Imaging Features and Interventional Treatment for Liver Injuries and Their Complications
간 외상과 그 합병증의 영상 소견과 인터벤션 치료

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Liver injury is a common consequence of blunt abdominopelvic trauma. Contrast-enhanced CT allows for the rapid detection and evaluation of liver injury. The treatment strategy for blunt liver injury has shifted from surgical to nonoperative management, which has been widely complemented by interventional management to treat both liver injury and its complications. In this article, we review the major imaging features of liver injury and the role of interventional management for the treatment of liver injury.

Index terms Liver; Wounds and Injuries; Hemorrhage; Computed Tomography, X-Ray; Embolization, Therapeutic

INTRODUCTION

Liver injuries are common following blunt abdominopelvic trauma and present high morbidity and mortality rates up to 10% (1-5). Contrast-enhanced CT is the preferred diagnostic modality in hemodynamically stable patients because it allows to rapidly detect and evaluate the liver injury (1, 6-8). The American Association for the Surgery of Trauma established a scale of liver injury (Table 1) that has been revised in 2018 and sets the standard for grading liver injuries (9, 10). The grades have shown consistent correlation with patient outcomes in multiple studies (11-14). The injury grade of the affected organ depends on the presence, location, and size of lacerations and hematomas, and it has been essential to decide the appropriate clinical management (2).
The treatment strategy of blunt injuries in solid organs including the liver is shifting from surgical to nonoperative management (NOM) in hemodynamically stable patients (13, 15-18). In addition, interventional management has been widely used with high clinical success rates (15, 16, 19, 20). In this article, we review the imaging features of liver injuries and focus on interventional management as a complement to NOM in the effective treatment of liver injuries and their complications.

**LACERATION AND HEMATOMA**

Liver laceration and hematoma appear as ill-defined hypodense areas in nonenhanced or contrast-enhanced CT scans (Fig. 1A) (1, 6). Hematomas may either be intraparenchymal or extend into the subcapsular region (6), and they usually resolve within 6 to 8 weeks with conservative treatment if no recurrent bleeding occurs (21). If the hematoma is large enough to cause pain or direct compression to adjacent liver parenchyma, it can be effectively evacuated by percutaneous catheter drainage (Fig. 1B) (22, 23).

**Table 1. Liver Injury Scale Established by the American Association for the Surgery of Trauma**

| Grade | Injury Type          | Description of Injury                                                                 |
|-------|----------------------|----------------------------------------------------------------------------------------|
| I     | Hematoma             | Subcapsular, < 10% surface area                                                        |
|       | Laceration           | Capsular tear, < 1 cm, parenchymal depth                                               |
| II    | Hematoma             | Subcapsular, 10–50% surface area, intraparenchymal, < 10 cm                         |
|       | Laceration           | Capsular tear, 1–3 cm parenchymal depth, ≤ 10 cm in diameter                         |
| III   | Hematoma             | Subcapsular, > 50% surface area of ruptured subcapsular or parenchymal hematoma; intraparenchymal hematoma > 10 cm |
|       | Laceration           | > 3 cm parenchymal depth                                                              |
| IV    | Laceration           | Parenchymal disruption involving 25 to 75%                                             |
| V     | Vascular             | Juxtahepatic venous injuries (retrohepatic vena cava/central major hepatic veins)  |

Fig. 1. CT findings of liver laceration and hematoma.
A. Contrast-enhanced CT scan shows ill-defined hypodense areas consistent with a laceration in the liver parenchyma (arrows).
B. A hematoma extending to the subcapsular region (asterisks) is observed in another patient. The hematoma was percutaneously drained with a pigtail catheter (arrow).
ARTERIAL BLEEDING

