The Forensic Pathology of Liver Trauma

Christopher B. Rogers, Ronald Devera

ABSTRACT

The forensic pathologist is an integral part of the trauma surgery team. Trauma surgeons depend on autopsy descriptions for accurate measurement of the severity of trauma and determination of the chance of mortality. The outcome of liver injury improved greatly during the 20th century, primarily due to improved diagnostic and management techniques. In many trauma cases, survival depends on injuries to areas other than the liver.

Measurement of the severity of liver trauma often uses the TRISS (Trauma and Injury Severity Score) method, which depends on the nature, location, and size of injuries. Injuries produced by blunt trauma depend on the direction of the force and its interaction with the anatomic structures that surround the liver. Sharp force and gunshot injuries depend on the portions of the liver involved and the amount of kinetic energy transmitted to the tissue. The liver is susceptible to injury from resuscitation, although these injuries are usually not severe. *Acad Forensic Pathol.* 2018 8(2): 184-191

AUTHORS

Christopher B. Rogers MD MBA, Los Angeles County Coroner

Roles: Project conception and/or design, data acquisition, analysis and/or interpretation, manuscript creation and/or revision, approved final version for publication, accountable for all aspects of the work, principal investigator of the current study, general supervision.

Ronald Devera BS MS, Ross University School of Medicine

Roles: Data acquisition, analysis and/or interpretation, manuscript creation and/or revision, approved final version for publication, accountable for all aspects of the work.

CORRESPONDENCE

Christopher B. Rogers MD MBA, 1104 N. Mission Rd., Los Angeles CA 90033, crogers@coroner.lacounty.gov

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INTRODUCTION

The liver is the largest internal organ in the body, and the most commonly injured in abdominal trauma (1). With the increase in sophistication of the treatment of liver injuries has come an increase in the need for forensic pathologists to provide a detailed description of these injuries. Trauma surgeons can translate an autopsy description of liver injuries into a quantitative injury score, thus retrospectively determining how severely the decedent was injured. This information, in turn, provides an assessment of quality assurance of trauma care—if the injury score shows a high probability of survival, why did the decedent die?

Injury scoring depends on the degree of trauma to all parts of the body, as well as clinical factors such as blood pressure. However, the scope of this review is limited to autopsy assessment of injuries of the liver.

DISCUSSION

Trauma Scales

Injury scoring was developed over many years of trauma surgery (2). Although there have been many attempts to quantify the severity of trauma, the first scale usable for traffic accidents was the Abbreviated Injury Scale (AIS), developed in 1969 and updated several times (3). **Table 1** summarizes the 2008 update of the 2005 AIS (4). The AIS ranks the severity of injury to individual organs, but does not give a quantitative scale. Thus, the difference between AIS 1 and 2 is not necessarily the same as the difference between AIS 3 and 4.

Table 1: Abbreviated Injury Scale (4)

Severity Code	Severity Category
1	Minor
2	Moderate
3	Serious
4	Severe
5	Critical
6	Maximal

There have been several methods used to increase the precision of trauma scoring in patients with multiple injuries. One common method is the use of the Injury Severity Score (ISS) (5). To calculate the ISS, trauma surgeons take the highest AIS from the three most severely injured areas, and then add their squares. The highest possible ISS is 75. The ISS is not linear and some values occur more frequently than others. However, the ISS is reasonably correlated with the probability of survival (5). For example, in patients less than 50 years of age, an injury severity score of 20 is associated with less than 5% mortality, while an injury severity score of 40 is associated with about 50% mortality.

Another approach is to include physiological variables. The Revised Trauma Score (RTS) includes respiratory rate, systolic blood pressure, and Glasgow coma scale score, each of which is correlated with survival (6). Finally, the Trauma Score and Injury Severity Score (TRISS) combines measures of anatomical injury (ISS), physiological derangement (RTS), and the patient's age (7).

A recent survey showed 258 models for trauma assessment, of which 103 were externally validated (8). While there have been many attempts to improve the ability of the TRISS score to predict mortality, none is a clear improvement.

