

Navigating Chaos: Fatal Iatrogenic Liver Injury in a Patient Admitted for Leg Fractures

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The Case

A 60-year-old woman with a history of diabetes, hypertension, alcohol use disorder, and cirrhosis of the liver was brought into the emergency department (ED) after falling at home. She had bilateral knee pain and an open right ankle injury with visible deformity and moderate blood loss. She had hypotension, with blood pressure around 80s/50s. Pre-hospital personnel attempted to control the bleeding using a tourniquet. On arrival at the ED, she had weak pulses and was alert but confused, speaking in short sentences, and complaining of shortness of breath. Fluid resuscitation was initiated. Imaging confirmed bilateral tibial fractures and an open right ankle fracture. A pressure dressing and splint were applied. Her initial point-of-care hemoglobin was 7 mg/dl, and a “massive transfusion protocol” was initiated.

Just before chest radiography, the patient’s condition progressed to cardiac arrest. Cardiopulmonary resuscitation (CPR) was initiated, and bilateral chest tubes were placed. The left chest tube had neither air nor blood return; however, the right chest tube had some blood with no gush of air. Return of spontaneous circulation (ROSC) was achieved, and vasopressors were started. A post-intubation blood gas measurement showed hemoglobin of 5 gm/dl. Focused assessment with sonography for trauma (FAST) revealed fluid in the right upper abdominal quadrant, so the patient was immediately transferred to the operating room (OR) for exploratory laparotomy.

In the OR, blood was found in the peritoneal space. After packing the abdomen, the bleeding was noted to be coming from lacerations in the lateral chest wall, near where the right chest tube had been placed, and in the right lateral aspect of the liver. The liver was extremely large and visibly cirrhotic with splenomegaly. Multiple packing maneuvers were attempted but definitive hemorrhage control could not be obtained. In the meantime, the patient continued to bleed from her right ankle wound. Interventional radiology was consulted for angiography and embolization of the bleeding vessels. Despite this treatment, she remained hemodynamically unstable with declining neurological function; her family opted to change her code status to “do-not-resuscitate” and stayed with her until she died.

The Commentary

By Caitlin Loseth, MD

The management of severely injured patients requires complex decisions to be made quickly and treatment plans to be implemented faster than nearly any other clinical situation in the hospital. Given these difficult circumstances, Advanced Trauma Life Support (ATLS) guidelines were developed and have been refined over several decades. The first, and perhaps most avoidable, issue in this case was the deviation from the ATLS framework. The subsequent complications of an iatrogenic liver injury during tube thoracostomy placement and failure to rescue in the operating room arose from a potentially unnecessary, but certainly chaotic, procedure.

Background Information and Significance

ATLS is a widely accepted and propagated framework developed in 1978 after a plane crash in rural Nebraska laid bare the gaps in trauma care. The American College of Surgeons adapted a course that was adopted in 1980.¹ The basic approach to trauma under ATLS guidelines is often summarized by the “ABCs of trauma.” The basic approach to trauma under ATLS guidelines is often summarized by the “ABCs of trauma.” This acronym represents the components of the primary survey as well as their order of importance: Airway, Breathing, Circulation, Disability, and Exposure (ABCDE) assessment of the front and back of the patient. Adjuncts such as chest x-ray (CXR), pelvis x-ray, and/or the Focused Assessment with Sonography in Trauma (FAST) exam, comprise the standard of care for trauma patients. The imaging adjuncts are of particular interest in a hypotensive patient following blunt trauma, as in this case.¹

The primary utility of a CXR as an extension of the primary survey is to elucidate the need for a tube thoracostomy for hemothorax or pneumothorax. A pelvis x-ray can identify patterns of pelvic fractures that may need massive transfusion and/or treatment to stop pelvic hemorrhage (e.g., stabilization of the pelvic bones, pelvic arterial embolization, and pelvic packing). In this case, it appears that the CXR was not obtained until after the patient’s leg was x-rayed and splinted. Earlier identification of any thoracic pathology might have preempted the code and potentially mitigated the need for a high-risk tube thoracostomy placement.

In an emergency, a tube thoracostomy is placed by identifying the fourth or fifth intercostal space between the midaxillary and anterior axillary lines. The desired intercostal space corresponds to either the nipple line or inframammary fold. An incision is made, and the pleural space is entered using blunt dissection. The tract is dilated with a clamp and a finger sweep is performed to verify there are no adhesions and to confirm placement in the thoracic cavity. The tube is directed with the clamp and secured. The limited standing room for multiple providers performing simultaneous procedures in a patient undergoing active resuscitation can make tube placement difficult. The situation is particularly challenging on the right side, where peritoneal contents are more superiorly positioned, and in patients with cirrhosis, where the liver may be fused to the diaphragm. Important tenets of performing bedside procedures during ATLS include (1) briefly pausing CPR during critical portions and (2) strictly adhering to anatomic landmarks without compromises or “workarounds” that may make procedures more convenient to perform in limited space. In a trauma code event, the patient often will not recover without reversal of the immediate life-threatening

issue with an indicated procedure.

