Pictorial Essay

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대한영상의학회지

The Role of Interventional Radiology in Treatment of Patients with Acute Trauma: A Pictorial Essay

급성 외상 환자 치료에서 인터벤션 영상의 역할: 임상화보

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Acute trauma is a common cause of mortality in individuals aged < 40 years. As organ preservation has become important in treating trauma patients, the treatment is shifting from surgical management to non-operative management. A multidisciplinary team approach, including interventional radiology (IR), is essential for the optimal management of trauma patients, as IR plays an important role in injury evaluation and management. IR also contributes significantly to achieving the best clinical outcomes in critically ill trauma patients. This pictorial essay aims to present and summarize various interventional treatments in trauma patients requiring critical care.

Index terms Trauma; Injuries; Angiography; Interventional Radiology

INTRODUCTION

Acute trauma is a common mortality cause in individuals aged < 40 years. Proper diagnosis and appropriate treatments are crucial due to residual disabilities and sequelae (1, 2). Previously, surgeries, including surgical exploration and vessel ligation, were preferred for trauma-related vascular injuries (3, 4). However, management of hemodynamically stable patients has changed from surgical to non-operative management (NOM), as organ preservation became increasingly important. Recently, NOM has also been conducted in hemodynamically unstable patients (3, 4). Interventional treatment, equipment, and agents have developed dramatically since the introduction of endovascular techniques in the 1970s. Therefore, interventional radiology (IR) plays an essen-

tial role in treating trauma patients (3, 4).

This pictorial essay aims to present and summarize various cases that the IR plays an essential role in acute trauma management to achieve the best clinical outcomes of trauma patients.

LIVER INJURY

The liver is among the most frequently injured organs in blunt abdominal trauma. Liver injuries are detected in approximately 25% of severely injured patients with whole-body computed tomography (CT) (5).

The American Association for the Surgery of Trauma (AAST) liver injury scale is used to grade livery injury on CT. However, surgeries are determined based on hemodynamic stability rather than on grade severity (6).

Most hemodynamically stable patients with liver injury undergo conservative management. However, embolization can be considered when active bleeding is present on CT, or hemorrhage control is not achieved by laparotomy with perihepatic packing alone (Fig. 1) (7).

SPLENIC INJURY

The spleen is another organ frequently injured. The extent of injury is measured using the AAST splenic injury scale. Treatment decision is made based on CT results and various clinical factors (8).

Laparotomy with splenectomy or splenic salvage is performed for hemodynamically unstable patients, whereas conservative management is considered initially in hemodynamically stable patients. Splenic injury in patients with high AAST grades is less likely to be treat-

Fig. 1. Liver injury in a 32-year-old man who had an in-car traffic accident.
A. CT shows liver laceration (grade IV, American Association for the Surgery of Trauma) and active contrast extravasation (arrows) in the right hepatic lobe.
B. Angiography confirms the extravasation (arrow) from a branch of the right hepatic artery, which was successfully treated with transcatheter arterial embolization using N-butyl cyanoacrylate (arrowhead).

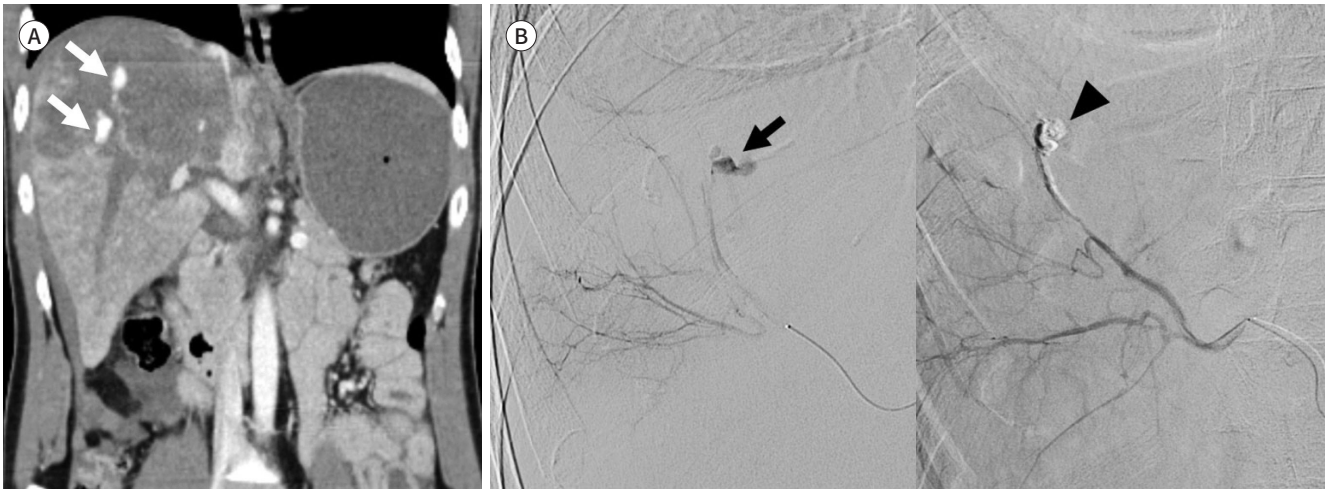
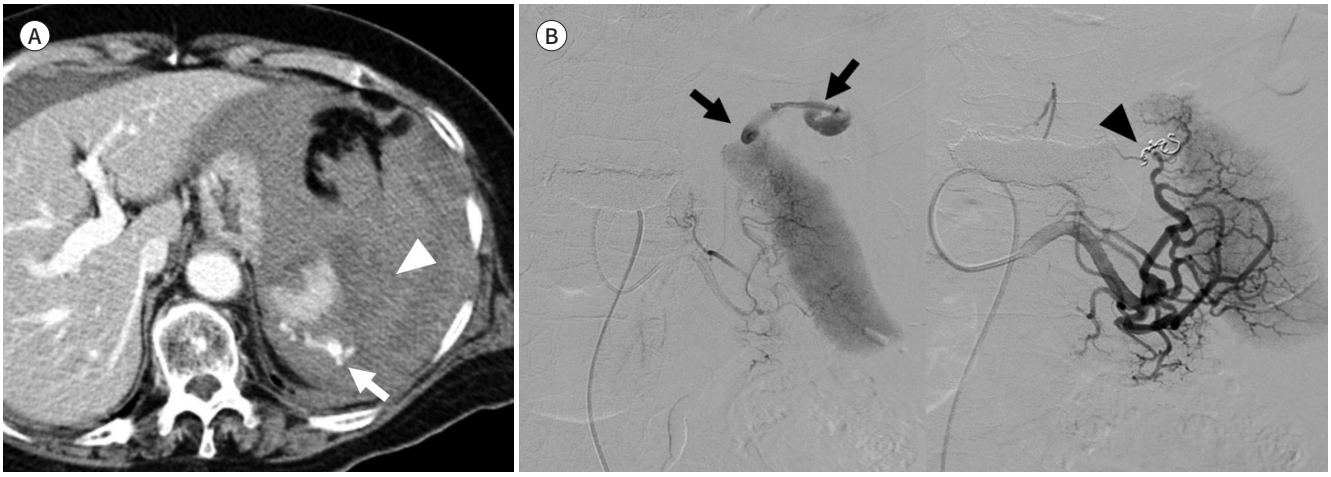


