Recent Experience with Major Hepatic Resection

JOHN H. FOSTER, M.D., MARION R. LAWLER, JR., M.D., MELL B. WELBORN, JR., M.D., GEORGE W. HOLCOMB, JR., M.D., JOHN L. SAWYERS, M.D.

From the Department of Surgery, Vanderbilt University School of Medicine and the Vanderbilt University Affiliated Hospitals

MAJOR HEPATIC resections are being performed with increasing frequency. A number of factors are responsible for this trend. Foremost among them were demonstrations by Lortat-Jacob, Quattlebaum, Pack, Brunschwig, Longmire and their associates and others of the feasibility of successfully resecting large portions of the human liver.[3, 7, 9, 19, 21] The major indication for massive hepatic resections reported by these surgeons was involvement of the liver by tumor. In the present decade there has been an increasing interest in surgery of trauma. From this experience, another indication for major hepatic resection has evolved—resection of large portions of the liver injured by blunt or penetrating trauma. In 1956, Mikesky, Howard and DeBakey reported a 15-year experience involving injuries of the liver in 300 consecutive patients, in only 3 patients had hepatic resections been performed.[17] Longmire reported a similar experience wherein of 90 patients with hepatic injuries only one was treated by major resection.[8] A change occurred in 1964 when McClelland, Shires and Paulos reported a 10-year experience involving injuries of the liver in 259 patients of whom 25 or 9.6% had been treated by hepatic resections.[10] Hepatectomy in the treatment of tumors of the liver is also being done with increasing frequency.[11, 20]

These trends prompted a review of our recent experience with hepatectomy at the Vanderbilt University Medical Center and a search for factors associated with success or failure of the procedures.

Clinical Material

The hospital records of all patients undergoing resection of a portion of the liver at the Vanderbilt University Medical Center during the period January 1, 1956 through December 1, 1967 were reviewed. Wedge resections and removal of minor amounts of liver tissue were excluded. The records of patients undergoing major hepatic resections were analyzed in detail. Patients who died in the operating room while undergoing a resection were *included* in the analysis.

Results

Fifty patients underwent major hepatic resections during the 12-year study period. There were 22 females and 28 males. Of 24 patients undergoing resection for trauma 15 were males and 9 females. The male-female distribution in the patients undergoing resection for other than trauma (tumors, etc.) was equal. Fifty patients ranged in age from 4 months to 87 years. Of 24 patients undergoing resection for trauma 21 were under 50 years and 17 were under 20 years of age. Of 23 patients undergoing resection for tumor 14 were over 50 years of age.

Figure 1 presents the incidence of resection during each year of the study period. During the first 7 years, 1956–1962, nine patients had major hepatic resections; whereas, during the last 5 years major hepatectomies were performed in 41 patients. Figure 1 also shows the indication for hepatic resection. Resection was seldom performed

TABLE 1. *Indications for Major Hepatic Resection*

Indication		Number of Cases
Trauma		24
Blunt		
Major Laceration	15	
Bursting Injury	6	
Gunshot wound	2	
Stab wound	1	
Malignant tumor		14
Hepatoma	6	
Metastatic or invading tumor	8	
Benign tumor		9
Hemangioma	2	
Cysts	5	
Hamartoma	2	
Miscellaneous		3
Biliary abresia	2	
Abscess	1	
Total		50

for trauma before 1963; only two of nine resections were performed for this indication. In the last 5 years 22 of the 41 major hepatic resections were done to remove traumatized portions of the liver. It is beyond the scope of this presentation to present our entire experience with treatment of patients with hepatic injuries; however, analysis of the experience over the past 5 years shows that more than 10% of such patients were treated by hepatic resection. During the first 7 years of the study period there were 7 hepatic resections for tumors, whereas in the last 5 years there have been 19 such procedures. This increase in the frequency of major hepatic resections seem to be real in as much as the number of hospital admissions did not increase proportionately during the study period.

Indications for Hepatic Resection. Table 1 presents the specific indication for each of the hepatic resections. Massive hepatic trauma was the indication in 24 cases. Blunt injury of the liver was the most common form of trauma and was responsible for 21 of the 24 cases. The resulting liver injuries were major laceration or lacerations in 15 and a bursting injury with stellate fractures of the liver in six patients. The major lacerations extended into the depths of the liver as shown in Figure 2. Fifteen patients sustained injuries while riding in automobiles. Two children in the series were struck by automobiles. Three patients were injured in tractor accidents and one child was kicked by a mule. Three of the 24 liver injuries were extensive penetrating injuries—two due to gunshot wounds and one to a knife wound.

Malignant tumors were the indication for resections in 14 patients (Fig. 3). Six patients had hepatomas. Three major resections were for carcinomas of bile ducts or gall bladder. In two patients a large portion of the liver was removed as part of an *en bloc* resection of tumor of an adjacent organ—one a carcinoma of the right colon and the other a reticulum cell sarcoma of the stomach. Finally three hepatic resections were done in patients with carcinoma of colon who had localized hepatic metastases, in one of these the resection was done some years after the colonic resection and in the other two the colonic and hepatic resections were simultaneous.

Benign tumors were the indication for resections in nine cases—2 hemangiomas, 5 cysts and 2 hamartomas. In another patient a large cystic mass in the lateral segment of the left lobe of the liver was resected and proved to be an abscess. Finally, two small children aged 2½ and 18 months with biliary atresias had resections of large portions of the liver (more than 100 Gm.) and hepato-jejunal anastomoses performed.

Preoperative Observations. This presentation will not consider all diagnostic studies and observations in patients who underwent elective resection for hepatic tumors. Some observations in patients undergoing emergency operation for trauma seem pertinent. A history of abdominal trauma or injury over the lower thorax was obtained in each case. Abdominal tenderness and ri-

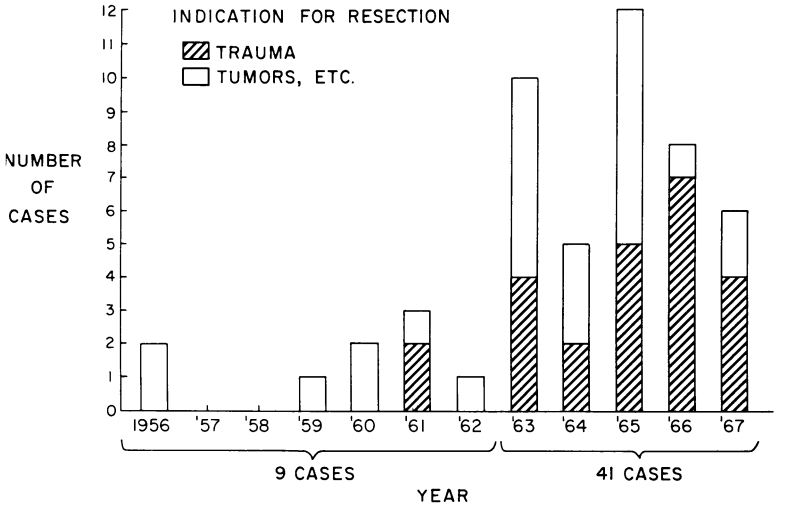

FIG. 1. Incidence of major hepatic resection at Vanderbilt University Medical Center by year and indication.

gidity in the right upper quadrant was frequently present. Seventy per cent of the patients were hypotensive on admission to Emergency Service, or became so shortly thereafter; however, the others remained normotensive or became hypotensive several hours later. A right upper quadrant mass or fullness was present in 40% of patients. There were obvious injuries to organs or systems other than the liver in 15 of the 24 patients. Fractures of bones were the most common associated injuries; these involved the ribs in 9, clavicles in 2, both femurs in 1, hip in 1, skull in 1, and jaw in one. Flail chests were present in two patients, facial lacerations in four and a pneumothorax in another. One patient had gross hematuria and a fullness of the right flank. One patient with an abdominal gunshot wound had free air under the diaphragm.

