routine operative cholangiography prevents ductal injury and there are multiple reports of surgeons failing to appreciate an abnormality. It is possible that cholangiography has prevented many injuries, but this is unproved.

We rarely use operative cholangiography for ductal identification, but we currently perform fluoroscopic cholangiography routinely once ductal identification has been achieved, using the aforementioned principles of identification. Cholangiography is done to look for stones in the duct, to become and remain facile at laparoscopic ductal intubation, which is helpful in transcystic ductal explorations, and to train residents in cholangiography. However, we desire to avoid opening the common bile duct for cholangiography, although we do not consider it a ductal injury, and thus, ducts are identified before cholangiography in almost all cases. Also, it may be difficult to rule out aberrant right segmental ducts by cholangiography. An instructive case is illustrated in Figure 8. In this case, an aberrant segmental right duct was identified by dissection. The laparoscopic cholecystectomy was completed without a cholangiogram because the cystic duct was short and wide. A postoperative ERCP was done because liver function tests were slightly abnormal and the cystic duct was wide. Note that had the aberrant duct been opened for cholangiography, the intrahepatic ductal system would have appeared almost normal. If cholangiography were the main means of identification, the aberrant duct might have been cut. It was identified by dissecting the entire Calot’s triangle before clipping or cutting any structure.

Cholangiography can also be done through the gallbladder. For ductal identification, this technique has the advantage that no duct needs to be cannulated. There is little information on the feasibility of this method. It is theoretically limited by obstruction at the neck of the gallbladder, which frequently occurs in difficult cases. There is also the potential for flushing stones into the bile duct.

Although routine operative cholangiography may not prevent biliary injury, there are some data suggesting that it increases the chance of intraoperative recognition (52, 53). It has also been suggested that intraoperative cholangiography lessens the extent of injury (52).

Prevention of ductal injury as a result of technical causes. Many suggestions regarding technique can
be found in the surgical literature already cited. The following is a brief summary that also incorporates our own experience.

**Failure of occlusion of the cystic duct by clips.** Two clips must be applied to the distal end of the cystic duct and one to the proximal end. Clips must be placed in such a way that the ends of both limbs of a clip can be seen projecting beyond the duct and that no extraneous material is included. Clips should not be manipulated in the subsequent dissection. Clips should not be used if the cystic duct is large or thick so that upon closure, the tips of the clips do not meet. Under these circumstances, applying a ligature (either preformed or hand tied) is the optimal technique to occlude the cystic duct.

**Entering a duct in the liver bed.** Avoidance of intrahepatic ductal injury depends on staying in the correct plane of dissection on the gallbladder. Use of the spatula dissector combined with irrigation to keep the field clear of blood is often helpful in difficult cases (88). The spatula is a blunt dissector that provides some tactile perception to the surgeon. Its round blunt shape is less likely to enter the liver. Dissecting can proceed by a combination of pushing, cauterization and irrigation, all with one instrument. The cautery scissors are also often helpful. There is no substitute for meticulous technique and experience in this dissection, emphasizing once again that the performance of difficult laparoscopic cases should be a graded experience.

**Cautery injuries.** A standard admonition in preventing ductal injuries at open cholecystectomy is that bleeding must never be controlled by blind application of hemostats, clips, or cautery. This applies also to the laparoscopic technique. However, it is more difficult to control brisk bleeding laparoscopically. One cannot do a Pringle maneuver or apply direct pressure as easily as in the open procedure. Bleeding is much more likely to obscure the field and the liberal use of suction results in loss of working space by aspiration of the pneumoperitoneum. Therefore, brisk bleeding interfering with visualization is an indication for converting the closed procedure to an open procedure. However, lesser degrees of hemorrhage may be misjudged as being more serious because of the magnification of laparoscopy. The operating surgeon must use judgment in such cases because the bleeding often stops spontaneously. Direct pressure with an anchored pledget or pads of oxy cellulose is often effective in stopping the bleeding and rarely causes damage to tissue.

Low cautery settings should be used in portal dissections. The cautery may arc at higher settings. Instruments through which the cautery is applied must be shielded adequately to a location close to the working end. When using the cautery, instruments should always be directed away from important structures, such as the bile duct, because an instrument such as a hook dissector may swing forward after transecting tissue. As noted previously, the use of cautery to divide the cystic duct may result in thermal necrosis of the cystic duct stump or adjacent bile duct and, thus, cautery should never be used to transect cystic structures (84).