Fig. 2. Splenic injury in a 64-year-old woman who fell from a height.
A. CT scan shows splenic rupture (grade IV, American Association for the Surgery of Trauma) with contrast extravasation (arrow) and hemoperitoneum (arrowhead).
B. Angiography confirms the contrast extravasation (arrows) from the splenic artery, which was successfully treated with transcatheter arterial embolization using coils (arrowhead) superselectively deployed in the bleeding vessel with preservation of the surrounding branches.



ed by conservative management alone (9). However, recent studies show that splenic arterial embolization meaningfully decreased the NOM failure rates in patient with high AAST grade splenic injury (10). Splenic artery embolization is indicated when vascular injuries, including active arterial bleeding, pseudoaneurysm, and arteriovenous fistula, are evident on CT of hemodynamically stable patients (Fig. 2) (11).

KIDNEY INJURY

Traumatic renal injury develops in approximately 10% of abdominal trauma patients and is the third most common abdominal organ injured. It mostly occurs after a blunt trauma and is considered non-life-threatening (6, 12). Traumatic renal bleeding is managed conservatively due to spontaneous cessation in most cases owing to the tamponade effect of the retroperitoneal fascia. However, endovascular or surgical intervention is required in cases with massive hemorrhage, pseudoaneurysm formation, continuous hematuria, and hemodynamic instability (12, 13). Recently, selective renal angioembolization has been preferred over surgery in hemodynamically stable patients with high-grade injury (grade III or higher) on the AAST kidney injury scale (Fig. 3) (6, 12).

PANCREATIC INJURY

Pancreas injury is rare, accounting for approximately 1% of blunt abdominal trauma cases. It usually accompanies other abdominal organ injuries (14).

Its management depends on the AAST pancreatic injury scale, and the presence of ductal injury determines the prognosis and treatment methods. In AAST grade III and higher injuries accompanied with ductal injury, surgery is performed. Recently, NOM has shown positive results in liver, splenic, and kidney injuries. Thus, NOM, including embolization and

percutaneous drainage, has been performed gradually in pancreatic injury (Fig. 4) (14). Percutaneous drainage can reduce symptoms and complications of enzyme leakage in pancreatic duct injury (14).

BILIARY TRACT INJURY

The biliary system remains relatively uninjured. because it is protected by the ribs, liver,

Fig. 3. Kidney injury in a 50-year-old woman who fell from a height.
A. CT scan shows renal laceration (grade III, American Association for the Surgery of Trauma) with active extravasation (arrow) and perirenal hematoma (arrowhead).
B. Angiography confirms the contrast extravasation (arrow) from the left anterior renal artery, which was successfully treated with transcatheter arterial embolization using coils (arrowheads).