Abdominal paracenteses were done in four of the 24 patients, in two this involved four quadrant taps while in the other two a single needle was inserted. One of the single needle paracenteses yielded blood; in the other three the procedure was not helpful.

In two patients major lacerations of the liver were initially treated by packing the lacerations with Gelfoam and suture of the lacerations; in each bleeding recurred and at subsequent operations right hepatic lobectomies were done to control massive bleeding. Most of the patients received 500–1,500 ml. whole blood transfusions prior to operation—two patients received 3,500 and 4,500 ml. of whole blood preoperatively. In 23 patients the time interval from injury to laparotomy ranged from one hour to 11 hours with an average interval of 4.7 hours. In the 24th patient there was a 9 day in-hospital delay between injury and laparotomy for what proved to be an expanding subcapsular hepatic hematoma which had occluded the vena cava and caused renal failure. The time interval from arrival at hospital to laparotomy ranged from 30 minutes to 6 hours and averaged 2.5 hours again excluding the patient delayed 9 days.

Extent of Hepatic Resection. Figure 4 shows the lobar division of the liver and segmental divisions of the left lobe. The right lobe is also made up of two major segments—anterior and posterior. Figure 5 shows the extent of hepatic resections in fifty patients and the number of resections done for trauma and the number done for tumors, etc. The left lateral segment was resected in 11, the left lobe in 13, the right lobe in 11, extended right lobe in 3, and lesser resection in 12. The normal human

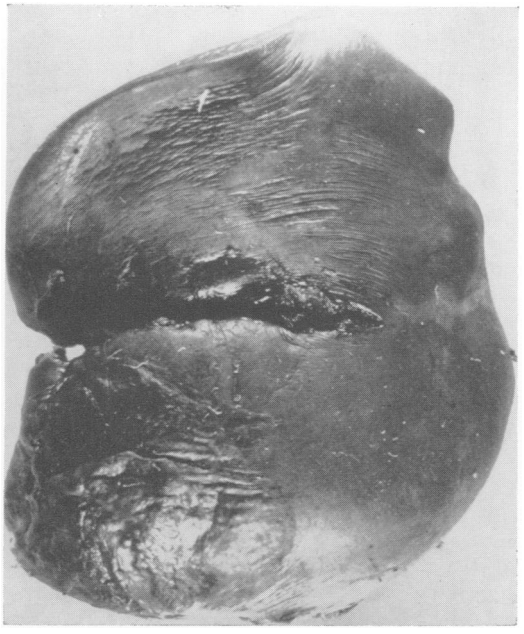

FIG. 2. Photograph of a right lobectomy specimen with a major laceration secondary to blunt trauma. Cut surface of liver is on the opposite side.

liver weighs 1,200–1,600 grams. The weight of resected liver specimens as recorded in the Surgical Pathology reports for resections for trauma were as follows: right lobectomies ranged from 150 Gm. in a 3½ year old to 790 Gm. in an adult, left lobectomies 300–400 Gm., and left lateral segmentectomies 200–250 grams. Recorded weights were low in many cases because of the amount of liver tissue which was fragmented, macerated, suctioned away, etc., and therefore was not weighed. The weight of specimens in resections performed for tumor varied from as little as 142 Gm. for a left lateral segmentectomy involved with metastatic carcinoma up to 2,500 Gm. in the case of right lobectomy for hepatoma.

Technic of Hepatic Resection. In all patients an initial abdominal incision was made and was most commonly midline through the linea alba. The incision was extended as necessary. This usually involved thoracic extension of the incision into the 8th intercostal space, incising the diaphragm and gaining wide exposure for removal of the right or left lobe of the liver. In an occasional patient an upper midline incision extended by means of a right transverse component just above the umbilicus or a long transverse upper abdominal incision provided adequate exposure.

In removing the right lobe or left lobe the technic described by Quattlebaum was generally used.[21, 22] This involved division of the peritoneal attachments of the liver and hilar dissection with ligation and division of the hepatic artery, portal vein and bile duct branches to the lobe to be removed. A probe placed into the hepatic duct via a choledochostomy aided in this dissection. In resections of the right lobe after hilar ligation and division was completed, the liver was retracted to the left and the hepatic veins from the right lobe isolated, ligated and divided close to the vena cava. Next the liver capsule was incised and the liver parenchyma divided with a blunt instrument (such as the knife handle or the finger) through the selected plane of resection. Individual vascular and ductile structures were ligated and divided as encountered. In resection of the left lobe, division of the hepatic veins was done after transecting the liver parenchyma. In the trauma cases in which hemorrhage persisted prior to hilar dissection the bleeding was controlled by packing the hepatic wound or hepatic inflow occlusion or both. In two patients with avulsion of hepatic veins from the venae cavae these measures were insufficient and partially occluding clamps were applied directly to the venae cavae. In resection of the lateral segment of the hepatic lobe and lesser resections as indicated in Figure 5, a mattress suture technic was used. Large mattress sutures of chromic catgut were placed through the liver substance and the liver tissue divided just lateral to the line of sutures by blunt dissection. Vascular and ductile structures were again individually ligated as encountered.

After resection was completed and hemostasis obtained, the cut surface of the liver was covered with greater omentum, a peritoneal flap, or the falciform ligament. In 16 patients Gelfoam was used to cover the cut surface of the liver and this in turn was covered with omentum, peritoneum or falciform ligament. Penrose drains were used extensively to drain operative sites. In a number of patients sump drains were also used. Decompression of the biliary ductile system was accomplished by placing a T-tube in the common bile duct in 16 instances, by cholecystostomy tube in one and by means of a straight catheter in a patient who had a roux-en-Y jejunal limb brought up to the left hepatic duct after right lobectomy with *en bloc* resection of the common duct.

During operative procedures in 24 patients with hepatic trauma whole blood was administered in amounts ranging from 1,000 to 10,000 ml., the mean amount was 4,750 ml. Blood transfusions during elective resections for tumors, etc., ranged from as little as 100 ml. in an 11-month-old child to 12,500 ml. in a 37-year-old woman undergoing extended right hepatic lobectomy, the mean amount in adults was 2,500 ml. Resections of the left or right lobe usually required from 4–6 hours. Resections for trauma were accomplished in lesser time.

