The Use of Segmental Anatomy for an Operative Classification of Liver Injuries

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There is no universally accepted standard classification for liver injuries, and thus accurate comparison of reports on the subject is impossible. Most published reports on liver trauma suggest that both mobidity and mortality have a linear correlation with not only the amount of liver parenchyma injured but also with the magnitude of the surgical intervention. The exceptions are retrohepatic vein injuries, which have a mortality independent of associated parenchymal injury but should be integrated in any classification of liver injury. The classification proposed is based on the segmental anatomy of the liver (as defined by Couinaud):

Grade I—Injuries requiring no operative intervention, or any injury that requires operative intervention limited to a segment or less.

Grade II—Any injury that requires operative intervention involving two or more segments.

Grade III—Any injury with an associated juxta- or retrohepatic vein injury.

We reviewed all patients with isolated liver injuries during the past 5 years and prospectively reviewed all patients for the 6-month period from January to June 1988 and applied this classification. Sixty-nine patients had grade I injuries, with one death (1%); thirteen patients had grade II injuries, with six deaths (46%); and 13 patients had grade III injuries with nine deaths (69%). Postoperative morbidity was 7% for grade I, 57% for grade II, and 50% for grade III. This study supports the conclusion that morbidity and mortality from liver injury are directly related to the volume of parenchyma involved, and that segmental anatomy can be applied to define this volume. Mortality from retrohepatic vein injuries is independent of associated parenchymal injury. We believe that this proposed classification will provide a simple, reproducible, and accurate means for reporting and comparing liver injuries.

IN 1984, PACHTER ET AL.[1] stated 'confusion continues to plague the surgical literature with regard to the classification of hepatic injuries, rendering comparison of different reports virtually impossible.' A review of six reports of liver injuries[1-6] justifies this statement because all six reports used a different methodology in presenting results (Table 1). Interestingly two different institutions reporting series of liver injuries within a 5-year period used different classification schemes in each of their respective reports[1,3,7,8] and in four recently published trauma textbooks a classification scheme is found in only one.[9-12] That little progress has been made since Pachter's observation is evident.

Regardless of the confusion over classification, it is apparent that minor parenchymal liver injuries result in no liver-related mortality. Moore et al.[5] and Pachter et al.[7] reported no hepatic mortality from minimal parenchymal injuries, while Feliciano et al.[2] reported an overall mortality of 7% for simple liver injuries. In contrast major parenchymal injuries have a substantial liver-related mortality. Moore et al.[5] reported mortality rates ranging from 37% to 53% and Pachter et al.[7] reported a mortality rate of 83%. In addition injuries with associated retrohepatic vein involvement have a mortality rate ranging from 50% to 100%, and this mortality appears to be independent of parenchymal involvement.[13]

Our hypothesis initiating this work was that the morbidity and mortality of liver injuries are direct reflections of the amount of parenchyma involved; such involvement is either the result of the initial injury or the operative intervention used to manage the injury. We do not believe, as reported by others[2,5] that injuries can be classified solely on the extent of the initial injury. Rather the initial injury dictates the extent of surgical intervention, and subsequent operative injury is as important as the initial injury. Thus mortality will be determined by the amount of parenchyma involved at the end of the operation. As noted, the exceptions are injuries with retrohepatic vein involve-

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TABLE 1. *Currently Used Classifications of Liver Injuries*

Institution	Schemes
NYU	4 grades: injury dependent
Baylor	2 grades: operation dependent
U. of Md.	6 grades: injury, operation, and outcome dependent
LSUMC	Not classified
U. of Co.	5 grades: injury dependent
NYMC	6 grades: injury dependent

NYU, New York University Medical Center, New York, N.Y.
Baylor, Baylor College of Medicine, Houston, TX.
U. of Md., University of Maryland, Baltimore, MD.
LSUMC, Louisiana State University Medical Center, New Orleans, LA.
U. of Co., University of Colorado, Denver, CO.
NYMC, New York Medical College, Bronx, NY.

ment. What is required in a classification scheme is an objective and reproducible means to quantitate the volume of liver parenchyma involved in either the initial or subsequent operative trauma, and which includes those patients with retrohepatic vein injuries.

