Original Article

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Prompt Procedures to Hemodynamically Unstable Patients with Pelvic Fractures

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Background: Angioembolization is a widely accepted method for an effective and useful hemostasis procedure in pelvic fracture (PF) patients. We evaluated and introduced the time course of the initial management and angiography in hemodynamically unstable pelvic fracture patients.
Methods: We retrospectively reviewed 56 PF patients who underwent interventional radiology (IR) from May 2010 to Dec 2016. We defined arrival to angiography time (ATAT), and this was recorded in all enrolled patients in which the first angiography image represented the initiation of angiography. We also evaluated total embolization time (TET) and single artery embolization time (SAET; time for artery selection, injection, embolization, and confirmation).
Results: The median ATAT and TET were respectively 73 and 33 minutes. They were much faster than the previous reports.
Conclusions: Our trauma IR strategy with a specialized team might contribute to a shortening of the management time.

Keywords: *Pelvic Fracture; Interventional Radiology; Damage Control*

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BACKGROUND

Pelvic fractures mainly result from motor vehicle collisions or falls from a height [1] and can cause extensive retroperitoneal bleeding. The mortality rate in hemodynamically unstable (HU) pelvic fracture still remains high at 40–50% [2]. Angioembolization (AE) is widely accepted as an effective hemostasis in pelvic fracture patients [3,4]. However even in Level 1 trauma centers, time from hospital admission to pelvic AE can be prolonged, and the delay of AE may not only make it more difficult to control the hemorrhage but also increase mortality rate [5,6].

Our trauma center employs a proactive trauma interventional radiology (IR) team established on the "Prompt and Rapid Endovascular Strategies in Trauma Occasions" (PRESTO) concept [7]. The AE procedure is based on the damage control interventional radiology (DCIR) protocol [7]. In this paper, we hypothesize that proactive IR team involvement contributes to early angiography and rapid procedures. We demonstrate the time to angiography and procedure time during the initial management of HU pelvic fracture patients.

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METHODS

PRESTO with DCIR

According to the PRESTO concept, the attending emergency physician/trauma surgeon activates the IR team when he/she assumed possible IR treatment as early as possible, even before the arrival of the patients. When hemodynamic instability or pelvic fracture were assumed, a femoral artery sheath is rapidly placed as part of the primary survey after the patient's arrival or recognition of shock. Bilateral femoral sheaths were obtained if needed for resuscitative endovascular balloon occlusion of the aorta (REBOA) or arterial pressure monitoring. The X-ray or CT images were evaluated by the IR physicians immediately. When the decision for IR was declared in the CT room, the patients were transferred to the angiography suite directly to minimize the time to angiography. All angiography was performed in the angiography suite 20 meters from the emergency room, which was next to the CT room. The IR team is ready to start angiography within 30 minutes from activation. All IR procedures are conducted by a trained radiology team which consists of IR physicians, fellows, radiology technicians, and nurses. The IR team comprises a conductor–operator–assistant. The conductor, a trained radiologist, diagnoses and processes the CT data to create virtual angiographic images in order to navigate the operator before or during the angiographic procedures (7).

Study Setting

We retrospectively enrolled HU pelvic fracture patients consecutively who required AE from March 2010 to May 2016 at a trauma center in a tertiary care hospital in Tokyo, Japan. The institutional review board approved the study prior to the registration of the patients' data. All patients were initially assessed and resuscitated by either emergency physicians or trauma surgeons. Pelvic injury was diagnosed by plain pelvic X-ray or CT. A pelvic binder was applied in open book type fractures in the emergency department. AE was chosen as the first-line hemostasis, then external fixation was added according to the fracture pattern as needed. Preperitoneal packing was not included in our institutional protocol. The indication of AE of pelvic fracture was hemodynamic instability, extravasation on the CT image, and hematoma neighboring to the fracture section. The decision of AE was preceded by hemodynamic response to the transfusion because a massive transfusion protocol with unmatched O-type blood was not established in the early study period. We aimed to perform AE in order to avoid or decrease the requirement of transfusion.

Data Collection and Definition

Patients' characteristics, injury severity score (ISS), and the revised trauma score (RTS) were collected and the probability of survival was calculated. HU was defined as shock index (SI) > 0.9 or systolic blood pressure (SBP) < 90 mmHg on arrival at the emergency department [8]. Hemodynamics data were recorded on arrival and after AE. Complications and transfusion requirement during the first 24 hours and survival outcomes were described.

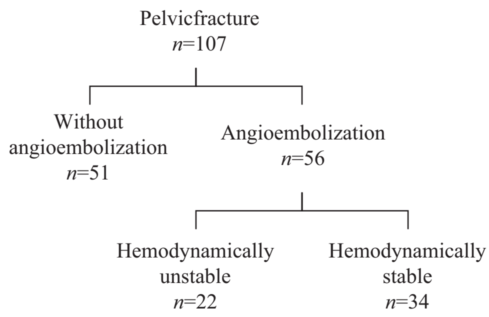

Figure 1 Flow chart of studied patients.

The time course was obtained from electronic medical records (EMR) or Digital Imaging and Communication in Medicine (DICOM) data. Arrival to angiography time (ATAT) was defined as the hospital arrival time on EMR to the first injection on DICOM data. Total embolization time (TET) was defined as the time from the first injection to the aortography after the embolization. In the cases requiring repeated AE, TET was calculated as the sum of each AE procedure. The number of embolized arteries were also recorded especially those observed in polytrauma patients. Single artery embolization time (SAET) was calculated by dividing TET by the number of embolized arteries. Embolic material such as gelatin sponge, metallic coil or N-butyl cyanoacrylate (NBCA) were also recorded.