There is one study in the literature suggesting an advantage to leaving a short cystic duct (90). Jonson and associates left no cystic duct, even if it required suturing of the common bile duct. Certainly, stones should not be left in the duct, but the technique of Jonson and associates (90) cannot be easily used in laparoscopic operation, and attempting to leave a short cystic duct could result in injury to the bile duct or slippage of clips and it cannot be recommended.

**How do biliary injuries present and how should they be investigated?**

Clinical presentation. Type A and type E injuries have recently been clearly characterized. There
are important differences in presentation that can be helpful in diagnosis. Type A injuries almost always present in the first postoperative week, although they have been reported as late as two to three weeks postoperatively. Only three of 33 injuries in which time of presentation was defined were discovered during operation (7, 9, 10, 11, 13, 14, 60, 63), although sometimes bile leaking from the gallbladder bed had been noted during operation (11, 58) in patients who later presented with a type A injury. There are 22 quite detailed descriptions of type A injuries in recent series. These descriptions indicate that there are two common modes of presentation (4, 8–11, 58, 63). About two-thirds of patients present with the symptom complex of abdominal pain coupled with fever and other signs of sepsis caused by bile collecting locally or generally in the peritoneal cavity. Some of these patients also have abdominal distension. About one-third of patients present with bile leaking externally through an incision. These two symptom groups do not overlap. This is not surprising because, when bile has a route of egress, local collection or generalized peritonitis are unlikely. A few patients present only with vague symptoms, such as anorexia, or failure to thrive. It is important to be aware of this third mode of presentation because such patients may be ignored or misdiagnosed. An important matter differentiating type A from type E injuries is that jaundice occurs quite uncommonly in type A injuries, although hyperbilirubinemia of 2 to 3 mg per dL is frequent (12), as is an elevated alkaline phosphatase. Only two of 33 patients, both in one report (4), were jaundiced. Brooks reported on nine bile leaks in which the mean bilirubin level was 0.82 mg per dL (8). The main abnormality in liver function tests was an elevation in the alkaline phosphatase, which has also been noted by others (4, 9).

Type E injuries are more likely to be appreciated during operation. Overall, 36 of 129 of reported cases with type E injury referred to tertiary centers, which can be characterized, have been recognized at operation (2, 9–11, 13, 14, 55, 56, 59, 60, 62). In the first two reports (55, 56), none of the injuries were recognized intraoperatively, but intraoperative recognition is becoming more common (10, 13), probably as a result of heightened awareness of the potential for injury. Intraoperative recognition occurs either because of observation of bile in the field, indicating a cut bile duct, or secondary to abnormalities seen on cholangiography. Like type A injuries, most type E injuries are discovered within 30 days of operation. However, unlike type A injuries, about 5 percent of type E injuries (seven of 129 classifiable cases [10, 11, 13, 55, 56]) present one or more months postoperatively.

There are two main modes of presentation in 55 cases that give detailed information of type E injuries (1, 2, 10, 11, 13, 14, 55, 56). About 50 percent of cases present with a combination of jaundice and pain. About 25 percent of patients present with painless jaundice, which is the sole manifestation in the very late presentations. Some patients present with pain, fever, and sepsis, while a few present with an external bile leak. The differences in presentation between type A and E injuries are listed in Table V. In summary, a patient with the classical type A injury presents early in the postoperative period with pain, fever, and sepsis or with a bile leak, an elevated alkaline phosphatase and bilirubin, but without clinical jaundice. The patient with a classical type E injury presents with jaundice and pain. The type C and D injuries are less well characterized, but when patients with those injuries are not diagnosed by intraoperative bile leak, they present much like type A injuries.

