Management of 1000 Consecutive Cases of Hepatic Trauma (1979–1984)

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From 1979 to 1984, 1000 patients with hepatic injuries were treated at one urban trauma center. Penetrating wounds were present in 86.4% of patients. Simple hepatorrhaphy, use of topical hemostatic agents, or drainage alone were the only forms of therapy required in 881 patients, and 65 (7.3%) died. Extensive hepatorrhaphy or hepatotomy with selective vascular ligation, resectional debridement or resection, selective hepatic artery ligation, or perihepatic packing were required, often in combination, in 119 patients, and 40 (33.6%) died. Uncomplicated recoveries occurred in 798 of the 918 patients (86.9%) surviving greater than 48 hours. In the remaining 13.1% of patients, intra-abdominal abscess formation was the most common late complication (32/918 = 3.5%). Mortality for the entire series of 1000 patients was 10.5%, with 78.1% (82/105) of all deaths occurring in the perioperative period from shock or transfusion-related coagulopathies.

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IN PATIENTS with abdominal trauma, the liver is the most commonly injured organ. As injuries to the porta hepatis, hepatic veins, or retrohepatic vena cava are rare, even in the busiest trauma centers, the hepatic parenchymal injury remains the primary problem for the surgeon.

The management of parenchymal injuries in this country has continued to evolve since the early descriptions of compression of the hepatoduodenal ligament, use of mattress sutures, and insertion of gauze packing into hepatic lacerations 80 years ago.[1–4] Certain forms of treatment that have been popular in the past are now used infrequently. Included among these are the use of deep mattress sutures, intrahepatic packing, frequent lobectomy, and hepatic artery ligation. In contrast, techniques such as hepatotomy with selective vascular ligation,[5,6] limited resectional debridement,[7] and perihepatic packing[8,9] have gained favor.

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This is a report of a recent 5.5-year experience with 1000 consecutive patients with hepatic injuries. All patients were treated at the Ben Taub General Hospital, a Level I trauma center affiliated with the Baylor College of Medicine in Houston, Texas, from 1979 to 1984.

Methods

Resuscitation and treatment of all patients with hepatic injuries during this time interval were similar.[8–10] Symptomatic patients with blunt trauma to the abdomen, stab wounds to the lower chest, anterior abdomen or back, or gunshot or shotgun wounds with peritoneal traverse were taken to surgery after resuscitation with warm crystalloid solutions and type-specific packed red blood cells.

Asymptomatic patients with blunt trauma to the abdomen and an altered sensorium or head or spinal cord injuries were evaluated by the technique of an open diagnostic peritoneal tap and, if necessary, lavage. Asymptomatic patients with stab wounds to the anterior abdomen that were found to have penetrated the peritoneum on local wound exploration were also evaluated by the technique of an open diagnostic peritoneal tap/lavage.[11]

Intravenous pyelography was performed in stable patients with hematuria after blunt trauma to the abdomen and in all patients with penetrating wounds to the abdomen. Perioperative antibiotics were given to patients with blunt trauma to the abdomen if the surgeon chose to do so and to all patients with perforating wounds to the intra-abdominal gastrointestinal tract other than the esophagus under a rigidly controlled protocol.[12]

In patients who were near death with a massively distended abdomen secondary to a hemoperitoneum, either

emergency center or operating room thoracotomy was occasionally performed to allow for cross-clamping of the descending thoracic aorta prior to or concurrent with celiotomy.[13]

After transfer to the operating room the patient's anterior trunk was prepared and draped from the chin to the knees. A midline incision was used to enter the abdomen, and all blood and fecal material evacuated manually and by a suction device. If gross hemorrhage without fecal contamination was present, a "BRAT" (Baylor Rapid Autotransfusion device) has been used in recent years to aspirate free blood from the abdomen as the magnitude of the hepatic injury was assessed. Visualization of the injury was improved by division of the round and falciform ligaments and insertion of a wide upper abdominal self-retaining retractor. If the hepatic injury was extensive, a Pringle maneuver was applied and manual or laparotomy pad compression was used until the anesthesiologist, scrub nurse, and blood bank were prepared for a major hepatic operation.