Additional Operative Findings and Observations. Nine of 24 patients who underwent *emergency* hepatic resections for trauma had injuries of other organs discovered at operation. Two patients had ruptured spleens as the only additional findings. One patient with a gunshot wound of the liver also had a laceration of the spleen and perforation of the stomach. Another patient with a gunshot wound of the liver had a laceration of the spleen, splenic vein and pancreas and a perforation of the stomach. One patient with a bursting injury of the liver also had an injury of the right renal artery with resultant renal artery thrombosis. Two patients had pulmonary hematomata, one of whom also had a ruptured spleen. The ninth patient had a laceration of the abdominal wall with herniation of small intestine through defect, and injury of 5 other abdominal organs; the spleen, duodenum, stomach, pancreas, and common bile duct in addition to a bursting injury of the liver and a laceration of the vena cava. In six other patients, injuries included avulsions of one or more hepatic veins from the vena cava with resultant lacerations of the venae cavae.

TABLE 2. *Postoperative Complications*

Complication	Emergency Resection	Elective Resection
Stress ulcer and massive G.I. hemorrhage	5	3
Subphrenic abscess	5	1
Sepsis	3	1
Pneumonia	2	0
Wound infection	1	2
Sudden, unexplained death	0	2
Hepatic insufficiency	0	1
Acute renal failure	2	1
Biliary fistula	1	0
Pancreatic fistula	1	0
Common duct obstruction	0	1
Wound dehiscence	1	0
	21*	12**

* In 10 patients.
** In 9 patients.

In patients undergoing *elective* hepatic resections for tumors there were six who had additional operative procedures. In two separate colonic resections were done for carcinomas, while one had an *en bloc* resection of right colon and partial right hepatic lobectomy. One had resections of a leiomyoma of the stomach and a cavernous hemangioma of the lateral segment of the left lobe. In another patient the common bile duct was resected *en bloc* with the right lobe of the liver and a roux-en-Y jejunal limb was anastomosed to the left hepatic duct. Finally one patient had *en bloc* resection involving the entire stomach, lateral segment of the left lobe of the liver, the spleen, left adrenal gland and part of

the transverse colon, diaphragm, esophagus, lung and pericardium for reticulum cell sarcoma of the stomach.

There were four deaths in the operating room of patients undergoing resections for trauma; there were none in patients who had elective hepatic resections. All four operating room deaths resulted from exsanguinating hemorrhages and associated injuries of other organ systems. One was the patient with injuries of 5 other abdominal organs. Another was a patient with a flail chest and facial lacerations undergoing tracheostomy and suture of facial lacerations under local anesthesia when extreme hypotension called attention to the hepatic trauma. This patient died shortly after laparotomy. A third patient had fractures of the shafts of both femurs and a femoral condyle, fibula and tibia on one side; there was delay while roentgenograms of these fractures were being obtained and before the intraabdominal injury was recognized. At laparotomy, in addition to a bursting injury of the right lobe of the liver, there was a laceration of the vena cava at the site of avulsion of the major right hepatic vein. In the fourth patient there was a large laceration of the left lobe of liver and a laceration of the vena cava which extended above the diaphragm.

There were four patients with hepatic trauma who had cardiac arrest in the operating room and who were successfully resuscitated. In two the liver injury included lacerations of the venae cavae controlled by placing partially occluding clamps on the cavae. A third patient who sustained a cardiac arrest was an 18-year-old girl who had a large laceration of the right lobe sutured twice and finally at third operation had cardiac arrest during performance of a right lobectomy for control of continued bleeding. A fourth patient with a laceration of the left lobe of the liver had a cardiac arrest just after induction of anesthesia—laparotomy and external cardiac massage were performed simultaneously. All four of these patients were resuscitated and three are long term survivors. The magnitude of the injuries in these four patients is indicated in the amount of blood administered in the operating room; respectively they received: 6,500, 8,500, 10,000 and 8,500 ml. of whole blood during the operations.

Postoperative Course. Postoperatively patients were maintained on a regimen of nasogastric suction, intravenous alimentation, parenteral antibiotics, Vitamin K administration and supplemental amounts of blood, plasma and albumen as needed. Patients who had massive resections (right or left lobe and the larger partial right lobectomies) required additional blood transfusions and administration of human serum albumen. In extensive resections increase in the prothrombin time, fall in serum albumen, rise in serum bilirubin and later rise in serum alkaline phosphatase were observed in every patient. Elevated alkaline phosphatase, which appeared later than other changes, was the last of the liver function tests to return to normal, usually in 2–4 weeks. In patients with right or left lobectomy, serial radioactive liver scans showed regeneration of the liver to normal size in 4 to 6 months (Fig. 6). In patients who had resections such as a left lateral segmentectomy, liver scan failed to show any appreciable increase in liver mass.

Postoperative Complications. Postoperative complications occurred in 19 of 46 patients who survived operation (Table 2). In emergency resections for hepatic trauma 10 of 20 patients had significant postoperative complications. Of 21 complications in emergency resections, seven occurred in four patients who died postoperatively, six occurred in one patient who is a long-term survivor with an excellent result, and another longterm survivor and excellent result had three of the listed complications—thus 16 of 21 listed complications occurred in six patients. The patient who had six

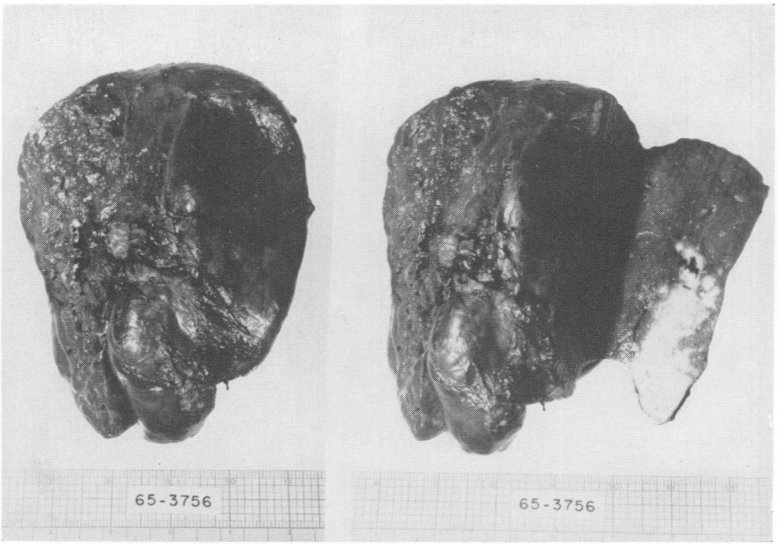

FIG. 3. Photograph of gross specimen from a right hepatic lobectomy for intrahepatic bile duct carcinoma. The gall bladder is present on the resected specimen. On the right, the lateral portion of the liver has been sectioned to demonstrate the tumor.

postoperative complications was a 27-year-old man with a flail chest and major laceration of the left lobe of the liver, the result of an automobile accident. In the postoperative period following resection of the left lobe of the liver he had sepsis with endotoxin shock, wound infection, wound dehiscence, a pancreatic fistula, acute renal tubular necrosis, and massive hemorrhage from gastric stress ulcers which required gastric resection and vagotomy after gastric hypothermia failed to halt the bleeding. This patient is living and well and liver scan shows the liver was regenerated to a normal size (Fig. 6).