**Table V.** CLINICAL PRESENTATION OF TYPE A AND TYPE E INJURIES

<table>
<thead>
<tr>
<th>Timing</th>
<th>Type A</th>
<th>Type E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency of intraoperative diagnosis</td>
<td>Rare</td>
<td>In about 25 percent of cases</td>
</tr>
<tr>
<td>Frequency of late presentation (after day 30)</td>
<td>Not seen</td>
<td>5 percent of cases</td>
</tr>
<tr>
<td>Clinical manifestations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jaundice</td>
<td>Very uncommon</td>
<td>Present in more than 66 percent of patients</td>
</tr>
<tr>
<td>Pain plus fever and sepsis without jaundice</td>
<td>Very common: greater than 50 percent of cases</td>
<td>Uncommon: less than 15 percent of cases</td>
</tr>
<tr>
<td>Laboratory tests</td>
<td>Mild hyperbilirubinemia</td>
<td>Bilirubin greater than 2.5 mg/dL</td>
</tr>
<tr>
<td></td>
<td>common, alkaline phosphatase</td>
<td>alkaline phosphatase</td>
</tr>
<tr>
<td></td>
<td>frequently elevated</td>
<td>frequently elevated</td>
</tr>
</tbody>
</table>

In summary, a patient with the classical type A injury presents early in the postoperative period with pain, fever, and sepsis or with a bile leak, an elevated alkaline phosphatase and bilirubin, but without clinical jaundice. The patient with a classical type E injury presents with jaundice and pain. The type C and D injuries are less well characterized, but when patients with those injuries are not diagnosed by intraoperative bile leak, they present much like type A injuries.
Strasberg et al.: Biliary Injury During Laparoscopic Cholecystectomy 117

### TABLE VI—COMPARISON OF DIAGNOSTIC TECHNIQUES FOR INVESTIGATING LAPAROSCOPIC BILIARY INJURIES

<table>
<thead>
<tr>
<th>Test</th>
<th>Major Functions</th>
<th>Characteristics</th>
<th>Negative outcomes</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hepatobiliary scintigraphy</td>
<td>Detect bile leak</td>
<td>Can be used with low levels of jaundice. Poor localization of site of leakage. Good screening test.</td>
<td>Noninvasive</td>
<td>Low</td>
</tr>
<tr>
<td>Ultrasound</td>
<td>Detect biloma, detect dilated bile ducts</td>
<td>Localizes bile collections well. Bowel gas interferes. Some user dependency. Good screening test when injury suspected. Can be combined with percutaneous aspiration.</td>
<td>Noninvasive</td>
<td>Low</td>
</tr>
<tr>
<td>Fistulagram</td>
<td>Detect site of leak and presence of biloma</td>
<td>Very useful when established external fistula exists.</td>
<td>Noninvasive</td>
<td>Low</td>
</tr>
<tr>
<td>CT scan</td>
<td>Detect biloma, detect dilated bile ducts</td>
<td>Can be combined with percutaneous aspiration.</td>
<td>Noninvasive</td>
<td>Moderate</td>
</tr>
<tr>
<td>ERCP</td>
<td>Detect exact site of leak or obstruction</td>
<td>Can be combined with sphincterotomy and drainage to treat Type A and D injuries. Important planning step for many operative procedures.</td>
<td>Invasive</td>
<td>Expensive</td>
</tr>
<tr>
<td>Percutaneous tranhepatic cholangiography</td>
<td>Detect exact site of leak and obstruction. Demonstrates intrahepatic biliary anatomy.</td>
<td>Decompresses ducts, can be used for some Type A and D injuries and E injuries with stricture. Important planning step for surgery and for treatment of cholangitis. Catheters guide operative dissection.</td>
<td>Invasive</td>
<td>Expensive</td>
</tr>
</tbody>
</table>

CT: Computed tomography, and ERCP: endoscopic retrograde cholangiopancreatography.

7, 9, 10–13, 55, 56, 60, 63, 67). A number of algorithms have been presented for diagnosis and management of biliary injuries (11, 12, 63). There are six main investigations used: computed tomography (CT) scan, ultrasound (US), hepatobiliary scintigraphy, ERCP, fistulagram, and percutaneous tranhepatic cholangiography (PTC). A bewildering variety of approaches are possible when there are this many potential investigations in an injury that has several subtypes and when some investigations, such as ERCP and PTC, may be coupled to therapeutic procedures. The main purpose of investigation should be to establish the diagnosis with the least risk of morbidity and the lowest cost. In choosing diagnostic procedures, the ability to treat the problem at the same time must be considered. The main role of each investigation and some of the advantages and disadvantages associated with each is given in Table VI. Note that the main roles of CT and US, coupled with percutaneous aspiration, are to establish the presence of bile in the peritoneal cavity and to drain it. The main role of a hepatobiliary scintigraphy is to establish the presence of a continuing bile leak. The main roles of the more invasive procedures, such as ERCP and PTC, are to provide exact anatomical diagnosis and to treat the injury by decompressing the biliary tree or dilating it, or by both. In choosing an investigation one should consider the clinical presentation. Algorithms starting with a single investigation are likely to fail because the injuries and presentations are so different. For instance, the order of investigation in a patient presenting with an external bile leak, in a patient with postoperative fever, with or without pain, but without jaundice, and in a patient with jaundice only, will not be identical. Endoscopic retrograde cholangiopancreatography has been advocated as a highly useful first investigation (12). Unquestionably, it is very useful in the management of biliary injuries (12, 62, 91–93), but it is an invasive procedure and can occasionally be avoided if there is a biloma without a continuing bile leak (9, 12). The morbidity rate of diagnostic ERCP is low, but when combined with sphincterotomy it has a complication rate that ranges between 7 to 11 percent (94) and the mortality rate is 0.6 to 1.5 percent (95).