Describing Liver Trauma

The Organ Injury Scales were developed by the Organ Injury Scaling Committee of the American Association for the Surgery of Trauma (AAST) starting in 1987. Each injury is placed on a scale from 1 (minor) to 6 (fatal). Specific scales for liver injury were developed in 1989 and modified in 1995 and 2008 (**Table 2**) (4, 9, 10).

The description of the liver injuries needed to determine the injury score includes the percent of the hepatic lobe involved, length and depth of lacerations, size of hematoma, and number of Couinaud segments involved. The Couinaud classification divides the liver into eight segments, each of which has its own

vascular inflow, outflow, and biliary drainage. The right hepatic vein divides the right lobe into anterior (segment 8) and posterior (segment 7) portions. The middle hepatic vein divides the liver functionally into right (segments 8 and 5) and left portions (segment 4) along Cantlie's line, which connects the inferior vena cava superiorly to the gallbladder fossa inferiorly. The falciform ligament divides the liver anatomically into right (segment 4) and left (segments 2 and 3) lobes (**Figure 1**) (11).

Mechanism of Liver Injury

The liver is covered with peritoneum, except for a patch on the superior surface called the bare area. The falciform ligament and the round ligament (ligamentum teres hepatis, the remnant of the umbilical vein) on its free edge connect the midline of the liver with the anterior abdominal wall and the diaphragm. These ligaments prevent displacement of the liver to the right. Additional ligaments (the right and left lateral ligaments and the coronary ligament) connect the superior surface of the liver to the diaphragm and prevent caudal displacement of the liver (12).

The abdominal organs are mostly covered by peritoneum, and peritoneal fluid lubricates the organs, re-

ducing friction. The liver, although somewhat mobile, is tethered in place by the inferior vena cava and ligaments. The ribs and spine protect the liver from outside forces, though trauma can overcome these protective mechanisms, resulting in predictable patterns of injury (13). Injuries are often due to movement of the liver while the inferior vena cava and ligaments remain relatively fixed. The most common types of trauma include blunt injury (acceleration, deceleration, and crush injury) and penetrating injury (sharp force trauma and gunshot wounds). Another common mechanism of trauma is for the liver to be compressed between the anterior aspects of the ribs and spine.

Acceleration injuries occur when there is a new external force (such as from a collision) that suddenly changes the direction the liver is moving. Acceleration injuries are most commonly due to forces from the lateral right side, as seen in a side impact collision of two automobiles. The force displaces the liver in the coronal plane. The right lateral ligament fixes the liver between Couinaud segments 7 and 8, making segment 7 relatively fixed while segments 5 and 8 continue to move. This creates lacerations between the anterior and posterior portions of the right lobe. Another type of acceleration injury occurs when the blunt force comes from the right front, as in a head-on

Table 2: Liver Injury Scale (4, 9, 10)

Grade*	Injury type	Description of Injury	AIS
I	Hematoma	Subcapsular, < 10% surface area	2
	Laceration	Capsular tear, < 1 cm parenchymal depth	2
II	Hematoma	Subcapsular, 10% to 50% surface area; intraparenchymal < 10 cm in diameter	2
	Laceration	Capsular tear 1 to 3 cm parenchymal depth, < 10 cm in length	2
III	Hematoma	Subcapsular, > 50% surface area of ruptured subcapsular or parenchymal hematoma; intraparenchymal hematoma > 10 cm or expanding	3
	Laceration	> 3 cm parenchymal depth	3
IV	Laceration	Parenchymal disruption involving 25% to 75% hepatic lobe or 1 to 3 Couinaud's segments	4
V	Laceration	Parenchymal disruption involving > 75% of hepatic lobe or > 3 Couinaud's segments within a single lobe	5
	Vascular	Juxtahepatic venous injuries, i.e., retrohepatic vena cava/central major hepatic veins	5
VI	Vascular	Hepatic avulsion	6

* Advance one grade for bilateral injuries up to grade III

AIS - Abbreviated injury scale

collision of two automobiles. In this case, the vena cava serves as a fixed point, while the rest of the right lobe is pushed posteriorly. This results in a vertical laceration along Cantlie's line. A third type of acceleration injury occurs when the blunt force is to the front of the chest, as in a resuscitative injury. The left lobe of the liver is displaced backwards, causing lacerations adjacent to the falciform ligament (14).