In the elective resections there were 12 postoperative complications and nine occurred in six patients who died postoperatively. In survivors there were only three complications—two wound infections and an obstruction of the common duct by inflammatory hyperplastic lymph nodes. The latter complication occurred in a 4-year-old boy who had an extended right hepatic lobectomy for hepatoma. Obstruction of the choledochus was corrected by a roux-en-Y choledochojejunostomy. He is living and well without evidence of recurrence 2 years later.

In general, the frequency of postoperative complications was proportional to the magnitude of the operation and severity of the injury or involvement by tumor. Seven patients in the right lobectomy group had postoperative complications, two in the extended right lobectomy group, four in the left lobectomy group, three in the partial right lobectomy group, two in the left segmentectomy group, and one patient who had partial resection of the left lobe. Postoperative complications could not be clearly related to delay between injury and time of resection, duration of the operation or magnitude of the blood volume replacement—there were isolated, obvious exceptions.

The effect of using hemostatic materials such as Gelfoam to cover the cut surface of the liver following resection upon the incidence of postoperative complications was assessed. Fifteen longterm survivors had Gelfoam placed across the cut surface of the liver; three of these developed subphrenic abscesses, none developed a biliary fistula, none had evidence of significant intraperitoneal bleeding and none had sepsis. Twenty-seven other patients who survived the early postoperative period did not have Gelfoam or other foreign material used to

TABLE 3. *Analysis of Deaths Following Major Hepatic Resection*

Patient	Age/Sex Years	Indication For Resection	Extent of Resection	Associated Injuries or Other Pathology	Time of Death	Complications	Cause of Death
1	17 M	Bursting injury	Left lateral segment	Spleen, pancreas, duodenum stomach and common bile duct	Operating room	—	Exsanguinating hemorrhage
2	26 M	Bursting injury	Right lobe	Fractures both femurs, femoral condyle, fibula and tibia	Operating room	—	Exsanguinating hemorrhage
3	54 F	Major laceration	Left lobe	Crushed chest and facial lacerations	Operating room	—	Exsanguinating hemorrhage
4	45 M	Major laceration	Left lobe	Vena caval laceration	Operating room	—	Exsanguinating hemorrhage
5	19 M	Knife wound	Partial left lateral segment	—	P. O. day # 14	Pseudomonas pneumonia	Pseudomonas septicemia
6	60 F	Major laceration	Partial right lobe	—	P. O. day # 20	Subphrenic abscess, massive hemorrhage 2° stress ulcers	Died following Vagotomy and pyloroplasty for stress ulcer
7	18 F	Major laceration	Right lobe	Spleen, hepatic wounds sutured twice before resection finally done	P. O. day # 4	Cardiac arrest at time of resection, acute renal failure	Renal failure, stress ulcer and fatty liver found at autopsy
8	41 F	Bursting injury	Right lobe	Renal artery injury and thrombosis	P. O. day # 6	Klebsiella pneumonia, hemorrhage 2° to stress ulcer	Hemorrhage 2° stress ulcer fatty liver
9	59 F	Bile duct carcinoma	Right lobe	Resection choledochus with roux limb to left hepatic duct	P. O. day # 19	Hepatic insufficiency, hemorrhage 2° to stress ulcer	Hemorrhage 2° stress ulcer
10	87 F	Hepatic cyst	Left lobe	—	P. O. day # 1	Cardiac arrhythmia and sudden death	Unknown
11	48 M	Hepatoma	Right lobe	—	P. O. day # 32	Acute renal failure, hemorrhage 2° stress ulcer	Hemorrhage 2° stress ulcer
12	2 mos./M	Biliary atresia	Partial right lobe	Congenital heart disease	P. O. day # 30	Sepsis	Hepatic insufficiency and sepsis
13	83	Metastatic carcinoma colon	Left lateral segment	Carcinoma sigmoid colon	P. O. day # 35	Sudden, unexplained death	Unknown
14	68	Hepatoma	Left lobe	—	P. O. day # 6	Massive G. I. hemorrhage ?stress ulcer	Massive G.I. hemorrhage

aid in hemostasis; three of these developed subphrenic abscesses, one had a transient biliary fistula and two developed sepsis. However, continued intraperitoneal hemorrhage culminating eventually in resection, occurred in 2 patients who had deep liver lacerations initially packed with Gelfoam and sutured.

Massive gastrointestinal hemorrhages from stress ulcers occurred during the postoperative periods of 8 patients. The diagnosis of stress ulcers was unequivocal in 6 (observed at operation or autopsy) and strongly presumptive in the other two. This complication contributed to or caused six of the postoperative deaths—three in the elective resection group and three emergency resections. Two patients in hepatic trauma group underwent operations for control of the bleeding from stress ulceration—one died following a vagotomy and pyloroplasty and the other who had gastric resection and vagotomy is a longterm survivor. Most patients with stress ulcers also had multiple other postoperative complications such as: azotemia, acute renal failure, hepatic insufficiency, sepsis, or subphrenic abscess.

The influence of biliary tract decompression, T-tube or catheter in common duct or cholecystostomy tube, on the postoperative course was also assessed. Eighteen of the 46 patients surviving operation had biliary tract decompression; postoperative complications in this group included: subphrenic abscesses—4, biliary fistula—1, sepsis—2, and stress ulcers in 8. The complications in patients who did not have biliary tract decompression were subphrenic abscesses in 2 and sepsis in 2; there were no instances of biliary fistula or stress ulcer. As mentioned patients who developed stress ulcer usually had other complications with an ulcerogenic potential.

Analysis of Deaths. There were 14 hospital deaths. Eight occurred in 24 patients undergoing emergency resection for trauma, a mortality rate of 33%. Six of 26

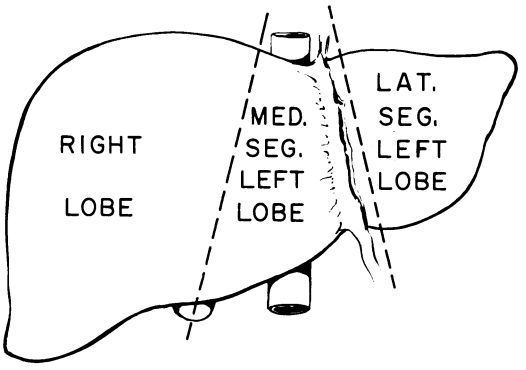

FIG. 4. Sketch showing the lobar divisions of the liver and the segmental divisions of the left lobe. The right lobe is made up of an anterior and posterior segment.

patients who had elective hepatic resections died in the postoperative period, a mortality rate of 23%. Figure 5 shows the deaths as related to extent of hepatic resections. The greatest mortality was in patients undergoing right hepatic lobectomies; however, all three patients having extended right lobectomy survived. Table 3 records in detail much data on 14 patients who died. The four deaths in the operating room during resections for trauma have already been discussed. There were four postoperative deaths in the patients undergoing emergency resections for hepatic trauma. Massive hemorrhages from stress ulcers accounted for two deaths and pseudomonas septicemia for a third. In the fourth patient (Case 7) a large laceration of the right lobe was packed with Gelfoam and closed-over with mattress sutures, this treatment was repeated 6 hours later because of recurrent bleeding and finally recurrent bleeding at 13 hours led to right hepatic lobectomy—during the course of which cardiac arrest occurred. The patient was successfully resuscitated. By the time the hepatic resection was completed this patient had received 55 units of whole blood. The patient died 4 days later in acute renal failure with evidence of hepatic insufficiency and gastrointestinal hemorrhage. At autopsy there was extensive fatty degenera-