We presently suggest the following. When the patient presents with pain, fever, and sepsis, but not jaundice (likely a type A injury with bile in the peritoneal cavity), the presence or absence of a bile collection should be established by US or CT with percutaneous aspiration if a collection is present. When this occurs, catheter drainage should be instituted unless the collection is simply serous fluid. If bile is found, hepatobiliary scintigraphy will determine if the bile leak is active. This approach may be less direct than ERCP, but it is also less invasive and costly. If an active leak is found, ERCP is used to demonstrate the
site and type of problem. If it is a type A injury, sphincterotomy and intubation or intubation alone can be done at the same time. If it is a more serious injury, such as an E type, the choice is between stenting or operation, depending on the type of injury found. If the patient presents with an external bile leak or with jaundice as the main symptom, beginning with an ERCP and following with other investigations or treatment, depending on the results of the ERCP, would seem to be reasonable. Sometimes, the most pertinent and informative investigation in the presence of a bile leak is a fistulagram. Percutaneous drainage of bile collections or PTC would be done based on the ERCP findings.

WHAT IS THE CORRECT MANAGEMENT OF BILIARY INJURIES?

Management of injuries recognized at the initial operation. Management depends on the type of injury and the time of diagnosis. The usual injury discovered at operation is to the main bile ducts, types C, D, or E. Type A injuries are rarely appreciated intraoperatively. Recognition of biliary injury, either on cholangiography or by detection of bile in the field, is almost always an indication for conversion. Management of type B injuries will be discussed later. Most authorities would agree that early repair of the more serious C, D and E type injuries, especially the E injuries, is desirable. However, the repair of these injuries is often difficult and may require dissection and suturing techniques that are not commonly used by many surgeons who perform cholecystectomies. The operations closest to bile duct reconstruction are resection of cholangiocarcinoma and portal dissections for liver resection. The keys to successful repair are the ability to dissect hepatic ducts up to and above the bifurcation and into the hepatic parenchyma, if necessary, and the ability to perform a mucosa-to-mucosa anastomosis without tension between a defined loop of jejunum and one or several hepatic ducts, sometimes of small caliber, while maintaining intact blood supply (96). This may require use of very fine suture material under magnification to obtain the best result. It must be noted that there is absolutely no information on success rates of repair of E type injuries when performed in community hospitals because only the failures of repairs are seen in tertiary care hospitals.

In nine surgical series, 52 operations done at outside institutions before referral may be characterized (1, 2, 10, 11, 13, 55, 56, 59, 60). Some of these were done after discovery of the injury in the early postoperative period. Twenty-seven patients had primary repair that failed because of stricture or leakage, while 25 had some form of drainage with or without T-tube placement (24 patients) or ligation of the bile duct (one patient) before referral. Primary repairs consisted of duct-to-jejunum, duct-to-duodenum or duct-to-duct repairs. Sometimes, less than optimal strategies for repair were used, suggesting that inexperience was a factor. For instance, duct-to-duct repairs should be reserved for clean transactions with little or no loss of ductal tissue, an uncommon event in laparoscopic injuries, and duct-to-duodenal anastomoses should be avoided. Occasionally, operative notes indicated that bile leakage was present after the anastomosis or that there was “slight tension.” Such repairs have a high chance of failure. Furthermore, the blood supply to the distal cut end of the common hepatic duct may be poor. The common hepatic duct normally receives its blood supply from above (97, 98), but after transection the distal cut end must be supplied by vessels traveling up the common bile duct. In high hepatic duct transections this blood supply to the cut end may be inadequate. Duct-to-duct anastomoses were used in almost one-half of the initial repairs. In comparison, only eight of 121 injuries repaired in referral centers were of the duct-to-duct type. The strategy of simple drainage of the right upper quadrant and referral to a hepatobiliary surgical unit seems to be safe. None of these patients were reported to have complications as a result of a short delay in repair.