Definition

We feel the ideal classification of liver injuries includes the following:

(1) Objective and anatomic identification of the volume of parenchymal involvement that will subsequently define the hepatic related morbidity and mortality, and thus correlate with clinical outcome.
(2) Reproducibility from institution to institution.
(3) Prospective and retrospective applicability.

Guided by these principles, we define the following classification of liver injuries based on segmental anatomy as described by Couinaud.[14]

Grade I—Injuries requiring no operative intervention, or any injury that requires operative intervention limited to a segment or less.

Grade II—Any injury that requires operative intervention involving two or more segments.

Grade III—Any injury with an associated juxta- or retrohepatic vein injury.

Operative intervention is defined as any procedure or maneuver used in the treatment of the injury. The volume of liver involved with the interventions, as quantitated by segmental anatomy, thus classifies the injury. Multisegmental involvement of hepatic parenchyma that does not require operative intervention in multiple segments remains a grade I injury.

Materials and Methods

All patients admitted to the trauma service of the Department of Surgery, University of Miami School of Medicine from January 1 to June 30, 1988 were prospectively entered into the study. Demographic data, associated injuries, operative procedures, and clinical course were recorded. Liver injuries were graded according to the proposed definition. All patients underwent initial evaluation, resuscitation, operation, and postoperative management as dictated by institutional protocol and surgeon preference. At the same time, a retrospective review including all patients with a diagnosis of injury to the liver was undertaken for the 5-year period from 1982 to 1987. All records in which the segmental anatomy of the injury and operation were described or could be defined from the operative reports were evaluated. Those patients with isolated injuries to the liver were analyzed specifically. Patients with isolated extermity fractures were included for review. Excluded were all patients with combined thoracoabdominal injuries, concurrent nonhepatic intra-abdominal injuries, pelvic fractures, and head injuries. A total of 95 patients were identified from both studies and form the basis of this report.

Results

There were 68 male and 27 female patients ranging in age from 13 to 82 years. Fifty-six patients suffered penetrating trauma and 39 blunt trauma.

Grade I Injuries

Sixty-nine patients had grade I injuries. A variety of techniques were used in the treatment of these injuries (Table 2). There was one death (1%) in a patient with cirrhosis who bled to death after a percutaneous liver biopsy.

The morbidity rate for grade I injuries was 9% (Fig. 1). Four patients developed intra-abdominal abscesses, one of whom required reoperation and three who were drained percutaneously. One patient had prolonged bile drainage from a drain tract with a right ductal leak demonstrated on isotopic scan and this subsequently closed spontaneously. A wound infection developed in one patient.

TABLE 2. *Grade I Injuries: Operative Procedures*

Operative Technique	n
None	7
Drain only	23
Hemostatic agent	4
Hemostatic agent and drain	6
Suture	2
Suture and drain	20
Autologous patch	1
Autologous patch and drain	1
Hemostatic agent, suture, and drain	1
Debridement and drain	4