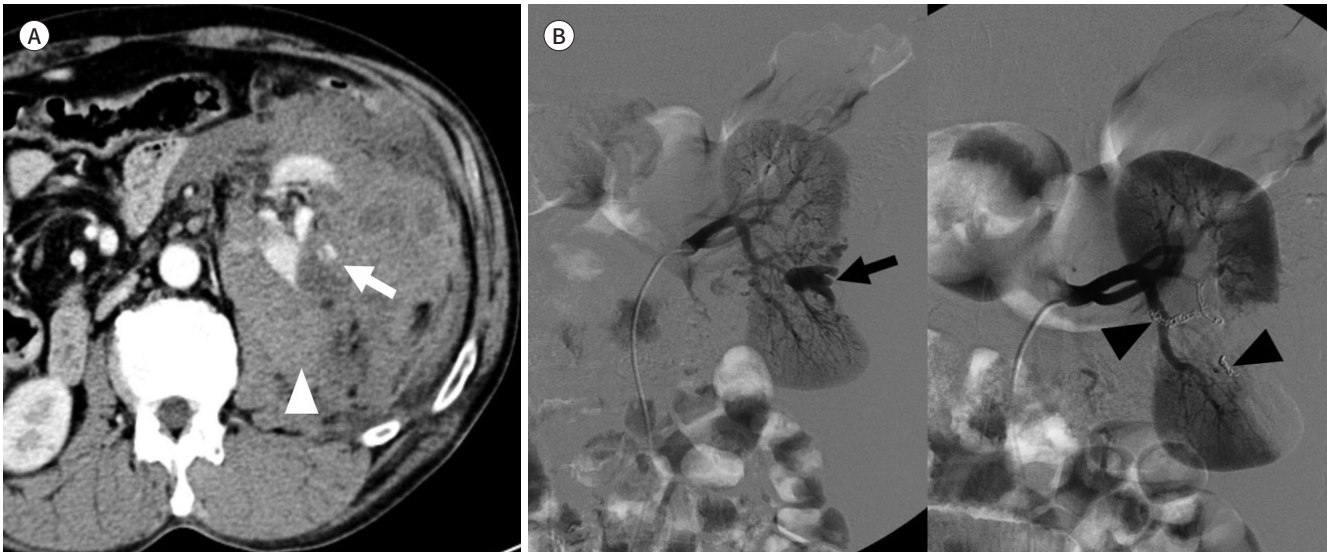
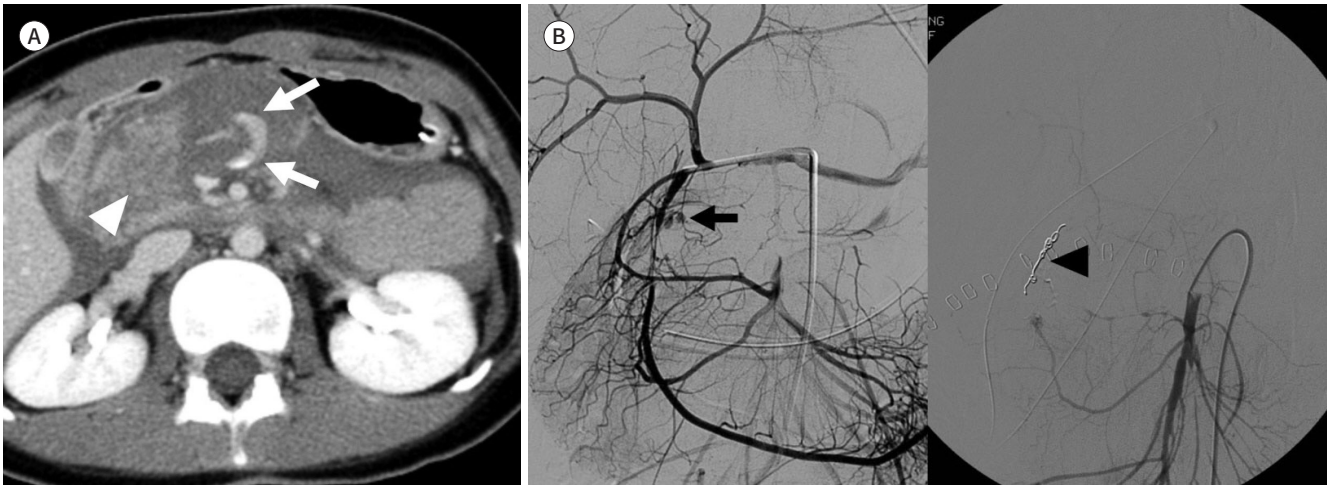


Fig. 4. Pancreatic injury in a 19-year-old man who had a pedestrian accident.
A. CT scan shows active extravasation (arrows) and pancreatic disruption (grade IV, American Association for the Surgery of Trauma) (arrowhead).
B. Angiography confirms the contrast extravasation (arrow) from the pancreaticoduodenal arcade of the gastroduodenal artery, which was successfully treated with transcatheter arterial embolization using coils (arrowhead).



and mesentery. According to the locations, biliary tract injury is classified as gallbladder, which is the most common, intrahepatic, and extrahepatic bile duct injuries. Gallbladder injury can be accompanied with cystic artery transection, causing major blood loss. Bile leakage leads to combined infection and sepsis (15).

Treatment options include endoscopic or percutaneous biliary drainage, and surgical biliary reconstruction. Interventional treatment involves percutaneous transhepatic biliary drain placement for biliary decompression and diversion (Fig. 5). Biloma, resulting from bile leakage, can lead to complications, including abscess, cholangitis, and sepsis, and may be treated with percutaneous catheter drainage (16).

MESENTERIC INJURY

Mesenteric injury is relatively rare and difficult to diagnose. It frequently results from seatbelt injury in motor vehicular accidents. Its rapid diagnosis and appropriate treatment are essential to avoid life-threatening conditions, including intraperitoneal and gastrointestinal bleeding, intestinal ischemia, and/or perforation from mesenteric vessel interruption (17).

Mesenteric injuries are traditionally managed surgically. However, isolated mesenteric vessel injury, without gastrointestinal perforation, can be treated with angiography and transcatheter arterial embolization (TAE) (Fig. 6) (17).