If minor hepatic lacerations were present, hemostasis was generally obtained by use of compression, application of topical agents, or suture hepatorrhaphy utilizing O-chromic sutures applied in a horizontal mattress or running fashion. With major hepatic lacerations, hepatotomy by finger fracture with selective vascular ligation or clipping, as described by Pachter et al., was performed.[5,6] Hepatotomy was also performed by connecting missile entrance and exit sites when active hemorrhage was noticed from either. In the last year of the review (1984), the insertion of omental packs into hepatotomy sites was first performed with some frequency.[5,6,14] When large peripheral sections of the liver were devitalized by shotgun wounds or blunt trauma, resectional debridement with selective vascular ligation or clipping was used. Left lateral segmental resection was occasionally necessary for avulsion-type injuries lateral to the falciform ligament; however, formal anatomic lobectomy was rarely required. Selective extrahepatic artery ligation was used only when selective intrahepatic vascular ligation could not control arterial bleeding in deep lacerations as the Pringle maneuver was released, but the reapplication of a Pringle maneuver appeared to slow the rate of hemorrhage.[15,16] Perihepatic packing with laparotomy pads was used when nonmechanical hemorrhage resulted in diffuse oozing from hepatic suture lines or raw surfaces or when large, nonexpanding, unruptured subcapsular hematomas were present.[8,9,17] Perihepatic packs were most commonly removed at a reoperation 3.7 days after the original operation for trauma.[9]

In general, the Pringle maneuver was released just prior to closure of the abdomen in order to assess the results of the various techniques of hepatic hemostasis. No adjuncts such as intravenous steroids or cooling the liver with iced Ringer's lactate solution were used to protect the liver during the period of Pringle-induced ischemia.[6]

Open Penrose drains were inserted after the repair of moderate and severe lacerations, after debridement of devitalized hepatic tissue, or after segmentectomy or lobectomy. When major lacerations were repaired or when extensive debridement or resection was performed, closed suction drains were inserted above and below the injured lobe as well. Open Penrose drains were removed when drainage ceased, usually between 2 and 7 days. Closed suction drains were also removed when drainage ceased, usually between 2 and 4 days.

Postoperative intraperitoneal abscesses were generally diagnosed by clinical examination and ultrasound. The first attempt at draining such a collection was by reopening an old right upper quadrant drain site, if possible. In the last 2 years of the review, percutaneous drainage of perihepatic fluid collections was occasionally performed by invasive radiologists.

The names of all patients undergoing celiotomy for hepatic trauma were recorded in a running log maintained by the Department of Surgery at the Ben Taub General Hospital. Data reviewed in this study were retrieved from this running log and from individual patient charts in patients undergoing a "complex" repair (to be described).

Results

From January 1979 to July 1984, 1000 patients or 183 patients/year with hepatic injuries were treated (Table 1). Hepatic injuries were seen in 25–30% of all patients who underwent celiotomy for abdominal trauma during this time interval. The most common mechanism of injury was a penetrating wound (86.4%), and gunshot wounds or shotgun wounds accounted for nearly 61% (525/864) of these (Table 2). Male patients predominated (91.2%), as in all trauma series.

There were 30 patients who arrived in the emergency center with profound hypotension or a state of cardiac arrest. All of these patients required an emergency center thoracotomy for cross-clamping of the descending thoracic aorta and, on occasion, internal cardiac massage prior to transfer to the operating room. Another 15 patients required an operating room thoracotomy at the time of laparotomy for similar reasons.

For purposes of analysis, patients were arbitrarily placed into one of two groups, "simple" or "complex" repair, depending on the type and extent of the *hepatic repair* required rather than on the extent of the hepatic injury itself. This type of analysis was utilized because of the present lack of agreement about classification of hepatic injuries in trauma centers.[6,7,16,17] The majority (88.1%) of patients in this series was treated by simple repairs, defined as suture hepatorrhaphy (640 patients), drainage only (202

TABLE 1. *Injuries per Year*

Year	Number (%)
1979	182 (18.2)
1980	196 (19.6)
1981	177 (17.7)
1982	194 (19.4)
1983	166 (16.6)
1984	85 (8.5)*

* January to July.

patients), or application of a topical agent (Table 3). In 37 patients no specific treatment was given for the hepatic injury because of the minor nature of the wound or because of the magnitude of other intra-abdominal injuries. Mortality in the simple repair group was 7.3% (65/881).

In 119 patients (11.9%) advanced techniques of hemostasis such as extensive hepatorrhaphy or hepatotomy with selective vascular ligation, resection or resectional debridement with selective vascular ligation, selective hepatic artery ligation, or perihepatic packing were required, often in combination (Table 4). Included in this group were 45 patients with perihepatic packing (22 alone, 23 with other therapy) and six patients with selective hepatic artery ligation (one alone, five with other therapy).