Multiphasic contrast-enhanced CT allows the effective detection and evaluation of arterial bleeding. Contrast media extravasation and pseudoaneurysm formation indicate the focus of active arterial bleeding. Contrast media extravasation is characterized by a focal hyperdense area in arterial-phase CT scans and expands on venous or delayed-phase CT scans due to the gradual collection of extravasated contrast media (Fig. 2A) (1, 2, 24). A pseudoaneurysm appears as a hyperdense round or irregular sac adjacent to the artery in arterial-phase CT scan (Fig. 3A). Active arterial bleeding is a predictor of poor NOM outcomes (1) and can be effectively treated by transcatheater arterial embolization (TAE). The superselective technique of TAE for the bleeding focus allows effective cessation of bleeding with a minimal decrease in the liver function (Figs. 2B-D, 3B). TAE in a bleeding lesion aims for the complete exclusion of the target and the minimization of non-target embolization. To achieve complete exclusion, both the inflow and outflow of the target lesion must be embolized, thus preventing the recurrence of the target lesion through intra- and extrahepatic collateral flow. To prevent or at

Fig. 2. Arterial bleeding treated by transcatheter arterial embolization.
A. Contrast-enhanced CT scan shows areas of contrast media extravasation (arrows) that indicate active arterial bleeding.
B. Conventional angiography also shows contrast media extravasation (arrow). Superselective angiography shows bleeding in A5 segmental artery (inlet).
C. Superselective embolization using microcoils (arrow) was performed, and complete exclusion of the bleeding focus is observed in the completion angiography.
D. The follow-up contrast-enhanced CT scan shows no evidence of residual bleeding and focal hypodense non-enhancing areas, suggesting localized hepatic necrosis (asterisk).
least minimize nontarget embolization, TAE of the outflow vessel just distal to the target lesion can be performed using microcoils in anticipation of the arterial supply of the distal portion of the hepatic parenchyma through the collateral area (25).

MAJOR VENOUS BLEEDING

Although rare, injuries of the major hepatic veins, including the retrohepatic inferior vena cava, can be combined with liver injury. Major hepatic venous injuries are suspected if liver lacerations or hematomas extend to major hepatic veins or the retrohepatic inferior vena cava (Fig. 4). Its overall mortality rate is high, reaching 92% (26, 27). Surgical treatment, such as packing, additional exposure to gain vascular control, direct repair, and shunting, are still being performed in patients who survive to arrival at a trauma center (7, 28, 29). However, the retroperitoneal location of the major hepatic veins or the retrohepatic inferior vena cava demands a large open surgery, leading to high morbidity and mortality (30-32). Endovascular repair by stent graft covering the injured vein may be a suitable alternative to surgical repair.
Unlike surgery, endovascular repair has a shorter procedure time because it neither require general anesthesia, nor additional dissection to access retrohepatic venous structures. For injury of the retrohepatic inferior vena cava, few cases of successful endovascular repair by stent graft placement covering the injured site have been reported (27, 33-35).

**DELAYED BLEEDING**

Delayed bleeding is the most common late complication following NOM (1, 15, 36). Several conditions such as expanding injury or biloma-induced pseudoaneurysm along with an expanding hematoma may induce delayed bleeding (1, 37). Overall, the mortality rate from delayed bleeding is 18% and confined to patients with surgical management (38). Increased areas of parenchymal or subcapsular hematomas may appear in serial follow-up CT scans. A conservative treatment, TAE, or surgical management can be used to treat delayed bleeding depending on the patient’s hemodynamic status (1, 39).

Traumatic intrahepatic arteriovenous fistula and arterioporal fistula are rare complications following blunt liver injury. They may form from direct lacerations of adjacent arteries and veins or via a connection with a pseudoaneurysm (40). TAE of the fistula tract can be a safe and effective treatment (Fig. 5).

**LATE COMPLICATIONS FOLLOWING NOM OF BLUNT LIVER INJURY**

NOM of blunt liver injury has been accepted as a standard of care for hemodynamically stable patients, achieving high success rate in patients with isolated low-grade blunt liver injuries (15, 36, 37). Although NOM has been extended to patients with high-grade injuries (1,
13, 15, 39, 40), their complication rates are higher than those of patients with low-grade injuries, reaching 21% and 63% for grade 4 and 5 injuries, respectively (39). Complications following NOM include biliary complications (e.g., bile leak, biliary stricture, and biloma) and hepatic necrosis (Fig. 6) (1, 15).