Statistical Analysis

Data are presented as the median and interquartile range. Wilcoxon signed-rank test was used in the comparison of changes in SBP before and after AE. All levels of significance are reported at the level $\alpha = 0.05$ using a two-tailed test. Analyses were performed using GraphPad Prism for Mac OS X version 7.0c (GraphPad Software Inc, USA).

RESULTS

During the study period, we treated 107 pelvic injury patients. Of these, 56 patients underwent AE and 22 of these patients were HU on arrival (Figure 1). The median SBP and SI were 94 (83–110) and 1.19 (1.04–1.33), respectively. The SI significantly decreased from 1.19 to 0.86 after AE ($P < 0.001$). Median ISS was 25 (16–34). Median 24-hour survival rate was 90.9%. Transfusion requirement within the first 24 hours was 13 units of packed red blood cell, and 12 units of fresh frozen plasma (Table 1). The median ATAT and SAET were 73 (51–93) minutes and 7 (5–11) minutes, respectively (Table 2). As concomitant procedures among 22 HU patients, 14 underwent solid organ embolization, 8 required external fixation, 1 received REBOA, and 1 underwent craniotomy.

Table 1 Patients' characteristics and outcomes.

Characteristics and outcome	*n = 22*
Age (years)	50 (23–65)
Male, *n* (%)	13 (59)
Young–Burgess classification	
LC-I	5
LC-II	6
LC-III	1
APC-I	0
APC-II	2
APC-III	3
VS	5
Systolic blood pressure (mmHg)	94 (83–110)
Shock Index on arrival	1.19 (1.04–1.33)
Shock Index after angioembolization	0.86 (0.69–0.99)
Injury Severity Score	25 (16–34)
Revised Trauma Score	7.55 (6.81–7.84)
Transfusion during first 24 hours	
PRBC (mL)	13 (4.5–19), 1820 (630–2660)
FFP (mL)	12 (8.5–21.5), 1400 (1020–2580)
Platelet (mL)	0 (0–18), 0 (0–360)
Complication, *n* (%)	
Gluteal necrosis	1 (4.5)
Bladder necrosis	0
Morell–Lavalle	0
24-hour survival, *n* (%)	20 (90.9)
30-day survival, *n* (%)	18 (81.8)
Probability of survival, (%)	93 (79–97)

LC, lateral compression; APC, anterior posterior compression; VS, vertical shear; PRBC, packed red blood cell; FFP, fresh frozen plasma; Ps, probability of survival.

The data are presented as median and interquartile range for categorical data.

Transfusion units are presented in Japanese units. One Japanese unit of transfusion is made from 200 mL of donor blood.

DISCUSSION

A delay in angiography affects the mortality in pelvic fracture patients [6]. Currently, the ATAT is reported to be more than three hours even in a high volume level 1 trauma center in the United States [8,9]. The time course to angiography mainly depends on IR team activation, diagnosis of the image, and decision of angiography. Our results present 73 minutes of ATAT. This number is much shorter than in previous reports [8,9]. Our IR team is tolerant to overactivation based on the PRESTO concept. In addition, more lucid activation criteria may contribute to earlier initiation of angiography.

IR is considered in procedures for hemodynamically stable patients in abdominal trauma. In addition, IR is utilized as a definite hemostasis in pelvic trauma [5]. However, pelvic AE procedure time was reported between 60 and 130 minutes in past literature [10,11]. Our results revealed 33 minutes of TET. Our AE procedures were based on DCIR protocol, such as permissive wide range embolization or waiving diagnostic angiography, in HU patients. We reported approximately 7 minutes of SAET, including cannulation, injection, embolization, and re-injection. Rapid procedures could be explained by bilateral non-selective internal iliac artery embolization (observed in 77% of the analyzed patients) or NBCA injection (observed in 27% of the analyzed patients). In addition, the "Conductor" doctor plays a key role in our IR team, the navigation of the operator is based on CT volume data to provide precise anatomical information concerning access to target vessels [7], such as the level of the branch of the aorta, clock position in the cross-sectional plane of the aorta, and a visual angiographic image with a clear catheter route. After the procedure, SI improved from 1.19 to 0.86, which could be explained by whole resuscitation effort, including AE, transfusion, and correction of coagulopathy.

The present study has several limitations. Firstly, this is a retrospective, single center, observational study with a small number of cases. Secondly, we did not conclude

Table 2 Time course in initial management and endovascular procedure.

Characteristics	*HU group (n = 22)*
ATAT (min)	73 (51–93)
TET (min)	33 (11–72)
Number of embolized arteries	3 (2–5)
Embolized artery	Internal iliac artery Branches of internal iliac artery Lumbar artery Femoral artery branches Splenic artery Hepatic artery
SAET (min)	7.1 (5.1–11.5)
Bilateral non-selective IIA embolization, *n* (%)	17 (78)
Embolic material, *n* (%)	
Gelatin sponge	18 (82)
Coil	0 (0)
NBCA	6 (27)

ATAT, arrival to angiography time; HU, hemodynamically unstable; TET, total embolization time; SAET, single artery embolization time; IIA, internal iliac artery; NBCA, N-butyl cyanoacrylate.

The data are presented as median and interquartile range for categorical data.

ATST and STAT were recorded and analyzed in the CT first cases.

the benefit in survival or transfusion requirement in the studied trauma care system. Thirdly, this study included both isolated pelvic injury and polytrauma; the heterogeneity of the studied population could affect the results. Despite these limitations, a proactive IR team may contribute to a novel trauma care system.

CONCLUSIONS

Our proactive IR team established on the PRESTO concept started angiography 70 minutes after the patient's arrival. The AE procedure based on the DCIR protocol took 7 minutes per single vessel.

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