Pringle times were not accurately recorded during the first 3 years of this review. In recent years, Pringle times of 30–60 minutes were routine for most patients who required complex repairs. Pringle times greater than 60 minutes were recorded for at least five patients on one author's (DVF) surgical service during the last 2 years of the review. Three of these patients survived, while two died from hemorrhagic shock.

The average operative blood replacement in this group was 14.8 units. In a subgroup of these patients in whom the information was available, the average closed suction drainage was 544 ml on postoperative day 1 and 280 ml on postoperative day 2. In contrast, open Penrose drainage averaged 155 ml on postoperative day 1 and 63 ml on postoperative day 2. Mortality for the 119 patients in the complex group was 33.6% (40/119).

Isolated hepatic injuries occurred in 277 patients (27.7%). Associated injuries to one or two organs occurred in 418 patients (46.8%), while associated injuries to three or more organs (3–9) occurred in 255 patients (25.5%). Associated injuries were, therefore, present in 723 patients (72.3%) and most commonly were to the diaphragm (29.6% of all patients), major vascular channels (20.4%), stomach (15.9%), lung (14.9%), and colon (13%).

Uncomplicated recoveries occurred in 798 of the 918 patients (86.9%) who survived more than 48 hours. In the remaining 13.1% of patients (120/918), intra-abdominal abscess formation (32 patients or 3.5% of patients surviving more than 48 hours) was the most common late complication (Table 5). When the group who developed intra-abdominal abscesses was examined, hepatorrhaphy, the most common type of repair in the series, had been performed in 23 of 32 patients (71.9%), drainage only in four patients, resection in two, and miscellaneous procedures in three others. One long-term survivor developed a common bile duct stricture after transfer to another hospital and required a biliary drainage procedure. This patient had suffered a bilobar gunshot wound, was profoundly hypotensive both during and immediately after operation, and had undergone a common hepatic artery ligation in a last desperate attempt to obtain control of hepatic hemorrhage. He is the only survivor known to have developed this complication related in part to the application of a Pringle maneuver.

Mortality for the entire series of 1000 patients was 10.5% (105/1000), with 78.1% (82/105) of all deaths occurring in the perioperative period from shock or transfusion-related coagulopathies. All 45 patients who had an emergency center or operating room thoracotomy per-

TABLE 2. *Mechanism of Injury*

Mechanism	Number (%)
Penetrating	
GSW	506
SW	339 (86.4)
SGW	19
Blunt	136 (13.6)

GSW = gunshot wound; SW = stab wound; SGW = shotgun wound.

TABLE 3. *Simple Repair or Drainage*

Technique	Number (%)
Hepatorrhaphy	640 (64.0)
Drainage only	202 (20.2)
No repair	37 (3.7)
Topical agent	2 (0.2)
Total	881 (88.1)

TABLE 4. *Complex Repair*

Technique	Number (%)	SHAL	A/C	Pack
Hepatorrhaphy, hepatotomy	54 (5.4)	3	5	12
Resectional debridement, resection	36 (3.6)	2	5	11
Packing alone	22 (2.2)	—	1	—
Miscellaneous	7 (0.7)	1	1	—
Total	119 (11.9)	6	12	23

SHAL = selective hepatic artery ligation; A/C = atriocaval shunt; Pack = perihepatic packing.

formed in addition to celiotomy died, thereby accounting for 42.9% (45/105) of all deaths. Late deaths occurred in 23 patients (21.9% of all deaths), 18 of which (78.3%) were secondary to renal failure, respiratory failure, or multiple organ failure. Included in this group was a 23-year-old man who developed extensive hepatic necrosis after common hepatic artery ligation, portal vein repair, and multiple hepatorrhaphies for a gunshot wound traversing the porta hepatis and both lobes of the liver. This patient, who died on the 47th postoperative day with multiple organ failure, is one of only two individuals in the series with hepatic necrosis as the major cause of death. The other patient, previously described in another publication,[8] died from hepatic necrosis related to attempted pack control of a perforation in an intrahepatic vein.