**BILIARY COMPLICATIONS**

Transient bile leakage is a common biliary complication following liver injury (1, 2, 37). However, persistent bile leakage, biliary fistula, hemobilia, and bile peritonitis may occur, especially in patients with high-grade liver injuries (1, 2, 15, 37). As blood supplying the vessels of the bile ducts mainly belongs to the hepatic arterial system, compromised hepatic arterial supply induces ischemic damage to the biliary epithelium followed by biliary complications. TAE of a hepatic artery may also reduce the hepatic arterial supply and induce ischemic bile duct injury (Fig. 6) (19). Indirect findings in CT scans can be useful for diagnosing bile leakage. For instance, the progressive extension of a well-circumscribed hypodense collection in either the perihepatic space or intraparenchymal area strongly suggests the occurrence of biloma (Fig. 7) (1, 2, 37, 41). Most bilomas disappear spontaneously, but enlarging or infected bilomas can be safely and effectively treated by percutaneous catheter drain-
Bile leakage into the peritoneal cavity caused by intra/extrahepatic bile duct injuries may induce bile peritonitis. Increased peritoneal fluid collection and enhancement or abnormal thickening of the peritoneum in a CT scan suggest the occurrence of bile peritonitis (1). Antegrade or retrograde cholangiography can be used to diagnose bile duct injury and bile leak by detecting contrast media extravasation (36) and support the treatment by biliary drainage tube insertion or biliary stent placement (Fig. 7C, D).

### HEPATIC NECROSIS

Although TAE is necessary to control active bleeding, several procedure-related complications may occur, such as arterial dissection at the arterial access site, localized hepatic necrosis (Fig. 2D), biliary tract necrosis, and ischemic cholecystitis of the gallbladder (Fig. 8) (15). Dabbs et al. (19) reported that major hepatic necrosis can be a common complication in pa-
Patients who undergo TAE, especially when treating high-grade injuries. Treatments, such as lobectomy, non-anatomic resection, debridement, percutaneous catheter drainage, and percutaneous cholecystostomy, can be used for managing hepatic necrosis, despite a standard treatment not being established yet. If the necrotic area is large and subsequent hepatic failure follows, liver transplantation should be considered (Fig. 9).

CONCLUSIONS

Liver injury can be detected and graded by evaluating CT scans. Injury treatment is gradually tending toward NOM for hemodynamically stable patients regardless of the severity. If interventional procedures such as TAE, percutaneous catheter drainage, and biliary drainage complement NOM, the treatment outcomes are expected to improve.
Author Contributions
Conceptualization, K.J.W.; data curation, K.J.W., P.S.; formal analysis, Y.S.H., P.S.H., P.S.; investigation, all author; methodology, K.J.W.; project administration, P.S.H.; resources, K.J.W., P.S.; supervision, K.J.H.; visualization, P.S., K.J.W.; writing—original draft, Y.S.H.; and writing—review & editing, P.S.H., P.S.

Conflicts of Interest
The authors have no potential conflicts of interest to disclose.