URETHRAL INJURY

Traumatic urethral injury results from iatrogenic, blunt, or penetrating trauma. Its management depends on injury location. Anterior urethral contusions are observed without treatment, but incomplete or complete anterior urethral injury is treated with suprapubic di-

Fig. 5. Biliary tract injury in a 51-year-old man who had a car accident.
A. CT scan shows liver laceration (grade IV, American Association for the Surgery of Trauma) (arrow).
B, C. A tubogram (B) through the Jackson-Pratt drain shows a collection (white arrowhead) of contrast material, communicating with the intrahepatic bile duct (white arrows) and common bile duct (black arrowhead), which disappearred after percutaneous transhepatic biliary drain placement (C).

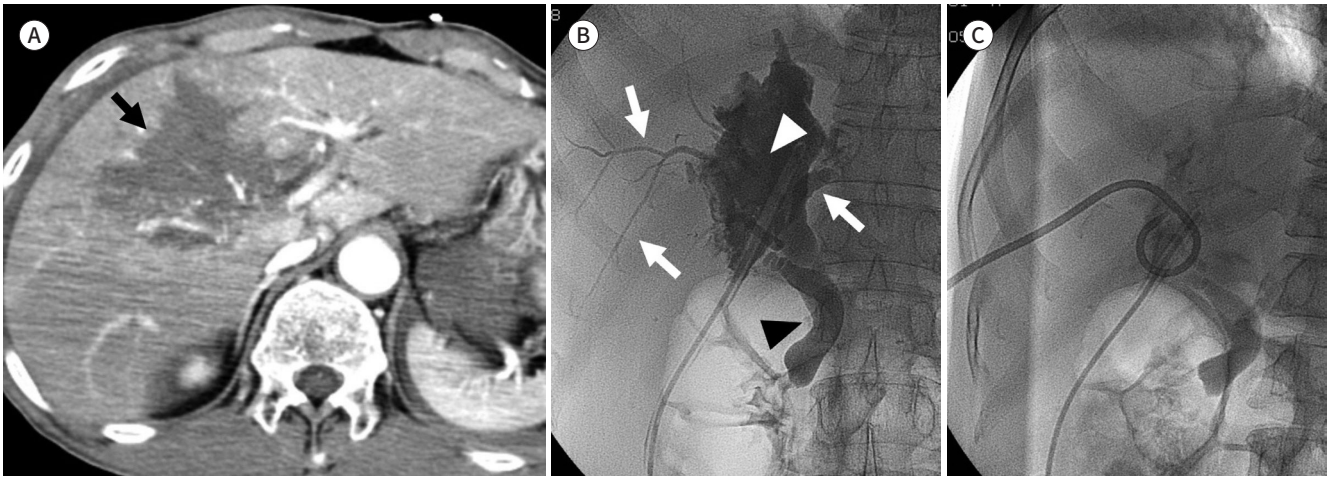


Fig. 6. Mesenteric injury in a 72-year-old man who had a car accident.
A. CT scan shows contrast extravasation (arrows) and mesenteric hematoma (arrowhead).
B. Angiography confirms the contrast extravasation (arrows) from the branch of the ileocecal artery, which was successfully treated with transcatheter arterial embolization using N-butyl cyanoacrylate (arrowhead).

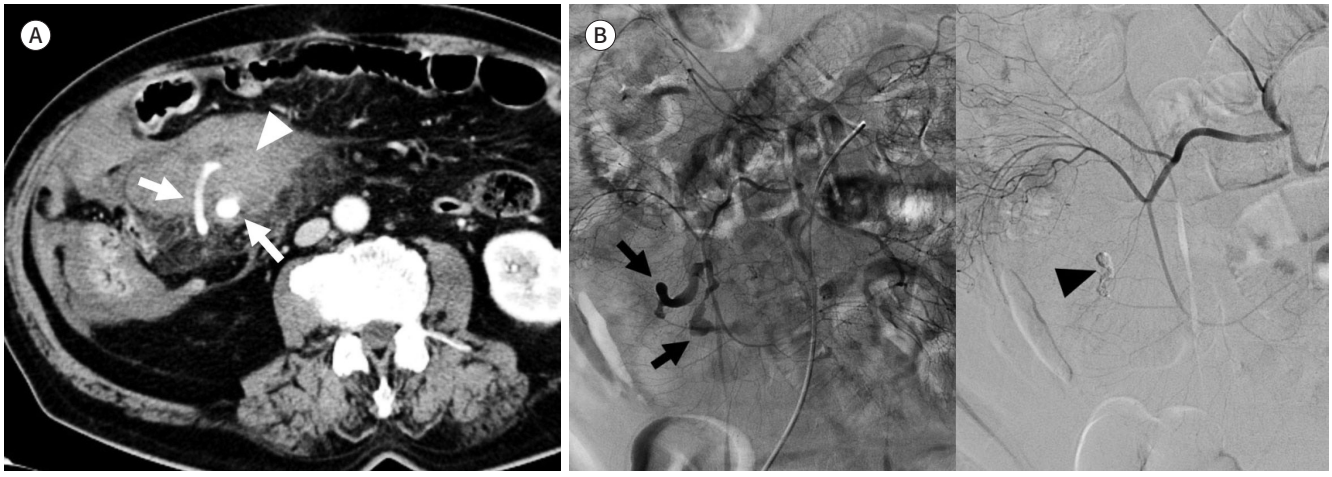
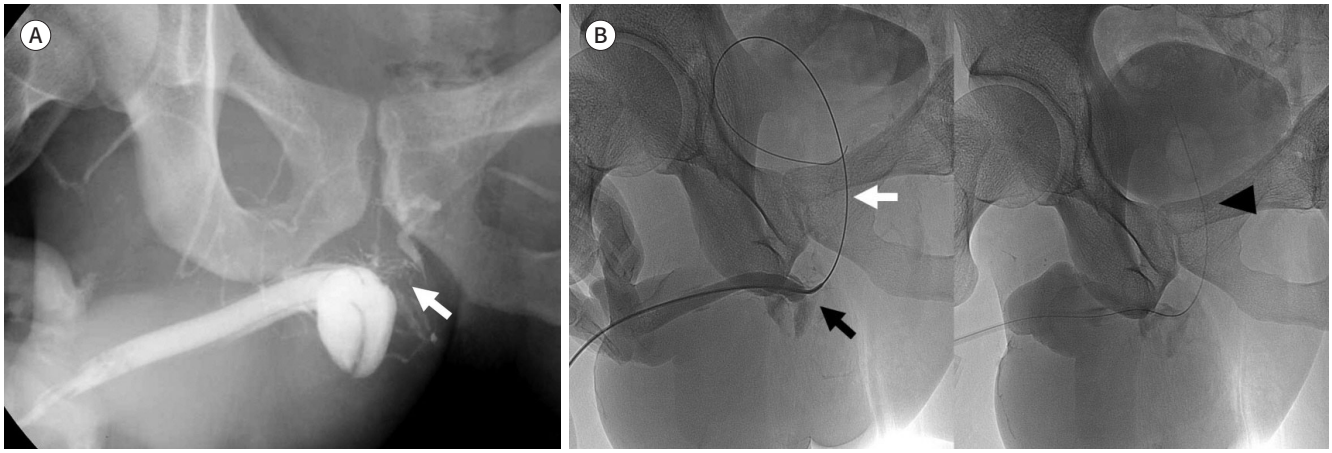


