# Transcatheter arterial embolization for Trauma

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**Introduction**

There are 3 major periods for trauma deaths. The half of trauma deaths are occurred in the 1st period within an hour (immediate death). The 30% of trauma deaths are occurred in 2nd period (few hours after injury). The trauma deaths in 2nd periods is mainly due to severe blood loss. The rest of trauma deaths is occurred in the 3rd period (days to weeks) due to infection, multiple organ failure or both. It is crucial to decrease the trauma death, especially in 2nd period. Thus, appropriate treatment strategy for bleeding control within an hour after trauma has to be developed. To accomplish this goal, it is imperative to organize and train a multidisciplinary team for trauma care. As interventional radiology (IR) for trauma has been developed, we, interventionalists (IRists), play a growing role in the trauma care.

Recent development of IR changed the treatment strategy for trauma patients that is a paradigm shift from operative to non-operative management, such as transcatheter arterial embolization (TAE), of hemodynamically stable and some of hemodynamically unstable blunt trauma patients[1)]. TAE can avoid unnecessary surgery or make the surgery easier by the creation of a relatively bloodless operation field, particularly for pelvic trauma. In addition to TAE, the efficacy of resuscitative endovascular balloon occlusion of the aorta (REBOA) for temporal control of intra-abdominal hemorrhage for the resuscitation of patients who are severely injured after abdominal or pelvic trauma was reported[2)].

**Damage Control Surgery (DCS) and Damage Control Interventional Radiology (DCIR)**

The term "damage control" originates from the United States Navy and refers to the quick fix to return to port, following complete fixation. The concept of "damage control surgery" was first developed in the early 1980s in an attempt to reduce mortality in severely injured patients[3)] . It is now well known that trauma patients are more likely to lapse into the metabolic failures, such as coagulopathy, hypothermia and metabolic acidosis, which exacerbate hemorrhage. These metabolic failures are called "deadly triad". Trauma patients with these metabolic failures cannot go through the complex operations such as formal hepatic resection or pancreaticoduodenectomy. Damage control surgery is a multi-step strategy focused on restoring hemodynamics and prevent to lapse into the metabolic failures, rather than complete fixation of injury. Once metabolic failures are corrected, the definitive surgical procedure can be carried

out as necessary[4].
Recently, the concept of "damage control inteventional radiology" has been suggested [5]. DCIR is IR in hemodynamically unstable patients which focuses on stabilization of patients' hemodynamics. Thus DCIR can be proximal and wide embolization to shorten procedure time. On the other hand conventional emergency interventional radiology is IR in hemodynamically stable patients which focuses on complete, selective, and less-invasive TAE procedure. IRists have to evaluate how long the patients can go through TAE procedure based on patients' hemodynamic status and choose the embolization strategy (DCIR or CEIR). All procedures from catheterization to the final angiography should be completed within one hour.

**Choice of embolic materials and coagulopathy**

IRists have to understand not only characteristics of each embolic material and also pathophysiology of trauma patients. Coagulopathy is most important factor for selection of embolic materials. Coagulopathy after trauma is called DIC with the fibrinolytic phenotype, which is characterized by the activation of coagulation, consumption coagulopathy, insufficient control of coagulation, and increased fibrinolysis. DIC with the fibrinolytic phenotype induces oozing-type non-surgical bleeding and significantly affects the patients' prognosis. Coagulopathy can be modified by acidosis, hypothermia, or hemodilution by fluid or blood resuscitation.

The embolic materials frequently used for TAE of trauma patients are gelatin sponge particle, metal coils, and n-butyl-Cyanoacrylate (NBCA). Gelatin sponge particle is basically the first choice of embolic material for TAE of trauma. Metallic coil is useful for embolization of pseudoaneurysm or avulsed artery. Since these embolic materials are depend on patients' clotting ability, these are effective only when patients' coagulopathic condition is normal. On the other hand, n-butyl-Cyanoacrylate (NBCA) polymerizes rapidly by the contact with blood and immediately embolize the vessel, regardless of patients' coagulapathic condition. Therefore, NBCA should be used as embolic material for the TAE of severely injured patients, especially in DCIR trauma care.

**Blunt abdominal trauma**

Abdominal organ injuries are found in 20% to 30% of patients with multi-organ injuries[6, 7].

The spleen is the most frequently injured organ, followed by the liver, kidney, pancreas and a hollow viscus. The management of splenic injury is a big issue for trauma care, because it causes massive intraperitoneal hemorrhage. Although splenectomy remains the gold standard for the patients with splenic injuries who are hemodynamically unstable, non-operative management (NOM), including observation and TAE, has become common treatment option in patients who are hemodynamically stable.

