

# Efficacy of median sacral artery embolization for treating severe pelvic fractures: a retrospective study

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## Abstract

**Objective:** Transcatheter arterial embolization (TAE) of bilateral internal iliac arteries (IIAs) in patients with a hemodynamically unstable pelvic fracture is associated with a low mortality rate. The persistence of unstable hemodynamics after IIA embolization indicates the involvement of other arteries, such as the median sacral artery (MSA). This study aimed to evaluate the efficacy of MSA embolization.

**Methods:** In this single-center, retrospective, observational study, medical records of patients who underwent MSA angiography or embolization for pelvic fractures ( $n = 21$ ) between January 2007 and August 2019 were reviewed. The percentage of patients achieving hemodynamic stabilization by MSA embolization was calculated.

**Results:** Fifteen patients underwent MSA embolization, and the remaining six underwent MSA angiography. The shock index value was significantly higher after MSA embolization than that before MSA embolization in hemodynamically unstable patients who underwent this procedure. The success rate of MSA selection was 100%. One patient presented with urinary retention because of bladder and rectal disorders after MSA embolization. The 30-day survival rate was 85.7%.

**Conclusions:** Severe pelvic fractures, such as a Dennis Zone III fracture and suicidal jumper's fracture due to trauma from a fall, may require MSA embolization.

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## Keywords

Median sacral artery, hemodynamical instability, pelvic fracture, transcatheter arterial embolization, suicidal jumper's fracture, shock index

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## Introduction

A pelvic fracture is a fatal traumatic injury that can cause massive retroperitoneal bleeding. The treatment of pelvic fractures can be performed using pre-peritoneal pelvic packing, transcatheter arterial embolization (TAE), external fixation (EF), or a combination of these treatments, depending on the patient's pattern of injury and the capabilities of the facility. In recent years, resuscitative endovascular balloon occlusion of the aorta has been used to temporarily control bleeding.<sup>1-3</sup> More than 80% of hemorrhage associated with pelvic fractures occurs because of venous bleeding, and originates from vessels supplying the fractured bone surface.<sup>4</sup> However, reports have stated that 54% of patients with pelvic fractures who are hemodynamically unstable have active arterial bleeding at the site of injury.<sup>5</sup> Indeed, patients with pelvic fractures who are in a hemodynamically unstable state have high mortality rates, and correspondingly, the control of arterial bleeding using TAE is associated with a decreased mortality rate.<sup>6</sup> Therefore, TAE is widely performed as a standard treatment modality to control arterial bleeding.<sup>7-11</sup>

In patients with pelvic fractures who are hemodynamically unstable because of hemorrhagic shock, TAE involves non-selective embolization on the proximal side of the bilateral internal iliac arteries (IIAs).<sup>12</sup> Previous studies have suggested that gluteal necrosis and ischemia/necrosis of pelvic organs, such as the bladder and rectum, are associated with non-selective

embolization.<sup>13-15</sup> However, currently, traumatic injury to the buttocks caused by strong, direct external forces is thought to be the cause of gluteal necrosis.<sup>16</sup> Furthermore, the incidence of this complication is not associated with non-selective embolization of bilateral IIAs.<sup>17</sup> When a patient is hemodynamically stable, selective embolization, which involves the identification of vessels exhibiting contrast extravasation (CE) on contrast-computed tomography (CT), as peripherally as possible, is recommended.

In pelvic fractures with unstable hemodynamics that persist even after bilateral IIA embolization, many arteries other than the IIA, such as the median sacral artery (MSA), external iliac artery branches, and lumbar artery, form a collateral path to contribute to the bleeding. Among these, external iliac artery branches are involved in only 11% to 17% of cases requiring TAE for pelvic fractures.<sup>18-20</sup> In contrast, a major source of bleeding after pelvic trauma is the MSA, which branches from the dorsal side of the bifurcation of the terminal aorta, and traverses in front of the sacrum. However, there have only been a few reports on MSA embolization for treating retroperitoneal hemorrhage occurring after bone marrow biopsy,<sup>21,22</sup> and little is known about the use of MSA embolization for pelvic fractures. We have frequently experienced prolonged hemodynamic instability after bilateral IIA embolization in patients with severe pelvic fractures. In these cases, MSA embolization may be additionally necessary.

This study aimed to determine the epidemiology of MSA injury associated with pelvic fractures and to evaluate the efficacy of MSA embolization.

## Materials and methods

### *Study design and patients*

This single-center, retrospective, observational study was conducted at our facility, which is a level 1 trauma center. Among patients who underwent TAE for pelvic fractures between January 2007 and August 2019, we examined the medical records of those who underwent MSA angiography or embolization. We retrieved the target cases using the Japan Trauma Data Bank and screened for cases of pelvic fractures treated at our facility. We excluded out-of-hospital patients with cardiac arrest. Subsequently, we extracted and reviewed the medical records of patients who underwent TAE as an initial treatment for hemostasis. We collected clinical data, such as the patients' information, vital signs, and examination findings, including those of imaging, using diagnostic records.