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REFERENCES
1. Yoon W, Jeong YY, Kim JK, Seo JJ, Lim HS, Shin SS, et al. CT in blunt liver trauma. Radiographics 2005; 25:87-104
2. Soto JA, Anderson SW. Multidetector CT of blunt abdominal trauma. Radiology 2012;265:678-693
3. Matthes G, Stengel D, Seifert J, Rademacher G, Mutze S, Ekkernkamp A. Blunt liver injuries in polytrauma: results from a cohort study with the regular use of whole-body helical computed tomography. World J Surg 2003;27:1124-1130
4. Boese CK, Hackl M, Müller LP, Ruchholtz S, Frink M, Lechler P. Nonoperative management of blunt hepatic trauma: a systematic review. J Trauma Acute Care Surg 2015;79:654-660
5. Croce MA, Fabian TC, Menke PG, Waddle-Smith L, Minard G, Kudsk KA, et al. Nonoperative management of blunt hepatic trauma is the treatment of choice for hemodynamically stable patients. Results of a prospective trial. Ann Surg 1995;221:744-753; discussion 753-755
6. Shanmuganathan K, Mirvis SE. CT scan evaluation of blunt hepatic trauma. Radiol Clin North Am 1998;36:399-411
7. Poletti PA, Mirvis SE, Shanmuganathan K, Killeen KL, Coldwell D. CT criteria for management of blunt liver trauma: correlation with angiographic and surgical findings. Radiology 2000;216:418-427
8. Becker CD, Mentha G, Terrier F. Blunt abdominal trauma in adults: role of CT in the diagnosis and management of visceral injuries. Part 1: liver and spleen. Eur Radiol 1998;8:553-562
9. Moore EE, Cogbill TH, Jurkovich GJ, Shackford SR, Malangoni MA, Champion HR. Organ injury scaling: spleen and liver (1994 revision). J Trauma 1995;38:323-324
10. Kozar RA, Crandall M, Shanmuganathan K, Zarzaur BL, Coburn M, Cribari C, et al. Organ injury scaling 2018 update: spleen, liver, and kidney. J Trauma Acute Care Surg 2018;85:1119-1122
11. Kalra VB, Wu X, Bokhari J, Forman H. Organ laceration grading adherence by radiologists. Emerg Radiol 2015;22:245-250
12. Homann G, Toschke C, Gassmann P, Vieth V. Accuracy of the AAST organ injury scale for CT evaluation of traumatic liver and spleen injuries. Chin J Traumatol 2014;17:25-30
13. Saltzberg TP, Van der Vlies CH, Van Lienden KP, Beenen LF, Ponsken KJ, Van Gulik TM, et al. Improved outcomes in the non-operative management of liver injuries. HPB (Oxford) 2011;13:350-355
14. Tinkoff G, Esposito TJ, Reed J, Kilgo P, Fildes J, Pasquale M, et al. American Association for the Surgery of Trauma Organ Injury Scale I: spleen, liver, and kidney, validation based on the National Trauma Data Bank. J Am Coll Surg 2008;207:646-655
15. Stassen NA, Bhullar I, Cheng JD, Crandall M, Friese R, Guillamondegui O, et al. Nonoperative management of blunt hepatic injury: an Eastern Association for the Surgery of Trauma practice management guideline. J Trauma Acute Care Surg 2012;73:S288-S293
16. Wallis A, Kelly MD, Jones L. Angiography and embolisation for solid abdominal organ injury in adults - a current perspective. World J Emerg Surg 2010;5:18
17. Brillantino A, Iacobellis F, Festa P, Mottola A, Acampora C, Corvino F, et al. Non-operative management of blunt liver trauma: safety, efficacy and complications of a standardized treatment protocol. Bull Emerg Trauma 2019;7:49-54
18. O’Neill SB, Hamid S, Nicolaou S, Qamar SR. Changes in approach to solid organ injury: what the radiolo-
gist needs to know. Can Assoc Radiol J 2020;71:352-361
19. Dabbs DN, Stein DM, Scalea TM. Major hepatic necrosis: a common complication after angioembolization for treatment of high-grade liver injuries. J Trauma 2009;66:621-627; discussion 627-629
20. Velmas GC, Toutouzas K, Radin R, Chan L, Rhee P, Tillou A, et al. High success with nonoperative management of blunt hepatic trauma: the liver is a sturdy organ. Arch Surg 2003;138:475-480; discussion 480-481
21. Geis WP, Schulz KA, Giacchino JL, Freeark RJ. The fate of unruptured intrahepatic hematomas. Surgery 1981;90:689-697
