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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.

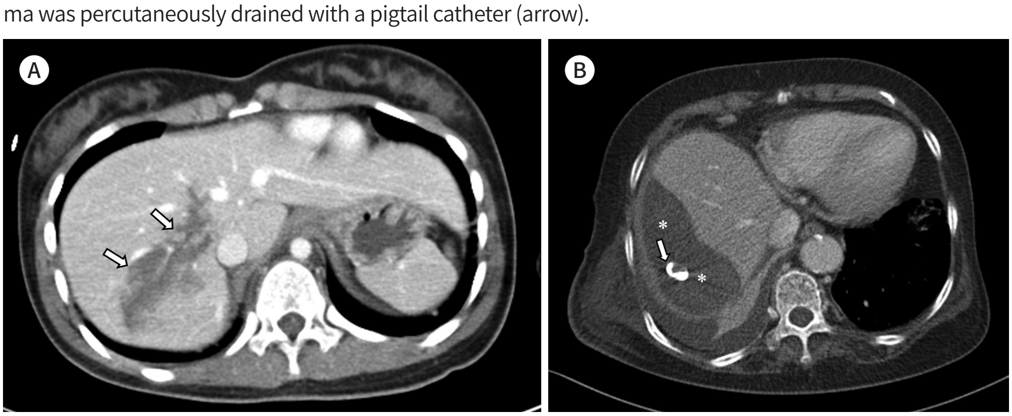
LACERATION AND HEMATOMA

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	Laceration	Parenchymal disruption involving > 75% of hepatic lobe
	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 transcatheter 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 nontarget 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).

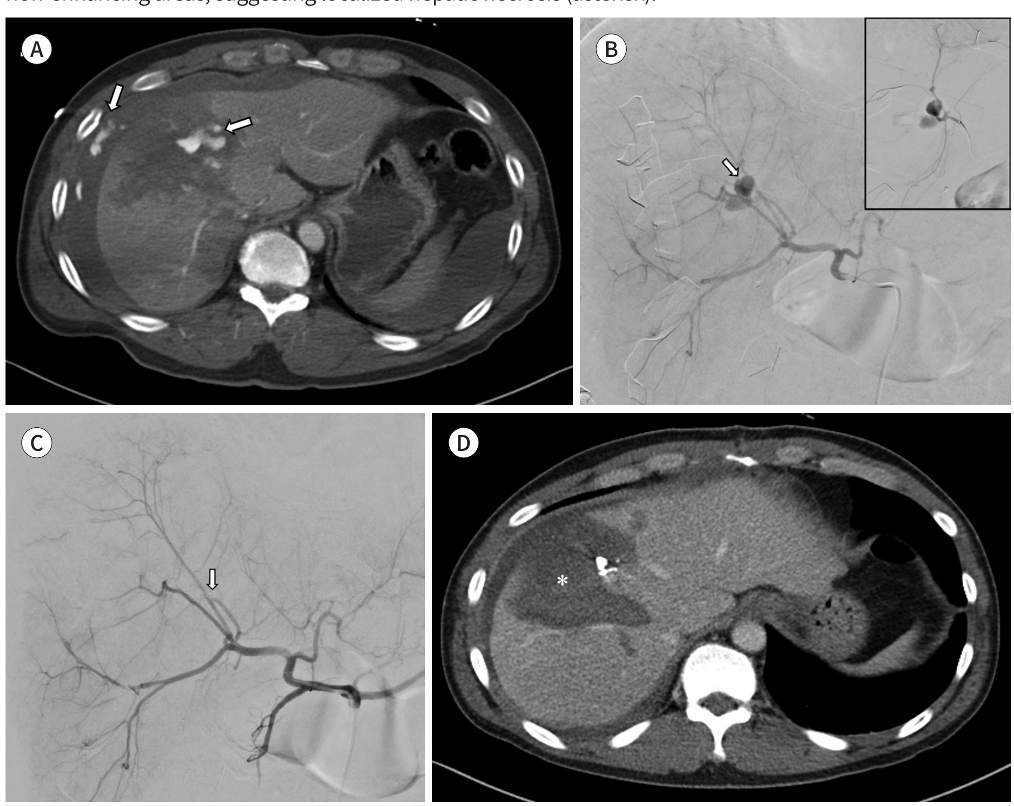


Fig. 3. Traumatic pseudoaneurysm treated by transcatheter arterial embolization.
A. Contrast-enhanced CT scan shows pseudoaneurysm (arrow) in the central areas of the liver.
B. Conventional angiography shows pseudoaneurysm (arrow). The feeder was superselected (inlet), and superselective embolization using N-butyl-cyanoacrylate was performed, and complete exclusion of the lesion was achieved (not shown).