The FAST is a point of care ultrasound examination performed by the providers assessing the patient in real-time. It consists of four windows capable of identifying actionable trauma that requires rapid intervention. The pericardium is examined for signs of effusion or tamponade, and then three intraperitoneal windows are obtained. The right upper quadrant is examined for free fluid in the hepatorenal pouch, between the liver and the diaphragm, and at the caudal edge of the liver. The left upper quadrant is examined between the spleen and the diaphragm and the left pericolic gutter. The final peritoneal view is the suprapubic view examining for fluid in the rectouterine/vesicouterine or rectovesical pouches.¹ An extension of the FAST exam has been deemed the e-FAST and includes views of the bilateral hemithoraces. In conventional trauma practice, the FAST exam is most helpful in patients with blunt trauma and hypotension.² If an e-FAST had been performed on this hypotensive blunt trauma patient, it may have staved off the ill-fated tube thoracostomy and/or obviated the immediate need for operative intervention.

Another tenet of ATLS is proper resuscitation. Various predictive tools have been developed to determine the need for a Massive Transfusion Protocol (MTP) in a trauma patient.³ In most scoring systems, hypotension is prioritized, as is evidence of ongoing bleeding. Altered mental status can be a defining feature of hypovolemic shock.¹ The patient in this case arrived hypotensive with a tourniquet in place, suggesting active ongoing bleeding. It appears that MTP was not activated until after a laboratory value for hemoglobin returned at 7 mg/dL. Most scoring systems consider the activation of MTP, combined with other laboratory values and vital signs, at a hemoglobin value of 11 mg/dL. This low hemoglobin value suggests that the trauma team was already behind in resuscitation before activation of MTP. Empiric MTP based on the patient's hypotension, active bleeding from her leg wound, and altered mental status may have potentially avoided the code event. Empiric treatment of presumptive coagulopathy with fresh frozen plasma, platelets, and possibly tranexamic acid (TXA), in the setting of cirrhosis and significant bleeding from a distal leg injury, should also have been considered with laboratory testing such as thromboelastography (TEG) to guide resuscitation.

Management of the Complication

Management of liver hemorrhage can be very difficult, especially in the setting of hemodynamic instability and/or cirrhosis. Liver injuries are classified according to their size and relative difficulty of management:

- Grade I injury is a subcapsular hematoma encompassing less than 10% of the surface area of the liver or a capsular tear less than 1 cm in parenchymal depth.
- Grade II injury can be a subcapsular hematoma that is larger, up to 50% of the surface area; an intraparenchymal hematoma less than 10 cm in diameter; or a capsular tear that is between 1 and 3 cm depth into the parenchyma and less than 10 cm long.
- Grade III injury is a subcapsular hematoma that encompasses more than 50% of the surface area of the liver, ruptures or has parenchymal extension; an intraparenchymal hematoma more than 10 cm; a capsular tear more than 3 cm into the parenchyma; or a vascular injury with active bleeding that is contained within the parenchyma.
- Grade IV injury is a parenchymal disruption involving 25-75% of one lobe of the liver (or up to 3 segments) or a vascular injury with active bleeding into the peritoneum.

- Grade V injury is a parenchymal disruption involving more than 75% of one lobe of the liver or a juxtahepatic injury involving the retrohepatic inferior vena cava (IVC) or major hepatic veins.⁴

The grading system has been validated based on a statistically significant increase in mortality, need for operative intervention for liver trauma, as well as increased costs.^{5,6} Penetrating liver trauma is relatively rare compared to blunt trauma, and it is more often managed operatively.⁷ Thus, there has been persistent debate about whether the grading system is as predictive in penetrating trauma as it has been in blunt trauma.⁸

After recognizing the grade of injury by imaging criteria, and assessing the patient's overall clinical condition, management follows various algorithms and decision trees. The first option is nonoperative management with bedrest, serial abdominal exams, and repeated laboratory tests to ensure no ongoing hemorrhage. For selected injuries, particularly those with active arterial extravasation, interventional radiology with angiographic intervention can be an invaluable diagnostic and therapeutic modality. The second option is operative management. Various authors have described hybrid approaches combining interventional radiology, intraoperative endovascular techniques, as well as standard operative approaches to the liver, further illustrating the difficulties of managing severe liver trauma.⁹ The most common operative approaches to liver trauma are perihepatic packing, direct suture ligation for hemostasis, electrocautery, argon coagulation, omental packing, hemostatic agents, and hepatorrhaphy. With major liver bleeding, a Pringle maneuver is usually employed, which entails clamping the portal triad, effectively limiting all inflow to the liver. This maneuver must be done for short periods of time to avoid significant ischemia.