In deceleration injuries, such as injuries to a passenger in an automobile striking a fixed object, the liver is compressed either against the anterior chest wall, resulting in injury of the anterior segments, or against the posterior chest wall, resulting in injury of the posterior segments. In a crush injury, the liver is compressed between the anterior and posterior chest walls, as might occur in an unbelted automobile occupant in a low-speed collision. The impact with the dashboard or back of the front seat results in laceration of both anterior and posterior segments (13, 15).

Liver lacerations have been created experimentally by blunt cardiac impact at a velocity of 12-18 m/sec (16). The mechanism of these injuries is believed to be “ex-

traordinarily high venous pressure that develops at the instant of impact” (16).

Decedents who fall from a height may sustain deceleration-type injuries, but the pattern of injury depends greatly on factors such as the height of the fall, the landing surface, the occurrence of secondary impacts, and the area of the body involved in the first impact (17). In a study of suicidal falls from height, rib fractures were present in more than 90% of cases, resulting in possible laceration of the liver by the fractured ribs. Liver injuries were significantly less common in victims who weighed less than 50 kg and in falls less than 12 m (17).

In primary blast injury to the abdomen with the pressure wave traveling through air, liver injuries are present in about 20% of victims (18). These injuries are associated with a very high intensity of the primary blast wave and proximity of the decedent to the blast. The injury can occur on any surface of the liver, depending on the surface struck by the primary blast wave.

While there is an association between liver injury and rib fractures in general (19), the severity of the liver injury does not correlate with the number of fractured ribs (20). The liver injury may or may not be caused by laceration from the fractured ribs.

Several forensic textbooks report that livers with significant fatty infiltration are more susceptible to trauma, but this is not statistically supported. In a study of 171 cases of blunt trauma, Molina divided the cases into those with and without hepatic trauma, and also rated the degree of fatty change (21). There was no statistical correlation between the degree of fatty change and the presence of liver trauma.

Penetrating trauma of the liver, in cases of simple stab wounds or low-velocity gunshot wounds, is often associated with minimal tissue damage, and may not require surgical intervention (22). However, stab wounds involving major vessels or gunshot wounds involving high kinetic injury may cause extensive liver injury and exsanguinating hemorrhage.

Figure 1: Couinaud segments of the liver. Hepatic vein branches are shown in blue, and portal vein branches, in purple.
PV - Portal Vein
IVC - Inferior vena cava
Image used under a Creative Commons Attribution 4.0 License (11).

In one study, cardiopulmonary resuscitation resulted in liver laceration or hematoma in 0.6% of patients (23). The most common site of laceration was the left lobe, suggesting that there may be a relationship between liver laceration and incorrect placement of the hands over the xiphoid process during resuscitation. Hemorrhage from liver laceration may be exacerbated by use of thrombolytics or preexisting coagulopathy in some patients.

Outcome of Liver Injury

In a study of 348 cases admitted to a trauma surgery unit, there was no mortality among patients with grade I-II liver injury (24). The mortality rate was 3.8% in patients with grade III injury, 13.2% with grade IV, and 62.2% with grade V. Risk factors for death included grade of injury, mechanism of injury (blunt injury was worse than penetrating injury), presence of retrohepatic venous injury, presence of other injuries, shock, high transfusion requirements, and coagulopathy.

A comparison of patients with isolated liver injuries and concomitant injuries of liver and other organs showed that in many cases the trauma to other organs was more significant than the trauma to the liver (25). Mortality from liver injuries has improved from 60-80% before World War I to about 6% at the end of the 20th century. This progress is attributed to a change in common mechanism of injury from blunt trauma to stab wounds, use of more precise diagnostic tools, such as computed tomography (CT) scan, and availability of new techniques, such as arteriographic embolization of bleeding vessels (26).

Death from liver injury within two days of admission is most often due to hemorrhagic shock and coagulopathy (27). After this time, significant liver-related complications include sepsis (abscess of the right subphrenic, subhepatic, or intrahepatic areas), bile leak (28), and hematuria due to hepatic artery pseudoaneurysms.