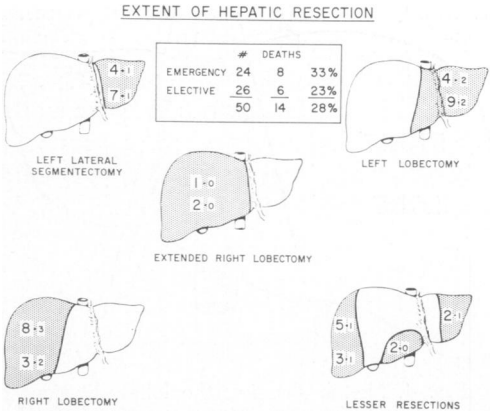

FIG. 5. Extent of hepatic resection in the 50 patients. Area resected is shaded. In the shaded areas the upper large figure represents resections for trauma, the lower large figure resections for tumor, etc. The small figure indicates operative deaths.

tion of the liver and multiple stress ulcers in the stomach (Fig. 7). A second patient (Case 8) had relatively normal hepatic structure at the time of hepatic resection for trauma and at death 6 days later there was extensive fatty infiltration of the liver. The high incidence of stress ulcers in patients who died postoperatively was discussed under Postoperative Complications, this complication caused or contributed to the postoperative death of 6 patients. There were two sudden, unexplained deaths in aged patients, in each coronary occlusion was suspected but not established as postmortem examinations was not done.

Followup Observations. In the hepatic trauma group there were 16 longterm survivors. All are living and well at the present time. Only one developed a late complication, this was a 22-year-old man who had a left lobectomy; a T-tube was used to decompress the common duct. The postoperative course was complicated by septicemia and endotoxin shock, a transient biliary fistula and a subphrenic abscess. Three months later he was readmitted to the hospital with jaundice. Operative cholangiography revealed a stricture of the right hepatic duct 4 centimeters from its junction with the common bile duct. The stricture was dilated and a T-tube placed through the narrowed area. The T-tube was removed 9 months later and the patient has been well since. The stricture was almost certainly due to blunt trauma of the right hepatic duct that was not recognized at the original operation.

Eight patients who had benign lesions of the liver are living and well, a ninth patient died of myocardial infarction 3 years after resection of a hemangioma of the left lobe. The second patient with biliary atresia died 1 year after hepatojejunostomy.

Of the patients with malignant tumors of the liver three are longterm survivors. One with a hepatoma treated by partial right lobectomy is living and well 5½ years later without evidence of tumor. Another is a 4-year-old boy with a hepatoma treated by extended right lobectomy who is living and well without evidence of recurrence 2 years later. The third is a man who had reticulum cell sarcoma of the stomach invading the liver and other structures. He is living and well without evidence of recurrence 32 months later. The other patients with malignant tumors of the liver died 6 months to 2 years after hepatic resections. The longest survival following resection for metastatic carcinoma was 2 years.

Discussion

A decade and a half ago surgeons were reluctant to perform resection of major portions of the liver. Today major hepatic resections are performed frequently. Successful cases of such resections during the early 1950's facilitated this development.[3, 7, 9, 19, 21] Descriptions of lobar and segmental anatomy of the liver by Healey, by Goldsmith and others played an important role in the development of technics for hepatic resection.[4, 6] The procedure is still not undertaken lightly though it can be undertaken with a reasonably low mortality and satisfactory regeneration of the liver. It has

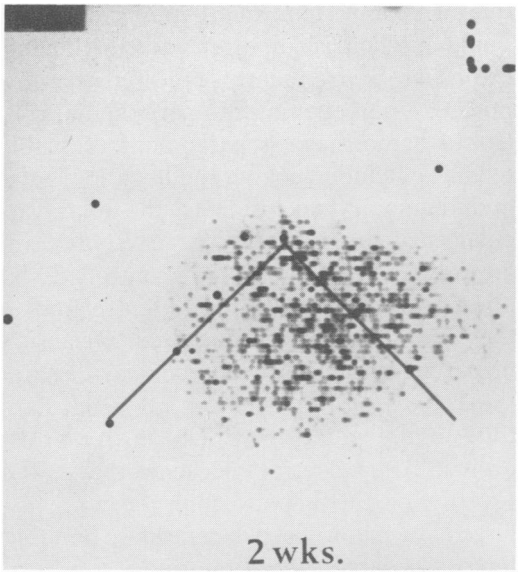

FIG. 6A. Liver scan 2 weeks after right hepatic lobectomy.

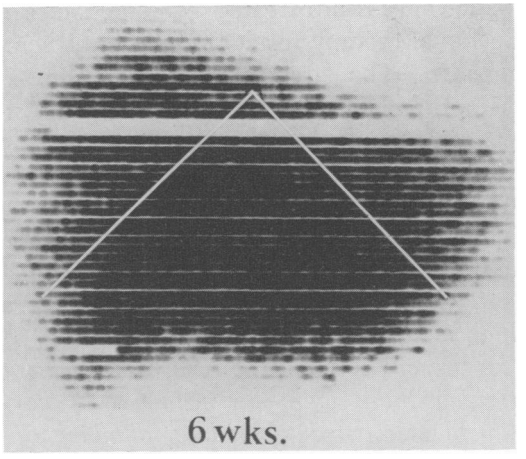

FIG. 6B. Liver scan 6 weeks after right hepatic lobectomy.

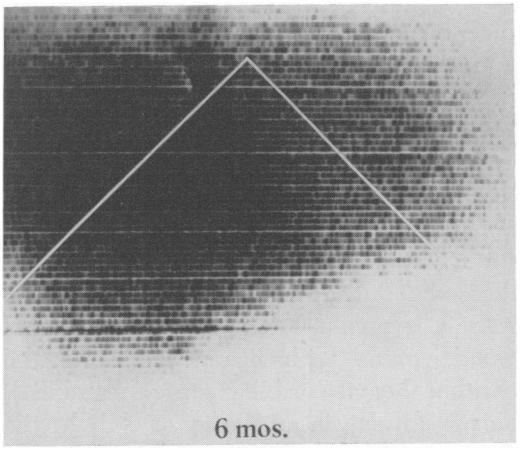

FIG. 6C. Liver scan 6 months after right hepatic lobectomy.

been shown that 90% of the human liver can be resected and that complete morphologic and functional regeneration occur within a few months.[18]

In the treatment of benign tumors of the liver morbidity and mortality is extremely low and longterm results are excellent. Longterm results with malignant tumors remain poor, and largely reflect the advanced stage of the tumor by the time it is recognized and treated. For the few longterm survivors, 3 in this series, the results have, of course, been worthwhile. In this small series we found no evidence that patients with metastatic carcinoma of the liver were benefited by resection.