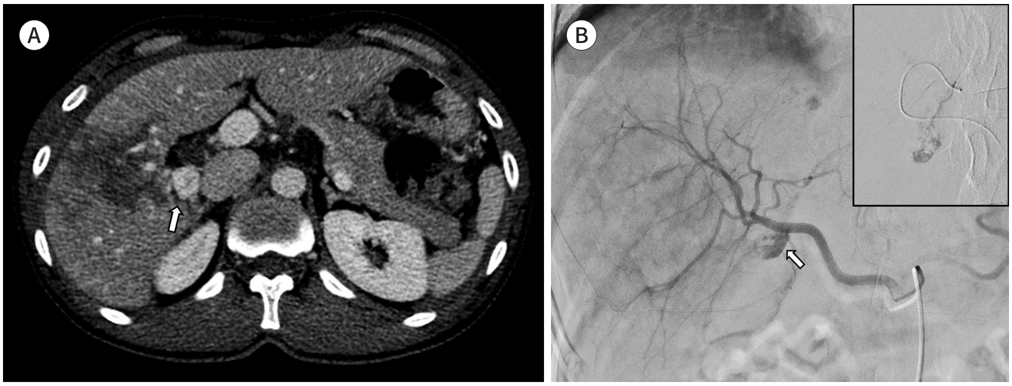


Fig. 4. Disruption of both the inferior vena cava (arrow) and adjacent large areas of laceration and hematoma formation suggest inferior vena cava injury as observed in contrast-enhanced CT scan.

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).

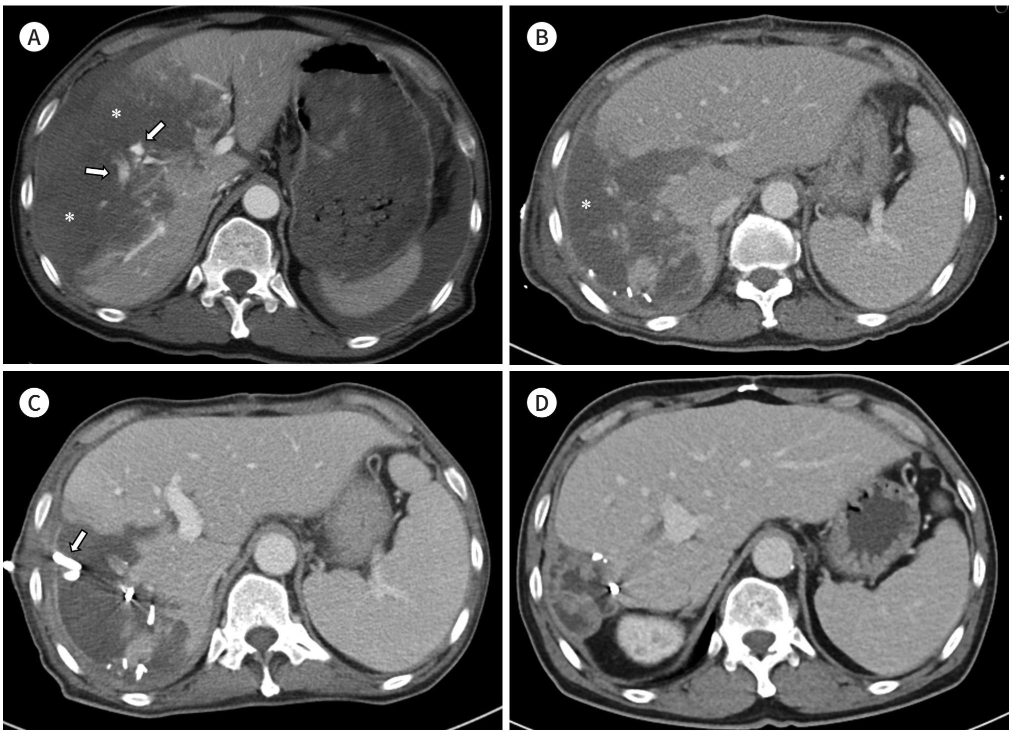
Traumatic intrahepatic arteriovenous fistula and arterioportal fistula are rare complications following blunt liver injury. They may form from direct lacerations of adjacent arteries and veins or via a connection with a pseudoaneurysm (40). TAE of the fistula tract can be a safe and effective treatment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

Fig. 5. Traumatic arterioportal fistula treated by transcatheter arterial embolization four days after the liver trauma (driver traffic accident).
A. Conventional angiography image of the A8 segmental artery shows a small pseudoaneurysm (arrowhead) and contrast filling to adjacent portal vein (arrow), suggestive of arterioportal fistula.
B. After performing superselective embolization with microcoils, the contrast filling of portal vein disappears.

Fig. 6. Hepatic necrosis treated by percutaneous catheter drainage.
A. Contrast-enhanced CT scan shows multifocal active arterial bleeding (arrows), large areas of laceration, and hematoma formation (asterisk). The patient underwent transcatheter arterial embolization and right posterior sectionectomy (not shown).
B. The follow-up CT scan shows large areas of hepatic necrosis (asterisk).
C. Percutaneous catheter drainage was performed (arrow).
D. The follow-up CT scan shows complete resolution of the necrotic fluid.