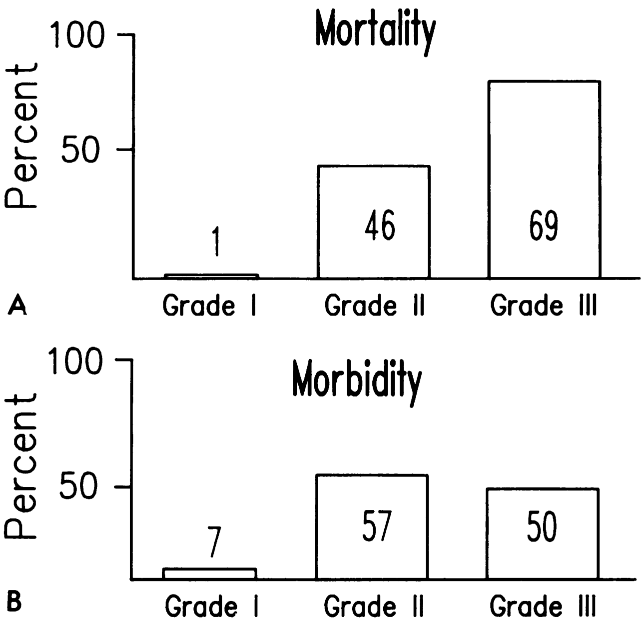

FIG. 1A and B. Mortality and morbidity for grade of injury.

Grade II Injuries

Thirteen patients had grade II injuries. In all patients, finger fracture and resectional debridement were performed with suture ligation of bleeding vessels. Five patients had finger fracture through two segments, six through three segments and two through four segments.

A total of six patients died (46%). Four patients died from exsanguination, of whom two had an attempt at packing. The remaining two patients died in the first postoperative week from intra-abdominal sepsis.

The morbidity rate for grade II injuries was 57%. Four of seven survivors developed intra-abdominal sepsis. One of these patients had been treated by packing. All required reoperation, one of them three times. The remaining three surviving patients recovered without significant complications.

Grade III Injuries

Thirteen patients had grade III injuries. Nine of these patients died (69%). Eight bled to death during operation and one died of sepsis on postoperative day 20. Four of the nonsurviving patients had associated parenchymal injury involving two or more segments.

Operative procedures included repair or ligation of the retrohepatic veins. A shunt was inserted in three patients and the finger fracture technique was used in two. One patient was packed after repair of the vein injury. Five patients survived operation, of whom one later died of sepsis. Four of the five surviving patients had associated parenchymal injury. The only patient without parenchymal injury was the one who died of sepsis.

The morbidity rate for grade III injuries was 50%. Complications developed in two of the four survivors. One patient required reoperation for bleeding on postoperative day 7, at which time resuture of the injured hepatic vein was performed. The other developed sepsis and multiple system organ failure.

Multiple Segment Involvement

The number of parenchymal segments involved for grades II and III injuries was determined (Table 3). There were no patients with more then four segments involved with grade II injuries. There were five patients with grade III injuries with parenchymal involvement of a segment or less. One patient with a grade III injury had six segments involved and the remaining patients with grade III injuries had between two and four segments involved. All survivors of grade III injuries had associated parenchymal injuries of at least two segments.

Discussion

The ability to reproduce clinical research requires standardization of classification. As an example, the introduction of the TNM system for the staging of cancer by the International Union Against Cancer and the American Joint Committee For Cancer Staging dramatically increased the ability of researchers to compare and contrast reports.[15,16] Unfortunately there still remain many areas in surgery without uniform classification schemes, and the field of trauma is no exception.

Many areas in the treatment of liver injuries remain controversial. Examples are the use of drains, shunts, ligation of hepatic arteries, and liver packing. Widely varied results have been reported with different approaches to liver injuries and it is impossible to accurately determine appropriate treatment. Central to this confusion is a lack of a standard classification for injuries of the liver.

Segmental anatomy of the liver was introduced by Couinaud[14] in 1954. In this scheme the liver is divided into eight segments based on end distribution of the portal

TABLE 3. *Liver Injuries: Grade and Patient Distribution*

Segments Involved	Grade I Patients (Deaths)	Grade II Patients (Deaths)	Grade III Patients (Deaths)
0	—	—	4 (4)
1	69 (1)	—	1 (1)
2	—	5 (2)	3 (1)
3	—	6 (3)	3 (1)
4	—	2 (1)	1 (1)
5	—	0 (0)	0 (0)
6	—	0 (0)	1 (1)
7	—	0 (0)	0 (0)
8	—	0 (0)	0 (0)
	69 (1)	13 (6)	13 (9)