The Medical Examiner and the Trauma Surgeon

Trauma surgery has a well-developed system of quality assurance. At our trauma center, each incoming case receives a trauma score (often a TRISS score), and the expected probability of survival is calculated. This enables the surgeons to determine whether there is discordance between the expected survival and the actual survival (29). Cases are later reviewed at morbidity and mortality conference to determine whether there should be any changes in procedure.

The medical examiner assists this process in many ways. The medical examiner performs expedited complete autopsies on cases that the trauma center designates as high priority. Ideally, a single forensic pathologist is assigned as a liaison with the trauma center coordinator. This insures that the injury descriptions are uniform. The medical examiner also fills out a preliminary draft of the AIS. This gives the trauma coder a more accurate idea of how to code individual injuries. For example, if the forensic pathologist describes the most severe injury as a 5 cm capsular laceration, the coder would assign an AIS score of 3 (see **Table 2**). The autopsy report provides a precise description of the injuries including measurements, percent of the liver parenchyma damaged, etc. Additionally, the AIS documents are sent to the trauma center on the date of the autopsy, providing findings and rapid feedback to the surgeons. A representative from the coroner/medical examiner's office also attends the trauma morbidity and mortality conference to provide feedback and improve the quality of trauma patient care. The main benefit of following this procedure is that the forensic pathologist provides information to the surgeons in a format that is usable for trauma coding. Thus, the surgeons can draw accurate conclusions about whether mortality rates exceed expected numbers. While the forensic pathologist must make a time commitment of a few hours a month, the more precise autopsy descriptions make the medical examiner's reports much more clinically useful.

CASE EXAMPLE

A 30-year-old woman was admitted to a Level 1 trauma center after being struck by a vehicle as a pedestrian. The initial pulse was 155, blood pressure 150/110, and respirations agonal. The Glasgow coma score was 3. She became bradycardic and a left thoracotomy was done and the aorta cross clamped. No thoracic injury was identified. Upon open cardiac massage, the pulse returned and she was taken for emergency laparotomy.

At surgery, she had lacerations of the liver, spleen, and left kidney. There was injury to the right internal iliac artery and vein. After the lacerations were packed and the left kidney removed, there was no significant abdominal bleeding. Her condition continued to be unstable and she was believed to have a significant brain injury; however, CT scan could not be performed because of her need for emergency treatment. The left tibia was fractured. Her pulse and blood pressure were unstable and she died about one hour after admission.

The case was sent to the morbidity and mortality review conference to establish whether the decedent had a significant brain injury or whether her death was due to a missed injury.

At autopsy, the major injuries included subdural and subarachnoid hemorrhage, partial transection of the cerebral peduncles, cardiac laceration and contusion, left kidney laceration, spleen laceration, and multiple fractures of the legs and ribs.

The liver showed a 17 cm long by 0.6 cm deep laceration of the anterior aspect of the right lobe, a small subcapsular hematoma of the right lobe, (**Image 1**), and a 9 cm superficial laceration of the inferoposterior aspect of the right lobe. **Table 2** indicates that a capsular tear of less than 1 cm parenchymal depth is a grade I injury (AIS score of 2), which would have a 10% expected mortality if it were the only injury (4). However, the decedent's brain injury was not survivable. The conclusion of the conference was that the decedent's injuries were so severe that treatment would not have improved the outcome.

CONCLUSION

In cases of fatal liver injury, the forensic pathologist is responsible for providing a clinically relevant description of the trauma. The relevant items include length and depth of lacerations, size of subcapsular hematomas, extent of parenchymal disruption, and the nature of vascular injuries. These elements are not always present in forensic autopsy reports, but a detailed description of injuries is important in determining whether the injury is survivable and whether there was an error in treatment.

The Los Angeles County Department of Medical Examiner-Coroner has established a relationship with a nearby trauma surgery team. This allows the medical examiner to prepare autopsy reports that are clinically relevant and useful in quality assurance. The interaction with the trauma surgeons has been mutually beneficial.

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Image 1: Liver showing a small subcapsular hematoma and a 17 cm laceration.

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