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-

Fig. 7. Biloma treated by percutaneous catheter drainage and plastic biliary stent placement.
A. Contrast-enhanced CT scan shows multifocal active arterial bleeding (arrows), large areas of laceration, and hematoma formation (asterisk). The patient underwent transcatheter arterial embolization (not shown).
B. The follow-up CT scan shows large areas of fluid collection (asterisk). Percutaneous catheter drainage was performed (not shown), and the bile was drained.
C. Endoscopic retrograde cholangiography shows bile leak of the right intrahepatic bile duct (arrows).
D. Plastic stent was placed in the right intrahepatic bile duct for biliary diversion (arrows).

age (1, 15, 37).

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-

Fig. 8. CT findings of ischemic cholecystitis.
A. Contrast-enhanced CT scan shows multifocal active arterial bleeding (arrows), adjacent laceration, and hematoma formation (asterisks).
B. Transcatheter arterial embolization was performed, but the completion angiography suggests that the cystic artery was partially embolized (arrows).
C. Follow-up CT scan shows enlarged gallbladder (asterisk) with mucosal enhancement defect and discontinuity at the fundus portion (arrows), suggesting perforated cholecystitis. Laparoscopic cholecystectomy was performed (not shown).

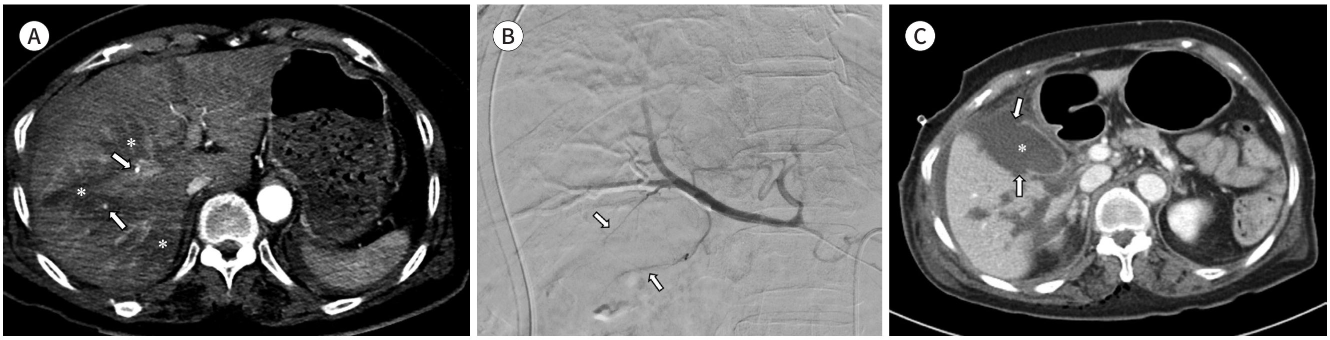
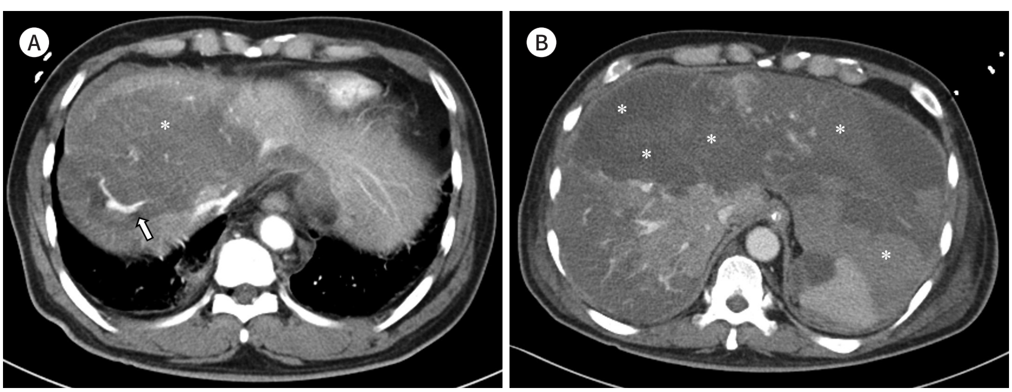


Fig. 9. Extensive hepatic necrosis following transcatheter arterial embolization.
A. Contrast-enhanced CT scan shows multifocal active arterial bleeding (arrow), large areas of laceration, and hematoma formation (asterisk).
B. Transcatheter arterial embolization was performed (not shown), but large areas of hepatic necrosis and hematoma (asterisks) are observed in the follow-up CT scan. The patient underwent deceased donor liver transplantation.



tients 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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간 외상과 그 합병증의 영상 소견과 인터벤션 치료

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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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