Fig. 7. Urethral injury in a 41-year-old man who had a straddle accident.
A. Complete disruption of the bulbous urethra (arrow) is seen on a retrograde urethrogram.
B. Retrograde primary interventional urethral realignment was performed using a 5-F catheter (black arrow) and guidewire (white arrow), and a 14-F Foley catheter (arrowhead) was placed transurethrally over the wire.



version and delayed repair (18).

Posterior urethral injury management includes primary surgical repair, suprapubic cystostomy with delayed urethroplasty, and primary interventional urethral realignment (PIUR). PIUR can accurately and rapidly evaluate injury severity through retrograde urethrography, and immediate realignment can also be performed (Fig. 7) (18).

PENILE INJURY

Priapism is a persistent erection regardless of sexual stimulation. Appropriate treatment is crucial to prevent complications, including structural damage or permanent erectile dysfunction. Its two major types are ischemic and non-ischemic (19).

Ischemic priapism develops from little or no cavernous arterial inflow and corpora cavernosa rigidity. Contrarily, non-ischemic priapism results from an increased corpora cavernosa inflow, occurring from the arteriolar sinusoidal fistula as a result of the trauma. Most non-ischemic priapism do not develop permanent injuries, but may require proper treatment because patients may experience decreased function (19).

The first-line treatment for non-ischemic priapism is clinical observation, as more than two-thirds of cases could achieve spontaneous resolution. If symptoms persist, treatment is required, and interventional treatment, including cavernous arterial embolization, can be performed (Fig. 8) (19).

PELVIC INJURY

Most pelvic fractures occur from high-energy crush injuries and are often accompanied with organ damages. Mortality rate with pelvic fracture alone ranges from 6% to 15%, increasing to 36–54% when accompanied with hemorrhage. Mortality rate can further increase with delayed diagnosis. Most pelvic injury-associated hemorrhages occur in fractured bones or disrupted pelvic veins, and 10–20% of cases involve hemorrhage from arterial injury, most commonly the internal iliac artery branch. Hemodynamically unstable patients require aggressive treatment, as pelvic bone fracture can lead to massive bleeding (11, 20). Treatment includes external fixation of the unstable fracture, pelvic packing, and TAE. Interventional treatment is preferred due to the risks of large volume loss or uncontrolled vessel bleeding with surgeries. When hemodynamically unstable, nonselective proximal gelfoam embolization is performed on both internal iliac arteries as life-saving procedures, followed by additional selective embolization after stabilization (Fig. 9) (11).

Evaluation for collateral vessel hemorrhage or additional site bleeding in the contralateral internal iliac artery is necessary after embolization. Moreover, thorough evaluations are criti-

Fig. 8. Penile injury in a 35-year-old man who had a straddle accident.
A. Color Doppler ultrasonogram shows aliasing phenomena (arrow) due to the turbulent high velocity flow in the cavernous artery.
B. Angiography confirms the presence of an arteriocavernous fistula (arrow), which was successfully treated with transcatheter arterial embolization using an autologous blood clot and a gelfoam (arrowhead).