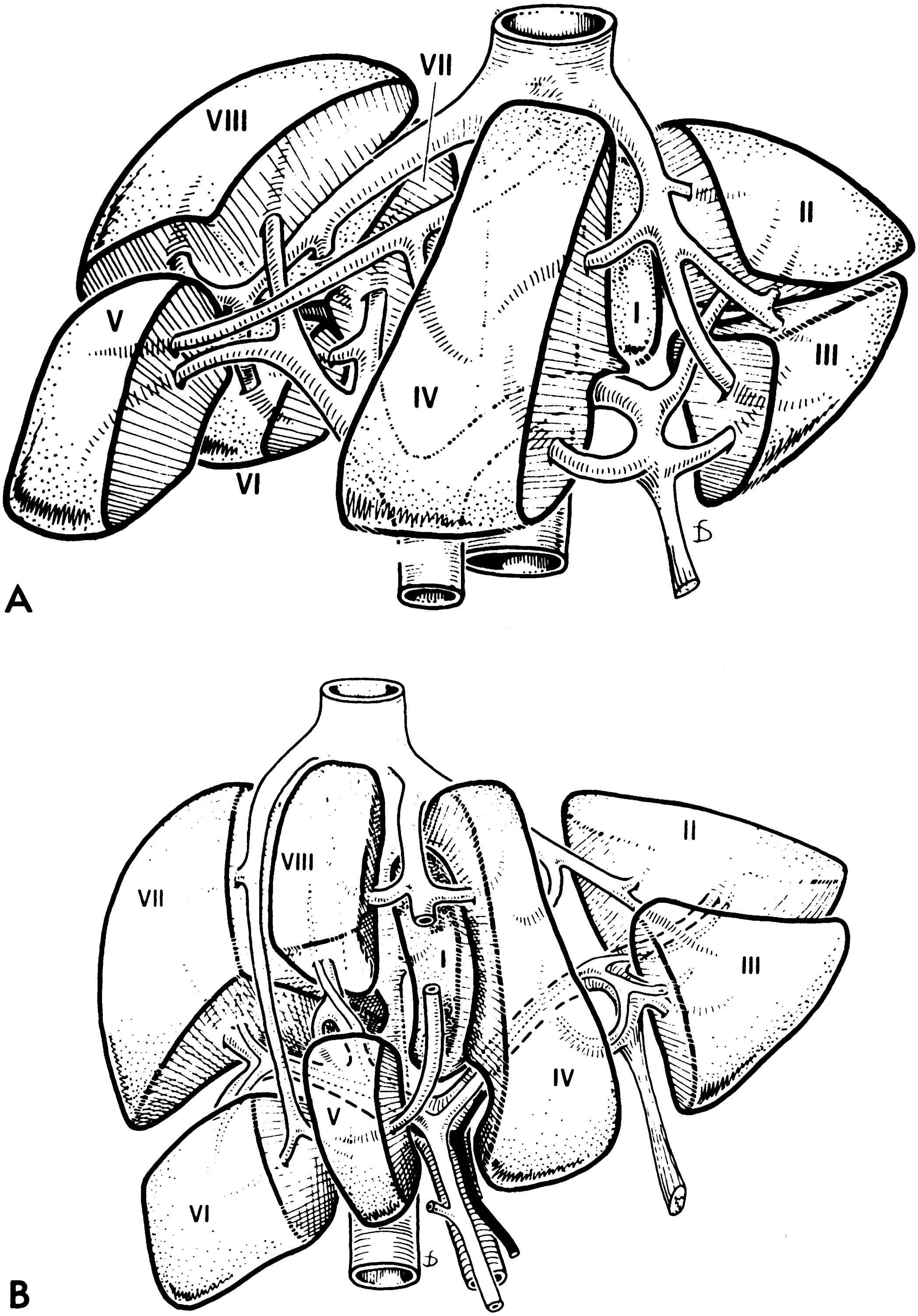

FIG. 2A and B. (A) *Ex vivo* positioning of the liver. Note that *ex vivo* positioning allows the right lobe to rotate laterally and posteriorly. This displaces the right lobe segments more laterally and posteriorly. (B) *In vivo* position of the liver as viewed intraoperatively. Reproduced with permission from *Surgery of the Liver and Biliary Tract* Ed. L. H. Blumgart, Churchill-Livingstone, Ltd. 1988.