TABLE 5. *Complications in 918 Patients Surviving for More than 48 Hours*

Complication	Number (%)
Abscess	32 (3.5)
Bleeding	25 (2.7)
Sepsis	17 (1.9)
Pneumonia	17 (1.9)
Renal failure	15 (1.6)

Discussion

The approach to hepatic injuries during the 30-year period after World War II remained relatively constant. Pringle times were limited to 15–20 minutes,[18] intrahepatic gauze packing was replaced by large mattress sutures for control of hemorrhage,[19] major resection was frequently employed,[20,21] and open Penrose drainage was mandatory.[18,19] In the last 10 years of this period, selective hepatic artery ligation became a popular form of treatment as well.[15,16]

As the volume and magnitude of civilian hepatic injuries increased, it became obvious that some of the approaches previously described were not scientifically sound, did not control parenchymal hemorrhage, or resulted in excessive morbidity and mortality. For these reasons, a significant evolution in therapy has occurred during the past 5–10 years. Some of the most notable changes include the extension of Pringle times, the use of hepatotomy with selective vascular ligation, the insertion of omental packs into hepatotomy sites or liver fractures, the selective use of perihepatic packing, and decreased use of open Penrose drainage.

Extension of Pringle Times

Carl Johann Langenbush (1846–1901), one of the most noted German surgeons of his time, is referred to by Pringle in his classical article in 1908.[4,22] In Langenbuch's *Chirurgie der Leber und Gallenblase,* Volume 2, published in 1897, the origins of a limited time interval for clamping of the hepatoduodenal ligament are clearly stated:

> In Gluck's second work . . . the ligation of the porta hepatis caused the immediate collapse in rabbits, but if the ligature was released within 10 or so minutes then the animals would recover.[23]

While Pringle was aware of Gluck's work, his own experiments in dogs did not result in the same dismal results. In 1908, Pringle noted the following:

> The (four) animals survived the temporary (one hour) obstruction of the portal circulation and did not appear to have been in any way injured by it.[4]

It is clear that Pringle's classical article did *not* establish a limited period of time for clamping of the hepatoduodenal ligament in man. Rather, continued experiments on animals with portal bacteremia in this country helped perpetuate the Pringle myth.[24,25]

In recent years, careful documentation of prolonged Pringle times by trauma surgeons such as Pachter,[5,6] elective hepatic surgeons such as Huguet,[26] and surgeons performing hepatic transplantation in many centers has made the former 15–20 minute time restriction invalid. Also, the more frequent use of arteriography after selective hepatic artery ligation has demonstrated extensive collateral flow to the liver even with the main arterial inflow permanently occluded.[27] The exact role of adjuncts such as intravenous steroids and topical cooling for protection of the liver during long clamp times in humans is unclear at present.[6]

In the patients reported in this series, Pringle maneuvers were not released to perfuse the liver at fixed time intervals during the time of repair. Rather, the Pringle maneuver was released only when hepatic hemostasis had been attained. The hypothermia associated with extensive transfusion and the excellent collateral flow to the liver if the supraceliac aorta is *not* clamped clearly protect the injured liver. As previously noted, only two patients had extensive hepatic necrosis as a cause of death in this review. In both, other factors, common hepatic artery ligation in one and inappropriate packing in the other, were most likely responsible.

Hepatotomy with Selective Vascular Ligation

As in the previous large review from this hospital, simple techniques of hemostasis and drainage were all that was required in over 85% of hepatic injuries that were treated.[28] This is undoubtedly a reflection of the large number of small caliber missile and superficial knife wounds seen in our urban population. When blunt trauma is more common, a greater percentage of patients will require advanced techniques of hemostasis, as previously described.[29]

Mattress sutures passed deeply through lobar lacerations or around missile tracts are accompanied by two prob-

lems. The first is the frequent failure of the sutures to control hemorrhage, while the second is the extensive amount of hepatic necrosis that occurs underneath the tied sutures. This latter problem will, of course, be aggravated by a simultaneous ligation of the hepatic artery.[30]

Hepatotomy with selective vascular ligation rather than the insertion of mattress sutures is now frequently utilized to control hemorrhage from deep lacerations or missile tracts.[5-7,29,31] With a Pringle maneuver in place, long thin retractors can be placed into a lobar laceration to allow for exposure of deeply placed bleeding vessels. When missile tract bleeding is occurring, the entrance and exit sites may have to be connected using finger fracture or another blunt technique for division of the hepatic parenchyma. Selective vascular ligation can then be performed using clips or sutures. In this series, either 2-0 or 3-0 chromic or silk sutures were frequently utilized. On occasion, large intralobar branches of the hepatic veins can be repaired with polypropylene sutures. Failure to control hemorrhage from deep lacerations or missile tracts with a Pringle maneuver in place strongly suggests the presence of injury to the retrohepatic vena cava or major hepatic veins behind the lobe.[6] Proper use of hepatotomy should significantly lower the incidence of major lobar resection in any center, though not all agree with this approach.[32] As noted previously, major resection or resectional debridement was used in only 3.6% of patients in this series.