Hepatic resection in patients with blunt trauma of the liver is a development of the past decade.[10, 13, 14] The dismal results of treatment of major hepatic injuries by other methods emphasize the value of this development. In 1956 Mikesky, Howard and DeBakey reported mortality rates that averaged 67% and frequently were as high as 80–90%. Injuries of the liver of the magnitude reported in the present study had a mortality rate exceeding 80% when treated by older methods of suturing or packing. In 1964 McClelland, Shires and Poulas reported 25 hepatic resections for massive trauma with success in 80%.[10] In the present series of 24 resections in patients with severe trauma 66% were successful. Success rates in such series is largely determined by the number of patients who have virtually exsanguinated before getting to the operating room and the incidence of associated major injuries of other organs.

A number of factors are responsible for the reduction in mortality when major he-

patic injuries are treated by resection. Resectional therapy results in control of hemorrhage. The greatest threat to life is hemorrhage. Packing and suturing are ineffective methods of controlling bleeding from deep lacerations or shattered portions of the liver; resection of the involved area along segmental or lobular planes is precise and effective. Packing or suturing, even if initially effective, are accompanied by a high incidence of recurrent hemorrhage. *In the present series of hepatic resections for trauma there were no instances of continued or recurrent bleeding following operation.*

The second important feature is that most devitalized liver tissue is removed. Necrotic tissue plays a role in recurrent bleeding, biliary fistula formation, sepsis and abscess formation. This is apparent in deep lacerations of the liver treated by packing or suturing. Necrotic tissue, blood and bile are dammed up in the wound and the pressure of the packing causes additional necrosis of liver. Restoration of the surface of the liver by suturing results in the same difficulties in the depths of the wound, sepsis, erosion of bile ducts and blood vessels with hemorrhage into the peritoneal cavity or biliary tree (hemobilia), biliary fistula, intrahepatic or subphrenic abscess.

Mortality and morbidity with severe liver injuries is influenced by the presence of associated injuries. Preoccupation with the treatment of obvious associated injuries is a pitfall in management. Successful treatment requires prompt and vigorous action. Factors in successful management include: large amounts of blood and fluids administered via two intravenous routes in the upper extremities—in massive blood loss from caval injuries temporary caval occlusion may be required. Early operative intervention is imperative. Waiting until blood volume is restored may be fatal, bleeding may exceed the rate of replacement. Cardiac resuscitation may be required in any stage of treatment. An adequate incision is important and a thoracic extension is frequently required for exposure. Upon opening the peritoneum, control of hemorrhage is paramount. Valuable technics include packing the hepatic wound and temporary occlusion of the hilar vascular structures. Hemorrhage from caval lacerations can often be controlled by tamponade; a partially occluding clamp to the vena cava may be required. Occlusion or partial occlusion of the vena cava carries the hazard of reducing central venous return to the point at which cardiac arrest occurs. After controlling hemorrhage, the severity of the hepatic injury can be assessed. In major deep lacerations, bursting injuries or large central injuries of the liver, segmental or lobar resection is indicated. All hepatic injuries do not require resection, in fact, most do not. Central injuries of the liver may be difficult to assess or detect. Operative cholangiography and hepatic arteriography can be helpful in this evaluation as demonstration of an injury to a major artery or bile duct serves as a guide to resection.

The technics of resection have been described in detail in a number of reports.[7, 19, 20, 21, 22, 23] Hepatic artery anomalies are frequent. During resection the bile duct to remaining liver tissue should be carefully protected—a probe placed in the duct via a choledochotomy is a valuable aid. Hilar ligation results in a line of demarcation which indicates the plane for transecting liver parenchyma. In resections for trauma it is often possible and safer to transect the liver about one centimeter short of this plane and thereby avoid injury to the middle hepatic vein. Blunt transection of the liver with ligation and division of vascular ductile structures as encountered minimizes further blood loss.

After resection the cut surface of the liver should be covered with omentum, a flap of peritoneum or the falciform ligament. In our series Gelfoam was at times used to

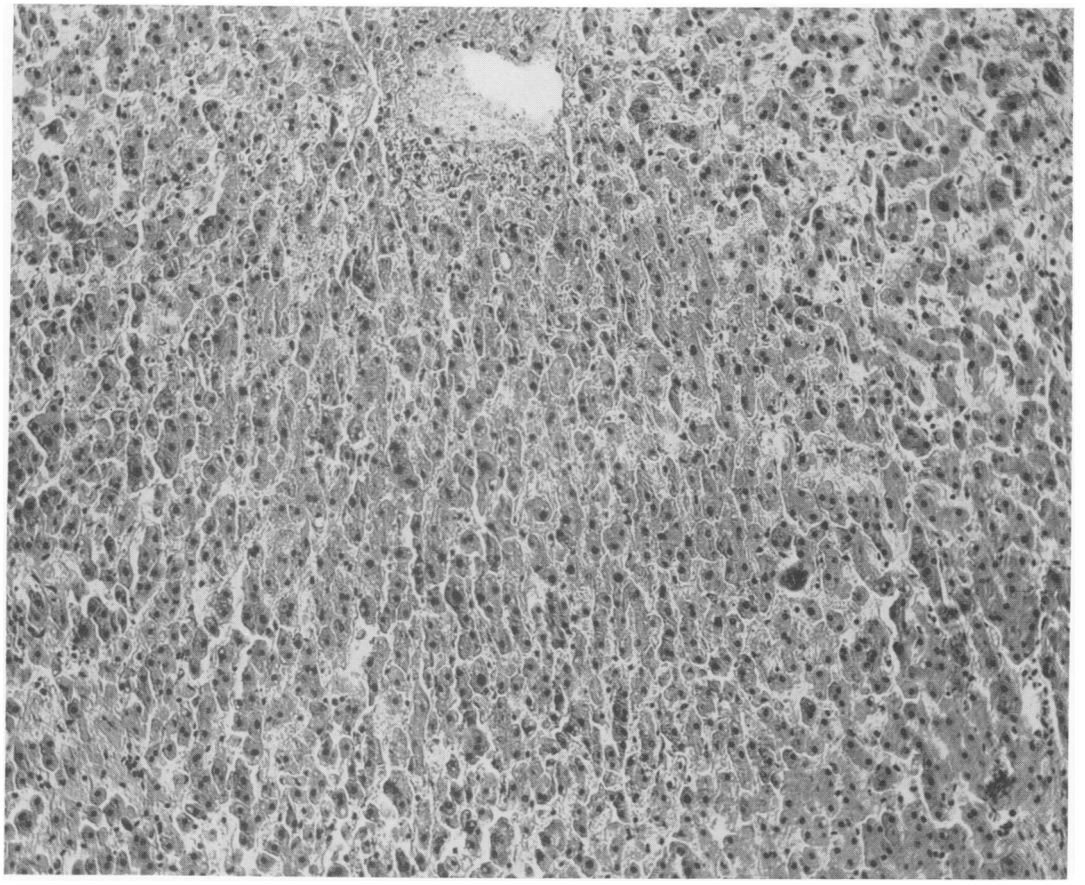

FIG. 7A. Photomicrograph of liver at time of right lobectomy.

cover raw liver surface, but its use is condemned as a foreign body likely to promote infection.[12] We have not encountered such a deleterious effect. However, the surgical principle of avoiding foreign material where infection is frequent is sound. Autogenous covering materials such as omentum or peritoneum are preferable. The packing of lacerations with Gelfoam or other foreign materials should be abandoned. We have had encouraging experiences with placement of a catheter attached to suction (i.e., Hemovac) into minor liver lacerations treated by suturing. This technic may obviate one of the hazards of this treatment.