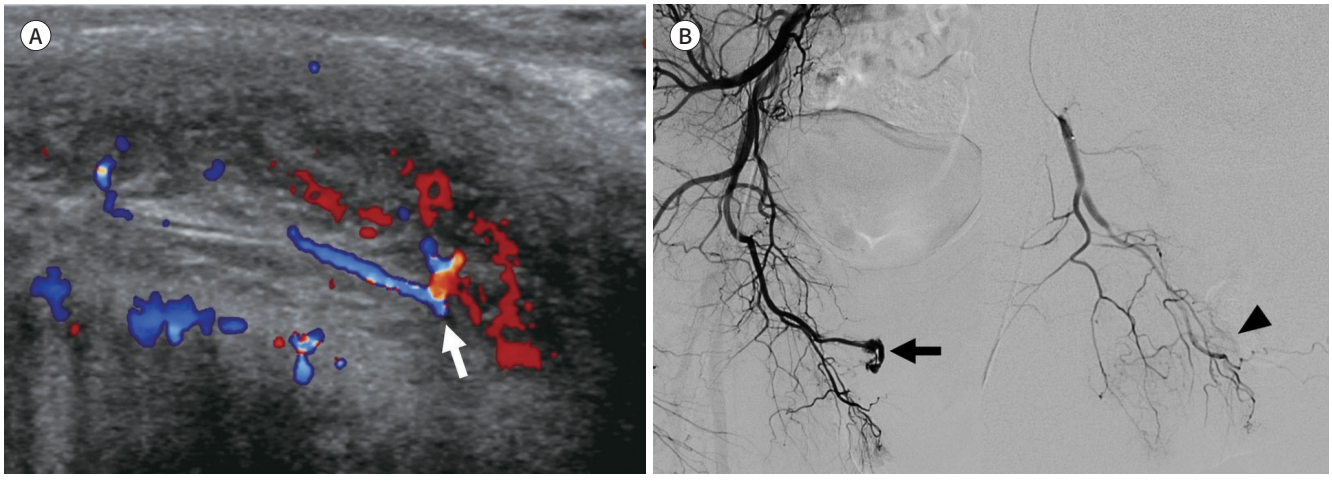


Fig. 9. Pelvic injury in a 74-year-old man who had a pedestrian accident.
A. CT scan shows contrast extravasation (arrow) and right pelvic bone fracture with hematoma.
B. Angiography confirms the pseudoaneurysm (arrow) from the right medial circumflex femoral artery, which was successfully treated with transcatheter arterial embolization using coils (arrowhead).

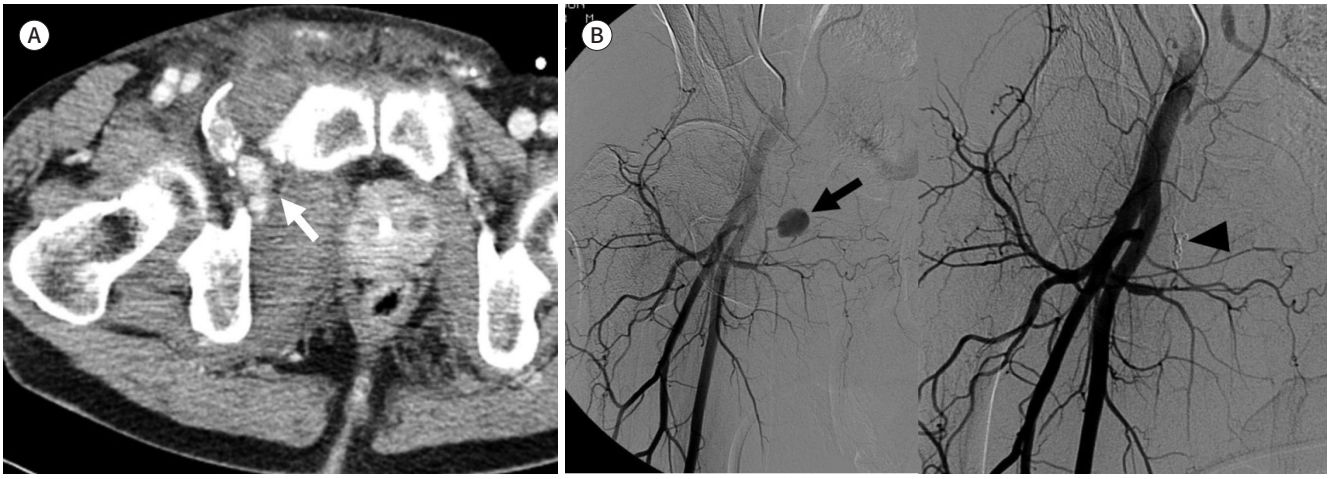
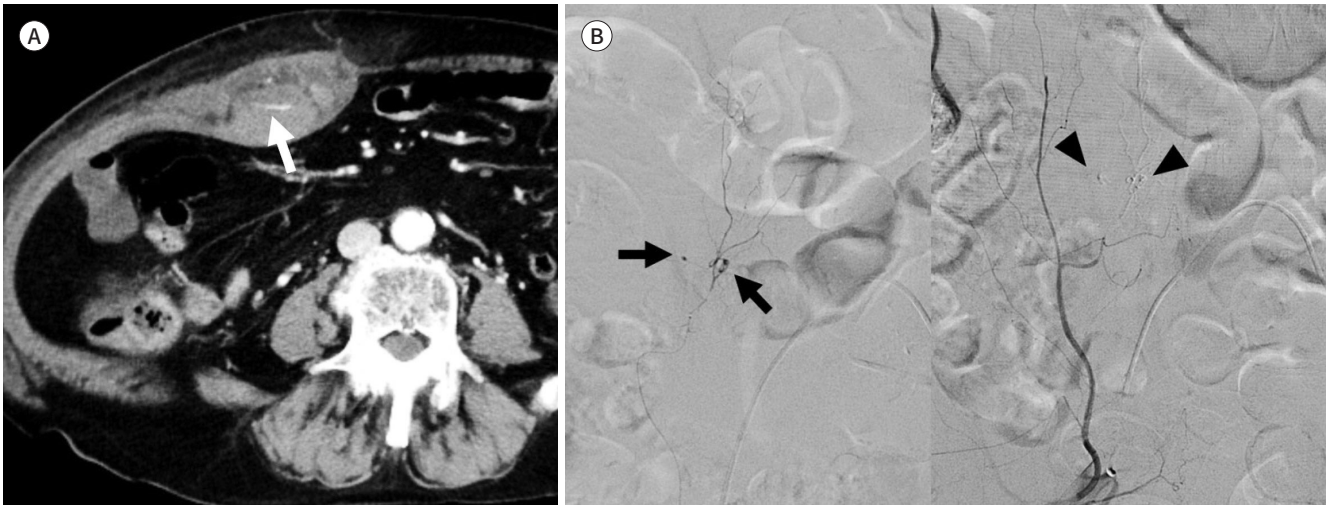