It is possible to have severe, uncontrolled hemorrhage even after clamping inflow to the liver, due to injury of the large outflow hepatic veins or the retrohepatic IVC (not reported in this case). Retrohepatic IVC and hepatic vein injuries are amongst the most fatal injuries encountered in trauma surgery. Options for handling these difficult injuries include packing, direct repair, and resection. Packing is typically the least risky and can offer temporary control. Direct venous repair at the injury site is difficult because exposure is challenging in a deep field with massive hemorrhage. Total hepatic venous exclusion is an option with clamping of both the suprahepatic and infrahepatic IVC, just superior to the renal veins, in addition to the Pringle maneuver. This is typically performed in conjunction with a shunting procedure, either veno-veno bypass or atriocaval shunting. Veno-veno bypass involves placing a cannula in the femoral or inferior mesenteric vein, with a bypass circuit and blood return via the axillary or internal jugular vein. This procedure is rarely performed in practice because it requires a perfusionist and a patient who is not hypothermic, coagulopathic, or acidotic. An atriocaval shunt is quicker but has prohibitively high mortality risk. The final option is hepatic resection. Formal, anatomic resections are time consuming and have largely been abandoned in the setting of trauma, except for cases with delayed necrosis or bile leaks after initial management. Nonanatomic resections of locally destroyed tissue is the most common indication for resection in the setting of trauma. Finally, total hepatectomy with orthotopic liver transplantation has been performed, with higher mortality rates than for other transplant indications. In modern organ allocation, long term survival after transplant is highly prioritized. Thus, liver transplantation should not be considered a viable option in severe hepatic trauma.

Regardless of the grade, mechanism, or management of the injury, the presence of cirrhosis makes management more difficult. Patients with cirrhosis exist in a delicate physiologic homeostasis where

relatively small insults can cause acute decompensation. Massive trauma can tip that balance into a downward spiral. Portal hypertension with shunting, cirrhosis-related coagulopathies, and overall frailty are factors in this potentially lethal combination. In addition, numerous anatomical considerations complicate surgical management of direct trauma to the cirrhotic liver. In this case, the liver was hard, presumably difficult to move, and the spleen was enlarged. There was no mention of abdominal wall varices, but this is a common pitfall in operating on patients with cirrhosis. An enlarged spleen takes up limited space and adds another friable surface that can hemorrhage. The injury was noted to be in the posterolateral portion of the right liver, an area that requires significant mobilization of the liver to visualize. Mobilization of a cirrhotic liver is a difficult task under controlled circumstances, let alone in massive intraabdominal hemorrhage. The extensive mobilization required to visualize the injury is also counterproductive when perihepatic packing is the primary strategy for hemostasis. It is difficult to create tamponade around a mobilized liver. Angiographic embolization in the operating room is a good adjunct; however, it is most effective in active arterial bleeding, which is relatively rare. Furthermore, if there is an injury to a hepatic vein or retrohepatic IVC, angiographic intervention is nearly useless, as these are low pressure vessels with large diameters.

System Improvement and Conclusion

This case highlights the challenges inherent in managing blunt trauma in actively bleeding patients with a history of cirrhosis. When such patients are hypotensive at presentation, and progress to require CPR in the field or in the ED, the prognosis is dismal. The best chances to have helped this patient would have been to (1) immediately initiate MTP and correct presumptive coagulopathy, (2) adhere diligently to optimal procedural technique to minimize the risk of iatrogenic injury, and (3) use an established protocol to prioritize assessments and interventions. In this case, the trauma team should focus on improving their technique of emergency thoracostomy tube insertion to minimize the risk of iatrogenic injuries to diseased livers in future cases.

Regional trauma systems have been established to triage patients of this type to hospitals (i.e., trauma centers) that meet defined standards, including ATLS training of providers, on-site availability of specialists and other resources, and robust quality improvement processes. These processes include retrospective review of individual cases such as this one, to identify quality improvement opportunities, and participation in registries such as the American College of Surgeon's Trauma Quality Improvement Program (TQIP) to allow comparison of performance with other centers. Such efforts empower trauma teams to understand their previous failures, learn from previous successes, and help to prevent iatrogenic events in the future.

Take-Home Points

- The ATLS framework exists to create order amid chaos. Adherence to the guidelines protects against misadventures in the trauma bay. Procedures performed in the trauma bay should have the same degree of surgical rigor as procedures performed in the operating theater.
- CPR often needs to be paused in the setting of acute ATLS procedures in order to ensure safety.
- Activation of MTP at the first sign of impending resuscitative failure is the safest option.

- Management of complex liver trauma is a difficult, but not impossible endeavor. Initial stabilization with effective perihepatic packing is the mainstay of the damage control laparotomy.

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