There is no direct advice given in the literature regarding the management of the injury at the time of initial operation at a primary care center. The choice is between primary repair and drainage and referral. The available information suggests that drainage and referral to an hepatobiliary unit is preferable whenever the surgical team is not expert at the repair required. When the repair that is required is suture of a lateral injury to the bile duct (type D) over a T-tube, expertise is usually available locally. When the injury is a type E, especially with high injuries of Bismuth level 3-5 (E8-a), or when, in any type, the bile ducts are very narrow, experience may be a critical factor and referral to a specialized unit should be contemplated. When the injury is discovered in the postoperative period, it is increasingly advisable to refer the patient...
as it is essential that the first repair be technically perfect.

Management of biliary injuries found in the postoperative period and management of patients referred with biliary injuries. Management depends on the type of injury, the type of initial management and its result, and the time elapsed since the initial operation or repair.

Type A injuries. As we have noted, few injuries of this type are found during operation. Once diagnosed, the treatment is to drain the intraperitoneal bile collection and if bile leakage is continuing, intrabiliary pressure is reduced by endoscopic techniques, such as ERCP. Although sphincterotomy alone may be adequate for this purpose, most authors recommend placement of a stent or a nasobiliary catheter (12, 14, 92, 99, 100). Percutaneous transhepatic cholangiography may also be used to decompress the duct if ERCP fails or if a high injury is present. There are approximately 35 reported type A cases that can be analyzed for type of management. About one-third of the cases have been successfully treated by external drainage of the biloma only, and another one-third were managed by external drainage, coupled with ERCP and biliary intubation. The other one-third were treated by operation. It seems likely that ERCP and biliary decompression would have been successful in the patients having an operation because this worked in almost every case in which they were used.

Type B injuries. These injuries may remain asymptomatic or present as late as ten or more years after the initial injury with pain or cholangitis (71). Patients who are symptomatic require treatment, usually hepaticojejunostomy and, more rarely, segmental hepatic resection when biliary enteric anastomosis is not possible. What to do in the patient who is asymptomatic is less certain. These injuries may be incidentally discovered months or years later as a result of low-grade abnormalities in liver function tests. Ductal dilatation is seen on US. In patients who are asymptomatic, treatment is not recommended when the affected section of liver is small or if the injury was remote and the problem is at the stage that the affected section has atrophied. What to do when the injury is recent and the section of liver affected is large (e.g., the whole right lobe), is less certain. There is not enough accumulated experience on which to base a recommendation. Most biliary surgeons would recommend hepaticoenteric anastomosis for the right lobar duct lesion, but a more conservative approach should be taken if the patient is asymptomatic and if the injury is to segmental or smaller ducts. Hepatic resection may be required in some instances.

Type C injuries. Type C injuries to major ducts require drainage of the bile collection and either biliary-enteric anastomosis or ligation of the transected duct. If the duct is very small, i.e., less than 2 mm, the biliary-enteric anastomosis is unlikely to be successful and ligation may be preferable. Whenever possible, the duct should be occluded by a ligature placed around the duct rather than suturing the end of the duct. Continuing leakage can occur through suture punctures in the duct. As with type E injuries, insertion of a transhepatic catheter before duct reconstruction is very helpful at operation to locate the duct. It also may be used to control bile drainage and to drain the subhepatic bile collection (Fig. 4).

Type D injuries. A number of these injuries have been reported, but the details of repair are often cursory. As noted, this is a more common injury than reports indicate because treatment is usually successful and referral to a tertiary center is usually not needed. Successful treatment by ERCP and stenting has been reported (62). Most injuries have been repaired at the time of the original operation or shortly thereafter by suture of the duct over a T-tube. Whether the T-tube should be brought out through the injury or a separate stab in the duct depends on the exact nature of the injury. When its location and length are similar to an intended choledochotomy and the injury is fresh, there is no reason to make a second opening in the duct. However, in most cases, a second stab opening for the T-tube is recommended. Some cases of D type injuries in which the cut in the bile duct is very small might be managed by external drainage and biliary intubation or by suture closure alone.