Fig. 10. Abdominal wall injury in an 83-year-old man who hit his abdomen against a chair.
A. CT scan shows active extravasation (arrow) and right rectus sheath hematoma.
B. Angiography confirms the small pseudoaneurysms (arrows) from the right inferior epigastric artery, which was successfully treated with transcatheter arterial embolization using N-butyl cyanoacrylate (arrowheads).



cal post-procedure to prevent complications, including tissue necrosis, abscess formation, re-bleeding, and sepsis (11).

ABDOMINAL WALL INJURY

Abdominal wall hematoma rarely occurs in blunt trauma. Conservative management is mostly sufficient, but it can cause life-threatening conditions as well. Traumatic abdominal wall hematoma develops mainly from injuries to the deep circumflex iliac or inferior epigastric arteries (Fig. 10). Treatment for hemodynamically unstable patients is not well established. However, TAE can accurately assess bleeding sites through angiography and provide

rapid bleeding control through embolization (21).

THORACIC INJURY

Intrathoracic hemorrhage in blunt thoracic trauma is caused by rib fracture-associated intercostal artery injuries. Self-limited bleeding can be managed conservatively, but persistent bleeding requires active treatment due to life-threatening complications (22).

Although exploratory thoracotomy was the treatment of choice in the past, interventional treatment is preferred for those not eligible for surgeries or have difficulty for surgical access due to deep posterior intercostal artery bleeding (Fig. 11). TAE of the intercostal artery is a minimally invasive, safe, and reliable treatment for intra-thoracic hemorrhage. However, cautions are required due to spinal cord ischemia, a severe complication of intercostal artery embolization (22).

EXTREMITY INJURY

Extremity vascular injury mainly occurs in blunt or penetrating trauma. Clinical practice has shifted from performing immediate surgeries in all suspected patients to those with distal pulse loss during physical examination, limb ischemia, expanding hematoma, thrill or bruit, pulsatile bleeding, significant external bleeding, or compartment syndrome (11).

Interventional treatments include embolization, balloon occlusion, and stent-graft placement. Large proximal extremity vessel injuries, such as subclavian or femoral arteries, are rare but may cause life-threatening conditions and require stent graft or balloon occlusion (11). Small vessel injury requires evaluation for collateral circulation of distal extremity before embolization. In the upper extremity, embolization can be performed safely in radial,

Fig. 11. Thoracic injury in a 43-year-old man who had an out-of-car traffic accident.
A. CT scan shows active extravasation (arrow) and multiple rib fractures with hematoma (arrowhead).
B. Angiography confirms the extravasation (arrow) from the 10th right intercostal artery, which was successfully treated with transcatheter arterial embolization using coils (arrowheads).