vein. Segmental boundaries are defined by the hepatic veins. Segmental anatomy enables segmental resection based on vascular inflow and outflow to liver parenchyma and has been useful in sublobar resectional surgery. A distinct advantage of segmental anatomy in an operative classification of liver injuries is its simplicity and consistency. Correct application, however, must take into account the difference in orientation of the liver *in vivo* and *ex vivo* (Fig. 2).

Besides offering a constant anatomic definition, we believe that segmental anatomy of the liver can be used to quantitate the amount of liver parenchyma that, when injured or operatively involved, dictates subsequent mortality. In grade I injuries involving parenchymal volume of a segment or less there was one death. The mortality rate substantially increases with involvement of two or more segments. However, although our series is small, our findings do not suggest that mortality is proportional to number of segments involved over two. Rather mortality is the same for at least up to four-segment involvement. Thus parenchymal volume of two segments appears to define a critical volume that significantly influences mortality. There were no patients with grade II injuries with five or more segment involvement. Thus application of this scheme in the rare case of five or more segment involvement without an associated retrohepatic vein injury is unknown at present.

Regardless of associated parenchymal injury, liver injuries involving the retrohepatic veins have significant mortality. Specifically our series suggests that mortality for grade III injuries is mainly related to injury of the retrohepatic veins. We had no survivors of isolated retrohepatic vein injuries and all survivors had parenchymal injuries involving at least two or more segments. This finding supports other reports that finger fracture technique through hepatic parenchyma to expose retrohepatic vein injuries does not increase mortality.[1,13] Rather in grade III injuries control of the retrohepatic vein must be immediately achieved because intraoperative exsanguination is the overwhelming cause of death in these injuries.[13]

This classification illustrates the importance of surgical restraint in the management of liver injuries. As pointed out by Levin et al.[4] and as is becoming clearer with the increased use of radiologic imaging in blunt abdominal trauma,[17-19] surgical restraint has a role in the management of liver injuries. Mortality is dictated by maneuvers required to control the injury. Surgery for the injured liver must be tempered with the understanding that the surgical intervention of two segments or more is as significant an insult as a traumatic injury of the same scope. We believe the goal of surgery should be control of bleeding with as little parenchyma involvement as possible. If the operation is anticipated to involve more than one segment, then mortality will increase accordingly. While our series has not addressed the results of various techniques as they relate to this classification of injury, we believe techniques that limit parenchymal disruption to a segment or less will improve patient survival.

While we are gaining experience with this classification we recognize that problems remain. Intuitively injuries involving segments II and III are easier to manage then those involving the right posteriolateral segments VI and VII. We have not analyzed independently left and right lobe injuries, which may require modification of this definition. We had no isolated injuries of segment I, but because of its unique anatomic location and vascular relations, injuries of this segment may also require special attention.

We present a new operative classification of liver injuries based on segmental anatomy, which, when applied to our patient population included in this study, seems to be easily reproducible, objective, and has an excellent correlation with morbidity and mortality. We believe application of this scheme will enhance communication among surgeons and afford a workable means for reporting liver injuries.

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Discussion

Dr. Francis C. Nance (Livingston, New Jersey): This study brings a very ingenious new technique of classification to liver injuries, which might have some application. However I remain skeptical about all forms of classification of injuries, mainly because I am too senile to remember them all, and at night at the operationg table I really can't remember how to classify these injuries.