Omental Pack

The use of a viable pedicle of omentum loosely placed into deep lobar lacerations or hepatotomy sites after selective vascular ligation has gained widespread use since its introduction by Stone and Lamb in 1975.[14] Without the insertion of an omental pack, the surgeon once again would have to consider closing lobar lacerations or hepatotomy sites with mattress sutures, which would cause parenchymal necrosis. Also, postoperative drainage would likely be greater from parenchymal surfaces if they are not covered in some fashion. As omental packs were used routinely only in the last year of this series, their exact role in maintaining the low incidence of postoperative perihepatic sepsis (3.5%) is unclear. Pachter's data are strongly suggestive of a beneficial effect in patients with severe injuries of the liver.[6]

Perihepatic Packing

Since 1975, there have been at least six published reports on the use of perihepatic packing, primarily with dry laparotomy pads, to control nonmechanical bleeding from exposed hepatic surfaces or suture lines.[8,9,34-37] At the present time, the major indication for perihepatic packing is the presence of transfusion-induced coagulopathies, while the major contraindication is the presence of active bleeding from large intrahepatic and retrohepatic vessels.[9]

The use of packs in this series was restricted to only the most severely injured patients. In half of these patients, diffuse oozing from parenchymal surfaces or suture lines after repair was the indication. The remaining half required packing as the sole treatment of the hepatic injury because of the magnitude of other intra-abdominal injuries, the presence of an early operative coagulopathy related to profound shock in the prehospital period, or the "irreparable" nature of the hepatic injury.

Based on an experience with 66 patients with perihepatic packing reported elsewhere, dry laparotomy pads appear to create the most effective hepatic tamponade.[9] When packs are removed at a reoperation 3–4 days after insertion, the abdomen should be irrigated, drain sites changed, and the injured liver reinspected for satisfactory hemostasis. The judicious use of packs in a highly selected group of patients with hemostatic failure should lead to survival rates of 60–90%.[9]

Drainage

Drainage after hepatic trauma has been controversial for over 80 years.[1] While routinely practiced after World War II,[7,38] recent reports have strongly suggested that open Penrose drainage or even a closed drainage system is not necessary in the majority of patients sustaining minor or modest hepatic trauma.[39-41] In the two prospective studies reported to date, the incidence of perihepatic sepsis was higher in the group that was drained, though neither study was perfectly randomized.[40,41]

It is doubtful that minor or modest hepatic injuries, the most common noted in this large series, need to be drained. When larger lacerations are present or a hepatotomy or resectional debridement has been performed, closed suction drains will probably eliminate most early postoperative fluid collections. As previously noted, these drains were most effective in the "complex" group of patients in this series; however, open Penrose drainage was also used in these patients. This combination in a selected group of patients was clearly effective in maintaining the low incidence of perihepatic abscesses noted in the series.

Conclusion

From a review of the operative treatment of 1000 patients with hepatic injuries over a recent 5.5-year period, the following conclusions can be drawn: (1) When penetrating wounds are the most common cause of hepatic injuries, simple techniques of hemostasis or drainage suffice in approximately 90% of patients. (2) Complex hepatic injuries not involving the retrohepatic vena cava can usually be managed by hepatorrhaphy, hepatotomy, resectional debridement, or packing. Lobar resection or hepatic

artery ligation were required in less than 3.5% of all patients in this review. (3) Intra-abdominal abscess formation is the most common complication after major hepatic trauma. (4) Mortality rates for hepatic injuries have stabilized at approximately 10%, with hepatic hemorrage or transfusion-associated coagulopathies accounting for greater than 75% of all deaths. (5) Late deaths after hepatic injuries are almost always due to single or multiple organ failure, often associated with the original state of shock and magnitude of injury.

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Discussion

DR. CHARLES E. LUCAS (Detroit, Michigan): Dr. Feliciano and his coworkers have compiled a gigantic series on liver injury. During the years when Detroit Receiving Hospital saw most of the trauma in Detroit and street drug traffickers were fighting over territorial control, we averaged 127 liver injuries per year. The Houston team is treating almost 200 per year.

This manuscript is excellent. Decisions on triage, early therapy, resuscitation, and procedures during operation are well presented. The authors' vast experience highlights the efficacy of proper hepatorrhaphy for hemostasis in most injuries. Extrahepatic hepatic artery ligation is