Extensive drainage of the wound is essential so that infection from bile leakage or necrotic liver tissue can be minimized and recurrent hemorrhage promptly recognized and treated. Quattlebaum [22] stressed the importance of placing a soft tissue drain beneath the material used to cover the cut surface (omentum or peritoneal flap) to avoid pocketing of blood or bile. A sump drain just dependent to the area of resection has merit.

In 1963, Merendino [16] recommended biliary tract decompression with a T-tube or cholecystostomy tube in hepatic injury to lower intraductile pressure and avoid increases in pressure associated with coughing, etc. This principle has been widely accepted. Merendino acknowledged lack of evidence to prove that biliary tract decompression was beneficial and stated "only

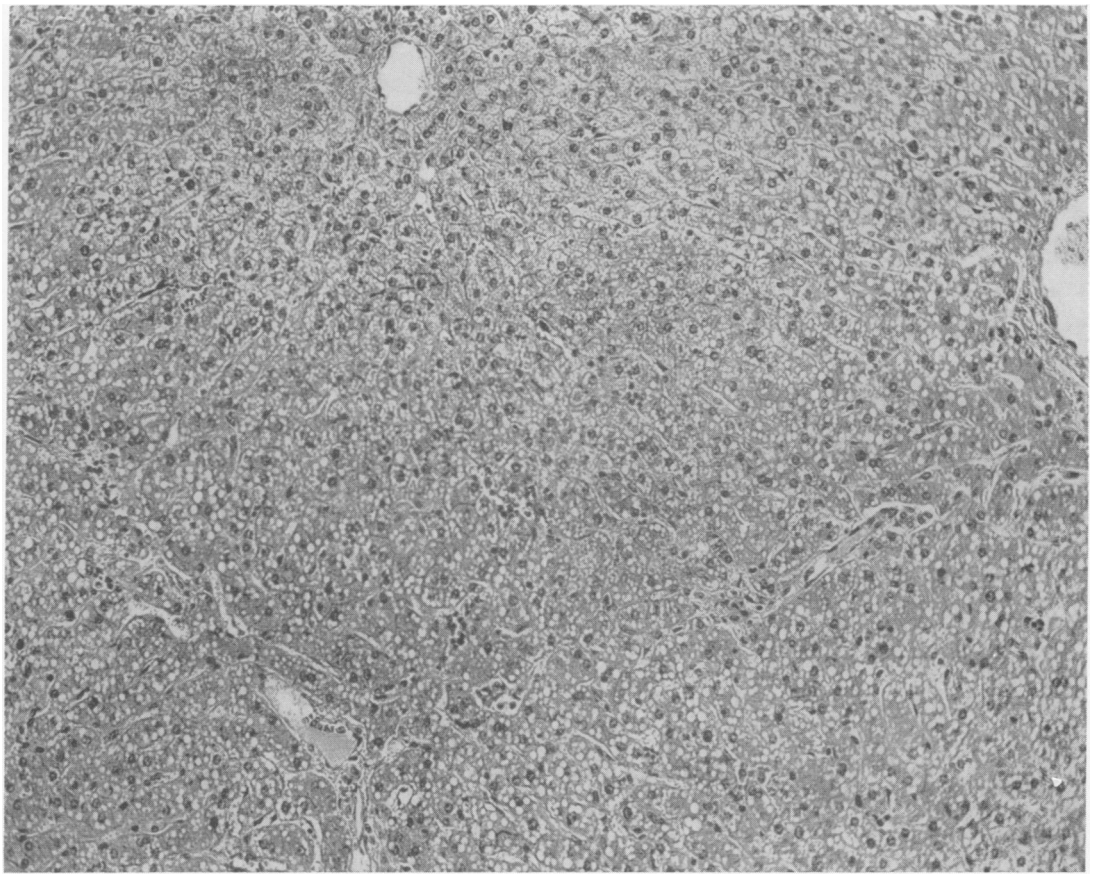

FIG. 7B. Photomicrograph of liver at time of death 6 days later. Fatty infiltration is apparent in the postmortem specimen as is some decrease in size of hepatocytes. Magnification ×200.

the rationale for its use appears clear." We used biliary tract decompression in 18 patients and find no proof that they fared better than patients without it. It was disturbing to find that all instances of stress ulcer occurred in the patients with biliary tract decompression; however, other factors, many with an ulcerogenic potential, were present in these patients. It is difficult to believe that partial biliary diversion plays a role in stress ulcer.

Finally, patients should be given parenteral antibiotics, a high caloric diet, Vitamin K and fresh blood transfusions if coagulation defects appear. Human serum albumen is often required. Pack advocates administration of small doses of steroids, as a stimulus to hepatic regeneration. We have had no experience with steroid therapy. The high incidence of stress ulcers in our experience prompted the institution of antacid therapy and oral feeding as soon as feasible in the postoperative period.

In addition to encouraging results in the majority of patients undergoing hepatic resection for trauma and benign tumors and in a few with malignant tumors there was another feature of the study which is of interest. There is little in literature concerning stress ulcer formation following major hepatic resection. McClelland and Shires reported one case in their series of 25 resections. However, in the series of hepatic resections reported by Quattlebaum, Mc-

Dermott, Longmire or Pack no mention of stress ulcer is made.[7, 8, 11, 19, 20, 21, 22] Nor is there any reference to stress ulcer as a complication following hepatic resection in books on liver disease by Schwartz and on hepatic trauma by Madding and Kennedy.[12, 23] There is considerable literature, much of it based on experimental animal studies, concerning hepatic disease as an ulcerogenic stimulus, Menguy and Eiseman summarized these reports.[15] In two of our patients fatty metamorphosis of the liver ensued during 4 to 6 days between hepatic resection and death. Both patients had stress ulcers (Table 3). Fatty metamorphosis of the liver following massive liver resections in experimental animals is well known.[2, 5] In experimental animals the fat content of the liver may double within 10 hours after major hepatic resection. These animals have alterations in liver function much like those encountered in patients undergoing extensive resections, i.e., hyperbilirubinemia, elevation in serum alkaline phosphatase and decrease in prothrombin levels. In experimental animals as remaining liver regenerates fatty changes disappear and liver function returns to normal. The cause of the fatty infiltration following hepatic resection is not known. Our experience leads us to speculate that after massive hepatic resection in man the remaining liver undergoes fatty metamorphosis during a period which coincides with alterations in liver function and during this period stress ulcers are likely to occur. Further study of this hypothesis is underway.

Summary

A series of 50 major hepatic resections have been reported. The indications for resection were severe liver injuries in 24 patients and tumor in 23 patients, biliary atresia in two and an abscess in one.