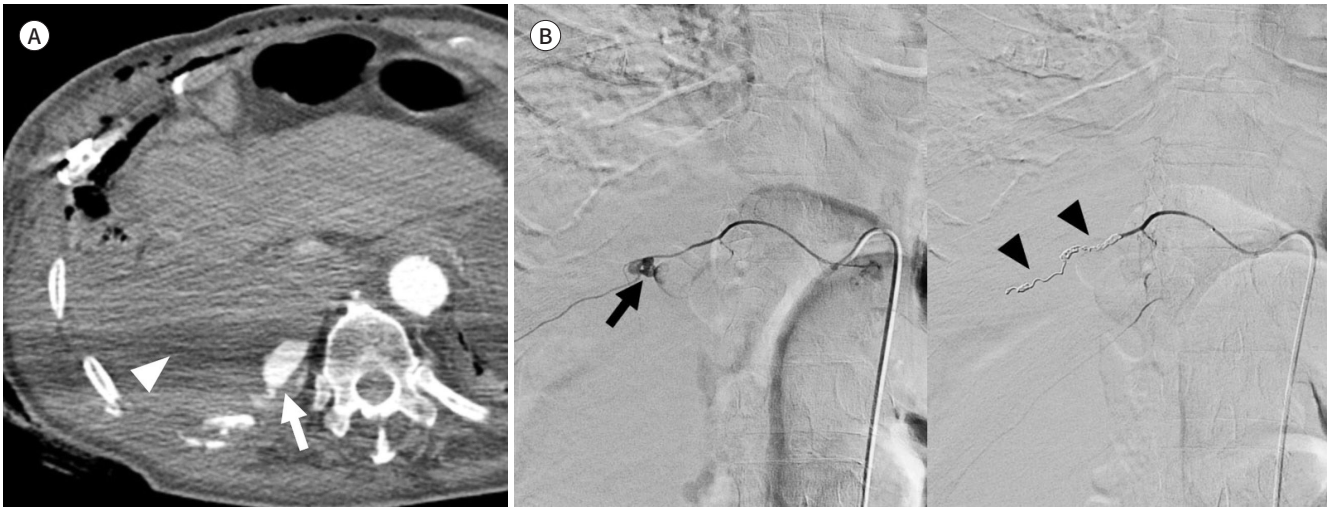
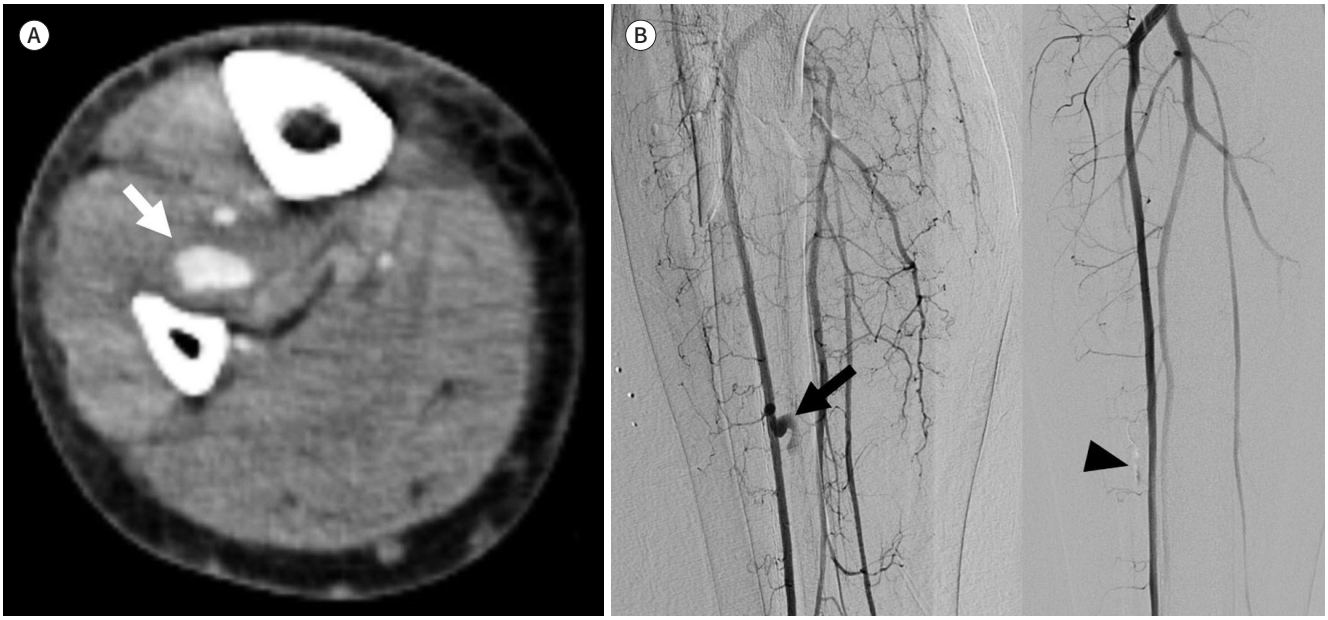


Fig. 12. Extremity injury in a 55-year-old man who had a pedestrian traffic accident.
A. CT scan shows active (arrow) in the tibialis muscle.
B. Angiography confirms the extravasation (arrow) from the muscular branch of the right anterior tibial artery, which was successfully treated with transcatheter arterial embolization using N-butyl cyanoacrylate (arrowhead).



ulnar, or interosseous arteries, as their collateral vessels are well developed. However, embolization in the iliac and femoral arteries in the lower extremity should be performed with caution, as they are vital vessels that cannot be sacrificed (Fig. 12) (23).

CONCLUSION

A multidisciplinary team approach among surgeons and interventional radiologists with use of advanced equipment is necessary for optimal management of trauma patients requiring critical care. Although emergency laparotomy remains the standard treatment for hemodynamically unstable patients, IR plays an essential role in acute trauma management to achieve the best clinical outcomes of trauma critical care patients.

Author Contributions

Conceptualization, L.M.S.; data curation, K.K.S., L.M.S.; investigation, K.K.S., L.M.S.; project administration, L.M.S.; supervision, L.M.S., K.D.R., K.Y.H.; visualization, all authors; writing—original draft, K.K.S., L.M.S.; and writing—review & editing, L.M.S., K.D.R., K.Y.H.

Conflicts of Interest

The authors have no potential conflicts of interest to disclose.

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급성 외상 환자 치료에서 인터벤션 영상의 역할: 임상화보

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외상은 40세 이하에서 가장 흔한 사망의 원인 중에 하나이다. 과거에는 외상 환자의 치료로 대부분 수술적 치료가 우선 되었다. 하지만 점차 외상 환자의 치료에서 장기 보존이 중요하게 되었으며, 외상 후 환자의 치료는 수술적 치료에서 비수술적 치료로 바뀌고 있다. 외상 환자의 적절한 치료를 위해서는 다양한 분야의 협력이 필요하다. 그중 인터벤션 영상 의학은 외상 환자를 평가하고 치료하는데 중요한 역할을 담당하고 있다. 이에 본 논문은 인터벤션 치료가 급성 외상 환자에서 중요한 역할을 했던 다양한 증례들에 대해 소개해 보고자 한다.

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