Since splenectomy has the future risk for overwhelming post-splenectomy infections (OPSI), NOM should be chosen as far as possible.

The procedure of TAE for splenic injury is divided into two major types, proximal and distal embolization. Proximal and distal embolization is defined as embolization in the splenic artery trunk and in the segmental branches in the intra-parenchymal portion, respectively. Proximal embolization is performed to decrease the volume of splenic arterial blood flow and then to produce relative hypotension in the splenic bed, allowing the spleen to repair itself without infarction. However, recurrent or persisting bleeding can occur via collaterals after proximal embolization, and recurrent/persisting bleeding is difficult to retreat by repeated embolization due to the embolic materials in the splenic artery trunk. In addition, proximal embolization may cause pancreatic ischemia.

Therefore, distal embolization is preferred in Japan (figure1). Although the risk of splenic infarction is higher with distal embolization, the infarctions caused by distal embolization is usually limited.

The liver is the second most frequent injured organ (figure2). As same as other organ injury, NOM is now the common treatment in hemodynamically stable patients. TAE is indicated for patients who showed extravasation of contrast media on contrast enhanced computed tomography (CT) or angiography. Surgical intervention is considered for the patients who are hemodynamically unstable or the patients with the injuries to hepatic vein and inferior vena cava (IVC).

**Pelvic trauma**

Blunt pelvic trauma is severe condition that often results in massive hemorrhage and has high mortality and morbidity. Pelvic radiographic imaging is a useful screening tool to rapidly determine the need for immediate intervention. Contrast enhanced CT is the mainstay when assessing pelvic fractures and retroperitoneal hematomas. Immediate and appropriate multimodality therapies including external pelvic stabilization, TAE and extra-peritoneal pelvic packing are effective. TAE for pelvic trauma is considered in the following situation; hemodynamically unstable, extravasation of contrast media on contrast enhanced CT, and elderly (>60 years old) [8] (figure3). As same as splenic injury, the embolization point (proximal or distal) and embolic materials has to be chosen based on patients' condition. In hemodynamically stable patients, selective embolization with GS can control the bleeding. On the contrary, bilateral internal iliac artery embolization with NBCA may be required in hemodynamically unstable patients.

**Summary**

Recent development of angiography and transcatheter techniques made IR an essential treatment option for the trauma patients. Not only hemodynamically stable patients, some of hemodynamically unstable patients can be performed IR. Recently, the concept of damage control interventional radiology (DCIR) has been suggested and

changing the damage control strategy. Therefore, it is crucial for IRists to understand time sensitive radiologic damage control strategies. This lecture focuses on expanding the knowledge of these strategies and the demonstration of representative cases for understanding the time sensitive procedures of emergent DCIR in trauma care.

**References**

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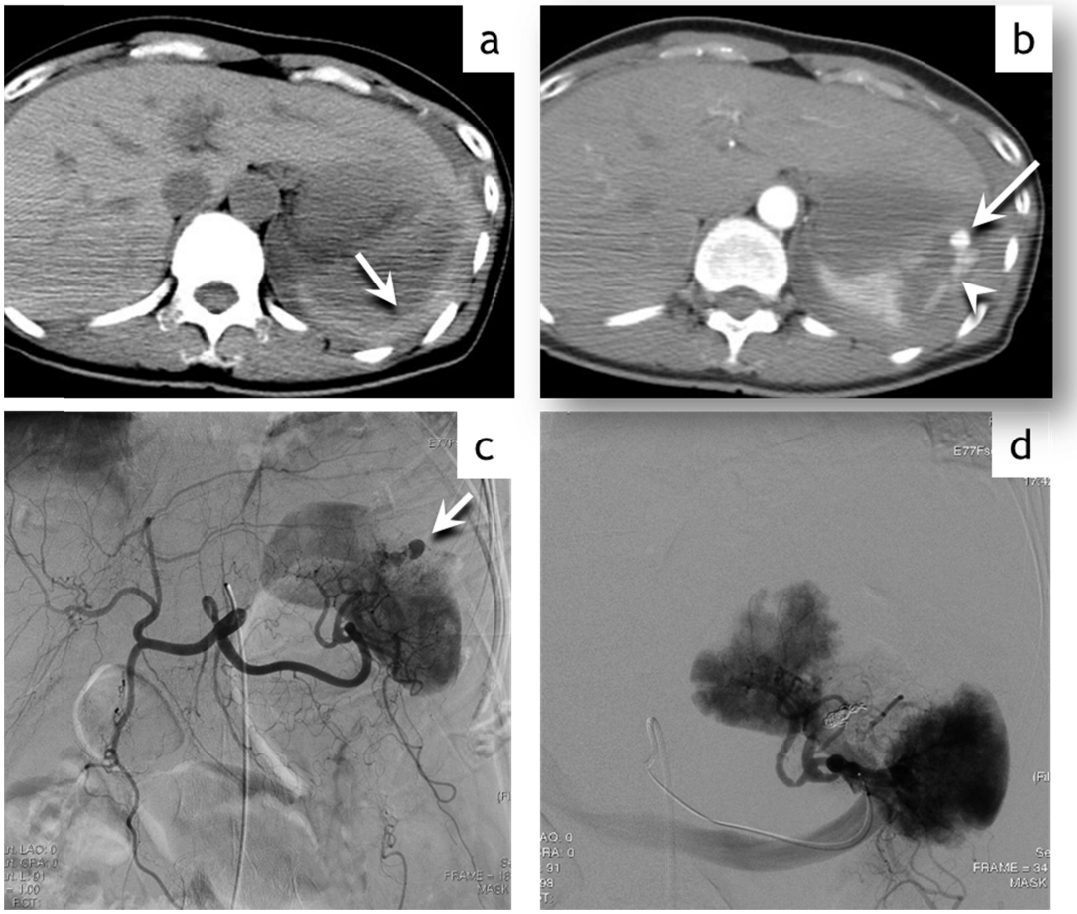