22. Zizzo M, Lanaia A, Barbieri I, Zaghi C, Bonilauri S. Subcapsular hepatic hematomas after endoscopic retrograde cholangiopancreatography: a case report and review of literature. Medicine (Baltimore) 2015;94:e1041
23. Klímová K, Suárez CP, Asanza CG, Pe AM, Arregui EC, Alonso AH. Subcapsular hepatic hematoma after ERCP: a case report and revision of literature. Case Reports in Clinical Medicine 2014;3:43760
24. Willmann JK, Roos JE, Platz A, Pfammatter T, Hilfiker PR, Marineck B, et al. Multidetector CT: detection of active hemorrhage in patients with blunt abdominal trauma. AJR Am J Roentgenol 2002;179:437-444
25. Madhusudhan KS, Gamanagatti S, Garg P, Shalimar, Dash NR, Pal S, et al. Endovascular embolization of visceral artery pseudoaneurysms using modified injection technique with n-butyl cyanoacrylate glue. J Vasc Interv Radiol 2015;26:1718-1725
26. Buckman RF, Pathak AS, Badellino MM, Bradley KM. Injuries of the inferior vena cava. Surg Clin North Am 2001;81:1431-1447
27. Briggs CS, Morcos OC, Moriera CC, Gupta N. Endovascular treatment of iatrogenic injury to the retrohepatic inferior vena cava. Ann Vasc Surg 2014;28:1794.e13-e15
28. Hagiwara A, Murata A, Matsuda T, Matsuda H, Shimazaki S. The efficacy and limitations of transarterial embolization for severe hepatic injury. J Trauma 2002;52:1091-1096
29. Barde JM, Grabo D, Lam L, Tadlock MD, Strumwasser A, Inaba K. Treatment algorithm and management of retrohepatic vena cava injuries. J Trauma Acute Care Surg 2017;83:340-344
30. Kuehne J, Frankhouse J, Modrall G, Golshani S, Aziz I, Demetriades D, et al. Determinants of survival after inferior vena cava trauma. Am Surg 1999;65:976-981
31. Cheli M, Alberti D, Adriana T, Zaranek E, Colusso M, Arnoldi R, et al. Successful bleeding control by a combined conventional surgical approach and video-assisted surgery: a case report. Ann Thorac Cardiovasc Surg 2009;15:253-256
32. Turpin I, State D, Schwartz A. Injuries to the inferior vena cava and their management. Am J Surg 1977;134:25-32
33. Erzurum VZ, Shoup M, Borge M, Kalman PG, Rodriguez H, Silver GM. Inferior vena cava endograft to control surgically inaccessible hemorrhage. J Vasc Surg 2003;38:1437-1439
34. Tanig U, Petit J, Thomas A, Abt P, Toy F, Lopez R, et al. Traumatic inferior vena cava laceration acutely repaired with endovascular stent graft and associated complications salvaged by surgery. J Vasc Interv Radiol 2019;30:273-276
35. Castelli P, Caronno R, Piffaretti G, Tozzi M. Emergency endovascular repair for traumatic injury of the inferior vena cava. Eur J Cardiothorac Surg 2005;28:906-908
36. Kozar RA, Moore JB, Niles SE, Holcomb JB, Moore EE, Cothren CC, et al. Complications of nonoperative management of high-grade blunt hepatic injuries. J Trauma 2005;59:1066-1071
37. Bala M, Gazalla SA, Faroja M, Bloom AI, Zamir G, Rivkind AI, et al. Complications of high grade liver injuries: management and outcome with focus on bile leaks. Scand J Trauma Resusc Emerg Med 2012;20:20
38. Fisher JC, Moulton SL. Nonoperative management and delayed hemorrhage after pediatric liver injury: new issues to consider. J Pediatr Surg 2004;39:619-622
39. Kozar RA, Moore FA, Cothren CC, Moore EE, Sena M, Bulger EM, et al. Risk factors for hepatic morbidity following nonoperative management: multicenter study. Arch Surg 2006;141:451-458; discussion 458-459
40. Goftette PP, Latere PF. Traumatic injuries: imaging and intervention in post-traumatic complications (delayed intervention). Eur Radiol 2002;12:994-1021
41. De Backer A, Fiersens H, De Schepper A, Pelekmans P, Jorens PG, Vaneerdeweg W. Diagnosis and nonsurgical management of bile leak complicated by biloma after blunt liver injury: report of two cases. Eur Radiol 1998;8:1619-1622
간 외상과 그 합병증의 영상 소견과 인터벤션 치료

유성현1·박소현1*·김종우2·김정호1·황정한1·박수영1·이기현1

간 외상은 복부 둔상에서 흔하다. 조영증강 전산화단층촬영을 통해 간 외상을 빠르게 진단하고 평가할 수 있다. 간 외상의 치료 전략은 수술적 방법에서 점차 비수술적 방법으로 바뀌어 왔는데, 간 외상뿐 아니라 그 합병증에 대한 보완적 치료 방법으로 인터벤션이 각광받고 있다. 이 종설에서는 간 외상에서 보일 수 있는 주요 영상 소견과, 치료에 있어서 인터벤션의 역할에 대해 알아보고자 한다.

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