Sixty-six per cent of patients in the trauma group are living and well, an improvement over previous experience treating these injuries by packing or suturing. There were eight deaths (33%) in emergency resections for trauma, four in the operating room secondary to exsanguinating hemorrhages. Associated injuries of other organs played a role in the mortality rate.

Operative mortality in resections for tumor was 23%. Excellent results were obtained in the patients with benign tumors. Three of fourteen patients with malignant tumors are longterm survivors.

Factors associated with successful hepatic resection have been described. A high incidence of stress ulcers following hepatic resection has been reported. This complication may be related to fatty metamorphosis of the liver which follows massive hepatic resection.

References

1. Baker, R. J., Taxman, P. and Freeark, R. J.: An Assessment of the Management of Nonpenetrating Liver Injuries. Arch. Surg., **93**: 84, 1966.
2. Bengmark, S., Olsson, R. and Svanborg, A.: Fat Infiltration after Partial Hepatectomy. Acta Hepato-Splenologica, **2**:276, 1964.
3. Brunschwig, A.: The Surgery of Hepatic Neoplasm, with Special Reference to Right and Left Hepatic Lobectomies. Cancer, **8**:1226, 1955.
4. Goldsmith, N. A. and Woodburne, R. T.: The Surgical Anatomy Pertaining to Liver Resection. Surg. Gynec. Obstet., **105**:310, 1957.
5. Harkness, R. D.: Changes in the Liver of the Rat after Partial Hepatectomy. J. Physiol., **117**:267, 1952.
6. Healey, J. E., Jr.: Clinical-anatomic Aspects of Radical Hepatic Surgery. J. Internat. Coll. Surg., **22**:542, 1954.
7. Longmire, W. P., Jr. and Marable, S. A.: Clinical Experiences with Major Hepatic Resections. Ann. Surg., **154**:460, 1961.
8. Longmire, W. P., Jr.: Hepatic Surgery: Trauma, Tumors and Cysts. Ann. Surg., **161**:1, 1965.
9. Lortat-Jacob, U. L. and Robert, H. G.: Hepatectomie droite reglee. Press Med., **60**:549, 1952.
10. McClelland, R., Shires, T. and Poulos, E.: Hepatic Resection for Massive Trauma. J. Trauma, **4**:282, 1964.
11. McDermott, W. V., Jr. and Ottinger, W.: Elective Hepatic Resection. Amer. J. Surg., **112**:376, 1966.
12. Madding, G. F. and Kennedy, P. A.: Trauma to the Liver. Philadelphia, W. B. Saunders, Co., 1965.
13. Mays, E. T.: Bursting Injuries of the Liver. Arch. Surg., **93**:92, 1966.
14. Mays, E. T.: Management of Severe Liver Trauma. Surg. Gynec. Obstet., **123**:551, 1966.

15. Menguy, R. and Eiseman, B.: Extragastric Factors Associated with Peptic Ulcer. Current Problems in Surgery. Chicago, Year Book Medical Publishers, Inc., August, 1964.
16. Merendino, K. A., Dillard, D. H. and Cammock, E. E.: The Concept of Surgical Biliary Decompression in the Management of Liver Trauma. Surg. Gynec. Obstet., 117: 285, 1963.
17. Mikesky, W. E., Howard, J. M. and DeBakey, M. D.: Injuries of the Liver in 300 Consecutive Patients. Internat. Abstr. Surg., 103:323, 1956.
18. Monaco, A. P., Hallgrimsson, J. and McDermott, W. V., Jr.: Multiple Adenoma (hemartoma) of the Liver Treated by Subtotal (90%) Resection; Morphological and Functional Studies of Regeneration. Ann. Surg., 159:513, 1964.
19. Pack, G. T. and Baker, H. W.: Total Right Hepatic Lobectomy. Ann. Surg., 138:253, 1953.
20. Pack, G. T. and Islami, A. H.: Operative Treatment of Hepatic Tumors. Clin. Sympos., 16:35, 1964.
21. Quattlebaum, J. K.: Massive Resection of the Liver. Ann. Surg., 137:787, 1952.
22. Quattlebaum, J. K. and Quattlebaum, J. K., Jr.: Technic of Hepatic Lobectomy. Ann. Surg., 149:648, 1959.
23. Schwartz, S. I.: Surgical Diseases of the Liver. New York, McGraw-Hill Book Co., 1964.

Discussion

Dr. William T. Rumage, Jr. (Louisville): I appreciate the opportunity of having seen Dr. Foster's manuscript. I endorse some of the points that Dr. Foster has made but differ with him on just a couple of, perhaps, minor issues. Dr. Mohammad Atik of the University of Louisville has developed a protocol for the care of liver injuries. Dr. Atik came to us from Dr. Cohen's group in New Orleans.

(Slide) I want to talk primarily about the use of hepatic resection for trauma. We use, almost routinely, the thoracic extension of the abdominal incision to adequately visualize the attic of the peritoneal cavity. We like to use kanamycin intraperitoneally, and prefer to occlude temporarily the hepatic artery and portal vein until we are reasonably certain of the extent of the resection that is necessary.

(Slide) The next slide brings to your attention the use of the sump drains in the subhepatic space, and postoperatively, you can then irrigate this area with antibiotic solution.

One representative case: (slide) is a patient who was referred to a plastic surgeon for obvious reasons. His entire face has been depressed with fractures of all facial bones; he has lost the vision in his left eye, and the plastic surgeon asked for a general surgical consultation. A tracheostomy was done on this patient.

(Slide) The next slide shows injury to the liver. In addition to facial lacerations, the patient had an extensive fracture of the left femoral shaft and hip. The orthopedic, ocular and plastic surgeons were all working on this fellow. After the tracheostomy, I examined his abdomen and could feel no particular problem. I encouraged them to continue and get their jobs done, which took almost 5 hours. The patient had multiple contusions of the abdomen and was examined repeatedly during operation. His abdomen continued to be soft. However, after 5 hours of operative procedures, the patient went into profound shock. We opened his abdomen and found extensive laceration of the liver.

In Dr. Foster's manuscript, it was emphasized that delayed shock is not an uncommon finding in patients with blunt trauma to the liver and they will go as long as 10 to 12 hours without shock.

(Slide) The next slide shows the gross section. Resection of the liver is pointed out because frequently the surface injury is not fully representative of the injury underneath. You can see in the bottom slide several very large defects within the parenchyma of the liver.

I am sure that more resections will be done for blunt trauma. However, I encourage you to be rather cautious about extending resections to patients, particularly those with punctures and stab wounds of the liver. We have had good results with these patients in the past without resection. I believe that if resection is applied to these patients indiscriminately, we may lose some or they will have a prolonged morbidity that is unnecessary.

Dr. Harwell Wilson (Memphis): I would like to emphasize the importance of this newer anatomical knowledge with reference to the segmental blood supply of the liver. This has made possible (as Dr. Foster and his associates have mentioned) major hepatic resections due to a clear understanding of the blood supply of the liver, just as knowledge of the blood supply of the lung made segmental resection possible.

This same knowledge regarding blood supply of the liver has been useful in exposing the intrahepatic ducts of the liver in patients suffering from stricture of the common bile duct. The use of this method of massive resection is much better than massive packs in certain patients with trauma that we have seen.