**Fig1. A 54 year-old woman with grade IIIb splenic injury from a traffic accident**
(a) Unenhanced CT showed focal hyperdence clots (*arrow*) adjacent to the spleen.
(b) Contrast enhanced CT image showed a pseudoaneurysm (*arrow*) and contrast material extravasation (*arrow head*) around the injured spleen.
(c) Celiac arteriogram showed a pseudoaneurysm corresponding to the CT finding (*arrow*).
(d) The splenic middle branch was embolized by inserting stainless steel coils. Splenic arteriogram after TAE demonstrated complete occlusion of the splenic middle branch and the disappearance of pseudoaneurysm.

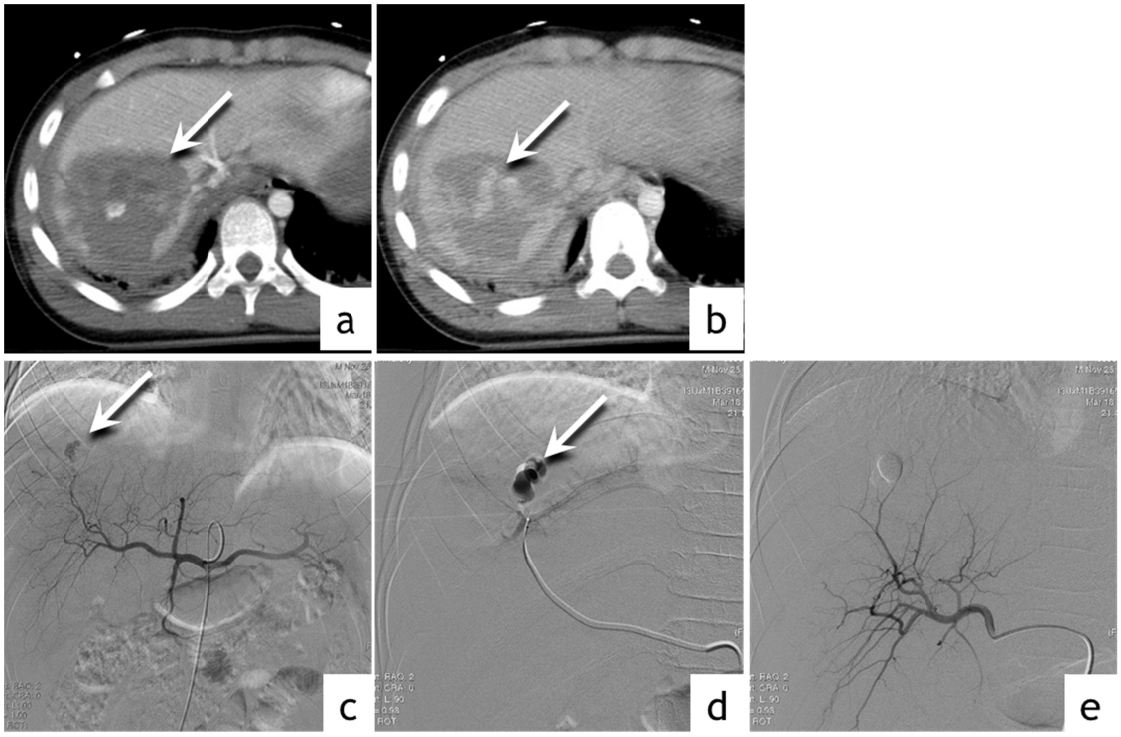


**Fig2. A 9 year-old boy with grade IIIb hepatic injury from a traffic accident**
Enhanced CT image showed a massive deep injury (*arrow)* with a central pseudoaneurysm (curved arrow) on the arterial phase image (a) and contrast material extravasation (*arrow)* in the equilibrium phase (b).