Type E injuries. The treatment of these injuries is quite similar to equivalent injuries occurring at open cholecystectomy. There have been a number of excellent reviews on treatment of injuries to the bile duct of this type in the past ten years (15, 68, 77, 101-103).

Strictures, and occasionally clip occlusions (14, 55, 81), may be treated primarily by nonoperative means, including balloon dilatation and stents placed either by ERCP or percutaneously through the liver. One series suggest that results are equivalent to operation (104). Other studies report frequent success, although long-term follow-
Fig. 9. Postoperative cholangiogram showing the side-to-side anastomosis between the left hepatic duct and the jejunum. The injury (E₉) was at the bifurcation. The tube was removed after cholangiography.

up findings are not commonly available (4, 62, 102, 105-109). Operation is required for failure of stent therapy and when there is ductal discontinuity.

The main purposes of operative therapy have been previously stated, namely to obtain a tension-free mucosa-to-mucosa anastomosis of adequate diameter. Several of the surgical series rec-

ommend preoperative placement of transhepatic tubes to aid identification of the ducts at operation (55, 57); this is our own practice (10). The use of postoperative stents is controversial. There is no evidence that they are helpful if a large caliber mucosa-to-mucosa anastomosis has been achieved. We use them when very small ducts have been anastomosed; in that case, we insert the stent through the jejunum. Occasionally, the transhepatic tubes are left through the anastomosis for several days to perform postoperative cholangiography.

Hepaticojejunostomy is used for biliary reconstruction in almost all cases. Whenever possible, an anterior longitudinal opening is created in the bile duct and a long side-to-side anastomosis is performed. Often, this is done to the extrahepatic portion of the left hepatic duct after it is lowered by dividing the hepatic plate (Fig. 9). This technique has been described by Couinaud and recommended by Blumgart (110). The advantage of this technique is that it minimizes dissection behind the ducts, thereby making the dissection technically easier and less hazardous and decreases the chance of devascularizing the duct at the point of anastomosis. It also permits a wide anastomosis, even when the ducts are not large, because the entire length of the extrahepatic left duct can be used. This approach is particularly suitable for injuries at, or just below, the level of the bifurcation (E₉, E₉). With type

Fig. 10. a, An E₉ injury treated at the time of laparoscopic cholecystectomy by a double barreled choledochocholangiojejunostomy and splinted with a T-tube (arrow) divided at the upper limb to go up both the hepatic duct and the aberrant right duct. These anastomoses strictured.

b, Immediate postoperative cholangiogram through left hepatic duct after double barreled hepaticojejunostomy. Contrast material injected into the left duct fills the aberrant right duct (arrow) indirectly through the jejunal loop. A large right anterior duct can also be seen (arrow).
Fig. 11. Biliary injury progressing with time. A type D injury to right hepatic duct was treated by suture and T-tube stenting at time of original operation. a. Postoperative cholangiogram done three weeks postoperatively, showing bile leak at repair. Left ductal system fills, although there is a suggestion of a stricture at the orifice of left duct (arrow). b. One month later, stricture at orifice has progressed and there is no filling of the left ductal system. Note also the wall abnormality of common hepatic and right hepatic ducts. c. Enlargement showing stenosis and position of T-tube (arrowhead) and percutaneous needle (arrow). After insertion of percutaneous transhepatic tube into left duct, the patient had follow-up evaluation for a further period. d. Two months later, the changes pictured in the right duct in b had progressed to stenosis of the right posterior sectoral duct orifice (arrow). Thus, this injury progressed from a type D to an E5. Progression is most likely the result of thermal or ischemic injury. Early repair might fail because of incorporation of injured duct into an evolving injury.

E3 and some E2 injuries, the common hepatic duct itself may be used. Right ducts are not as suitable for this approach as well because they have a short extrahaheptic length and the end of the duct must be used (Fig. 4). For the higher injuries and E5 injuries, repair may require suture of several ducts (Fig. 10), often after joining individual hepatic ducts before the jejunal anastomosis, as described by Blumgart (111). All ducts must be accounted for, and for this intraoperative
US and contrast cholangiography are invaluable. The consequence of missing a major duct in repair has recently been described (8).