(c) Celiac arteriogram showed a pseudoaneurysm within the right upper liver parenchyma (*arrow*). (d) Super selective right hepatic arteriogram also showed a pseudoaneurysm within the hepatic parenchyma. (e) Common hepatic artery arteriogram obtained after embolization with gelatin sponge particle showed complete occlusion of the right upper branch of the hepatic artery and the disappearance of pseudoaneurysm.

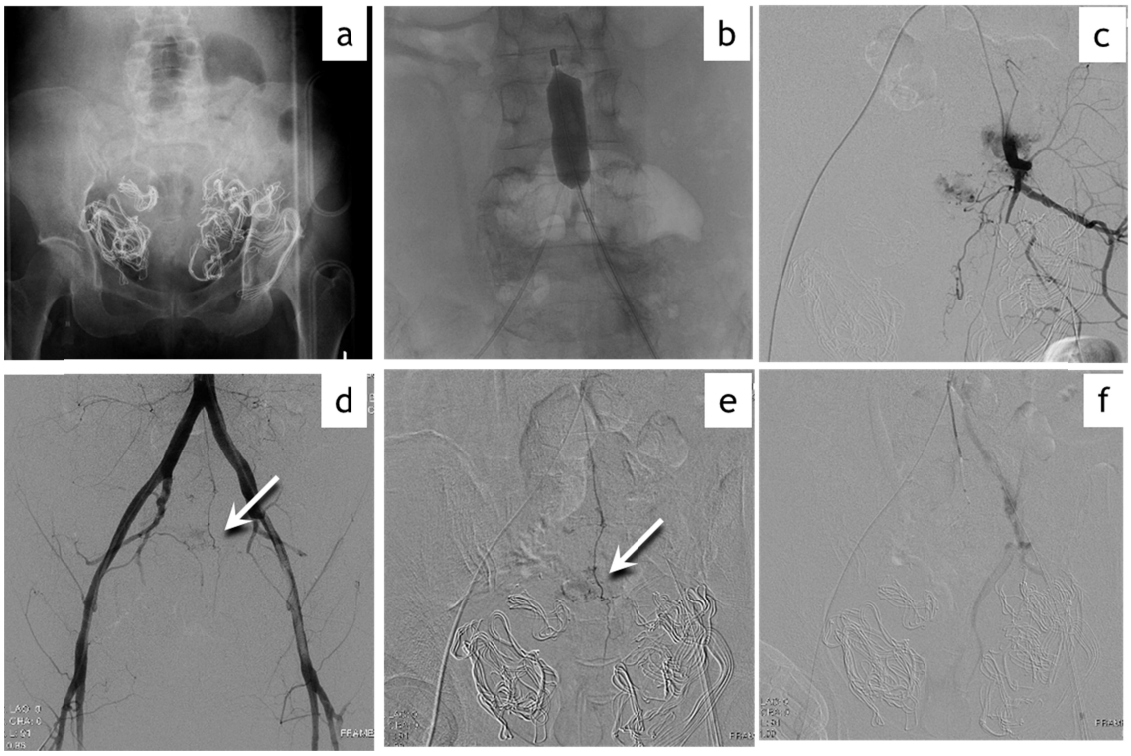


**Fig3. A 58 year-old woman with grade III pelvic injury from a fall**
Despite resuscitation at ER, the mean SBP was 60 mm Hg so pelvic packing with XP gauze and IABO were performed. (b) Balloon catheter was placed in the abdominal aorta. After pelvic packing and IABO, the mean SBP restored up to 80 mm Hg. (c) Left internal iliac arteriogram showed an active contrast material extravasation (arrow) in the pelvis. (d) Pelvic arteriogram after bilateral IIA embolization with gelatin sponge particles showed an active contrast material extravasation from the median sacral artery (arrow). (e) Super selective median sacral arteriogram also showed an active contrast material extravasation (arrow) and embolized with gelatin sponge particles (f).