The optimal timing of reconstruction is variable. Operation can be performed immediately if the patient is referred promptly. However, in our experience, patients are often referred after a preliminary attempt at repair or after prolonged external drainage. Occasionally, referral coincides with the period when one would expect greatest inflammation and vascularity. In these cases, we control the drainage with percutaneous or endoscopically placed tubes and wait until inflammation can be expected to have subsided. Another reason for waiting, is that with catherization and devascularization injuries, the process may progress over several months (Fig. 11). We believe that it is best to wait for definitive reconstruction until stabilization has occurred. In our experience, patients adjust well to the external tubes that are usually required during this period, provided they understand the benefits of waiting. In this type of serious injury, one must advocate that the operation be performed at the optimal time and place so it has the greatest chance of success.

In cases in which a primary repair has failed, it is not always necessary to perform a fresh hepaticojejunostomy. Occasionally, the problem is only a bile leak from an adequate anastomosis, or a slightly stenotic anastomosis. These can often be treated by nonoperative means (6, 14) when the stricture is very short, reserving reoperation if these procedures fail.

WHAT IS THE LONG-TERM OUTCOME OF TREATMENT?

Most surgical series of biliary reconstruction cite good short-term results (1, 2, 10, 11, 13, 55, 56, 59, 60, 67). However, it is well known from older literature describing ductal injury during open cholecystectomy, that there is a progressive restenosis rate. Two-thirds of recurrences are diagnosed in the first two years after repair, but restenosis has been described after ten years. The restenosis rate varies from 5 to 28 percent (15). There is a recent indication that the results in the laparoscopic era may not be as good as these, perhaps because of increased severity of injury. In the largest report to date, consisting of 50 injuries, 25 hepaticojejunostomies were performed and five of the patients required further operation during the short-term follow-up period (3). Other early failures have been described (14, 60), but too few large series are available to know if this is a general trend. Two series also describe cases in which hepatic resection was required after failed repairs (3, 13).

In summary, biliary injury is the greatest problem besetting one of the greatest advances in biliary operation during this century, the laparoscopic cholecystectomy. The key to this problem is not in complicated repairs at tertiary centers, but in prevention. Prevention requires commitment to perform meticulous dissection so that only structures that have been unequivocally and conclusively identified are divided.

ACKNOWLEDGEMENT

The authors are grateful to Doctors G. Aliperti and S. Edmundowicz of the Division of Gastroenterology, Department of Medicine, Washington University School of Medicine, and to Doctors D. Ficus and D. Balfu of the Mallinckrodt Institute of Radiology, Washington University School of Medicine.

REFERENCES

12. Vitale, G. C., Stephens, G., Wierman, T. J., and Larson, G. M. Use of endoscopic retrograde cholangiopancreatography in the management of biliary compli-


92. Vitale, G. C. Interventional endoscopic retrograde cho- 
langiopancreatography: state of the art. Part I. J. R. 

100. Vitale, G. C. Interventional endoscopic retrograde cho- 
langiopancreatography: state of the art. Part II. J. R. 

101. Moossa, A. R. Iatrogenic bile duct injuries—some 
myths and realities. In: Progress in Hepatic, Biliary, 
and Pancreatic Surgery. Edited by J. S. Najarian and 

102. Blumgart, L. H., Kelley, C. J., and Benjamin, I. S. 
Benign bile duct stricture following cholecystectomy: critical 

105. Czerwiak, A., Thompson, J. N., Soreide, O., and others. 
The management of fistulas of the biliary tract after injury to the 

104. Davids, P. H. P., Tanaka, A. K. F., Rauws, E. A. J., 

105. vanSonnenberg, E., Casola, G., Wittich, G. R., and 
others. The role of interventional radiology for com- 

106. Millis, J. M., Tompkins, R. K., Zinner, M. J., and 
others. Management of bile duct strictures. Arch. 

107. Geenen, D. J., Geenen, J. E., Hogan, W. J., and others. 

108. Raute, M., Podlech, F., Jachke, W., and others. Man- 
agement of bile duct injuries and strictures following 

109. Traverso, W. L. Clinical manifestations and impact of 

110. Blumgart, L. H. Benign biliary strictures. In: Surgery of 
the Liver and Biliary Tract. I. Edited by L. H. 

111. Blumgart, L. H. Hilar and intrahepatic biliary-enteric 
II. Edited by L. H. Blumgart. Pp. 899-913. Edinburgh: 