### *Initial treatment for pelvic fracture and application of TAE*

The initial evaluation of trauma was performed by emergency physicians on the basis of the Japan Advanced Trauma Evaluation and Care guidelines. When an unstable pelvic fracture was identified on a pelvic X-ray during the initial examination, patients were given a pelvic binder to wear. TAE was performed in patients who were non-responders despite the initial infusion. Patients with stable pelvic fractures, as determined using a pelvic X-ray, or transient responders/responders to the infusion who had unstable pelvic fractures, were evaluated by contrast CT scans. TAE was performed if they showed positivity for CE.

Normally, even if contrast CT indicates the absence of CE, TAE is sometimes performed in patients with an unstable pelvic fracture, and unstable hemodynamics characterized by a modified shock index  $\leq 1$ . The modified shock index was calculated by dividing systolic blood pressure (mmHg) by heart rate (beats/minute). At our facility, TAE was performed by interventional radiologists or equivalent doctors. EF was performed by orthopedic surgeons if the pelvic ring was unstable, but if TAE was going to be performed together with EF, patients wore a pelvic binder during TAE. In principle, retroperitoneal packing was performed when the hemodynamics did not stabilize, even after TAE and EF.

### *TAE procedure for pelvic fractures involving the MSA*

Non-selective embolization of bilateral IIAs was performed by first placing a 5 Fr sheath in the femoral artery on the less damaged side, and then selecting the contralateral IIA with a 5 Fr cobra catheter (Cook, Bloomington, Indiana, USA) or a shepherd hook type catheter (Hanaco Medical, Saitama, Japan). A gelatin sponge cut to a uniform size of 2 mm was injected from the beginning of the IIA and embolization was performed. Similarly, the IIA on the same side was also embolized. MSA arteriography was performed if a pelvic X-ray or CT findings showed injury to the posterior pelvic components, such as a sacral fracture or sacroiliac dissection, or if hemodynamics were unstable after bilateral IIA embolization. The MSA was selected by pulling down the shepherd hook, which faced backward, to sit on the aortic bifurcation. At this stage, a 2.2 Fr microcatheter (Goldcrest; Kosin Medical, Tokyo, Japan) was advanced to the MSA and selectively contrasted. Embolization was performed at the location of CE, but if selective

contrast did not show any enhancement, the procedure was completed with a contrast scan alone. Embolizing agents, such as a gelatin sponge and n-butyl-2-cyanoacrylate, were selected for MSA embolization with the discretion of the interventional radiologist, depending on the coagulation capacity of the patients (Figure 1).

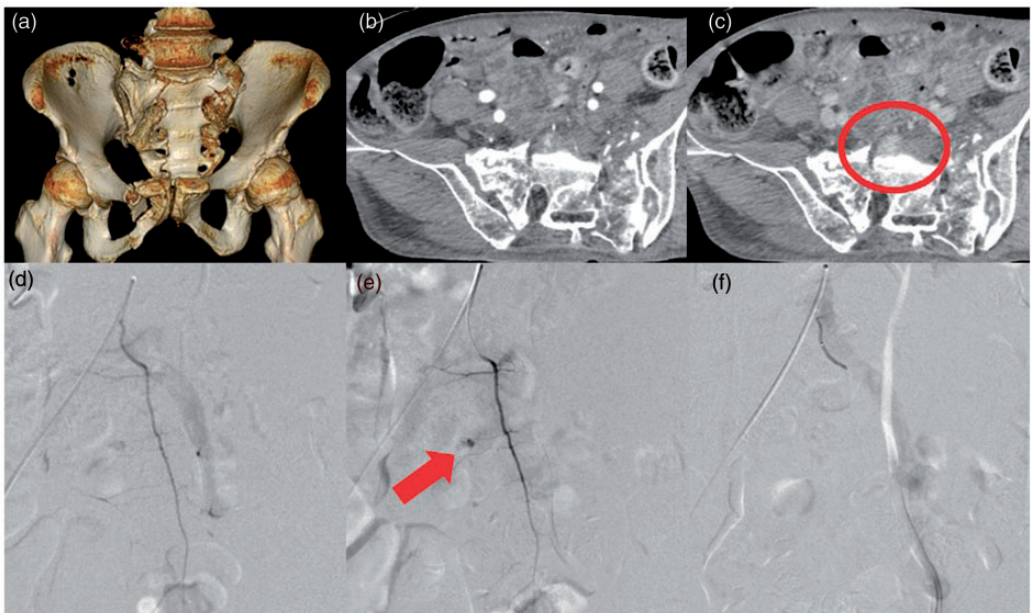
### Study endpoints

The primary endpoint was the proportion of patients who achieved hemodynamic stability with MSA embolization. Hemodynamic instability was defined as a

modified shock index of  $<1$ . Secondary endpoints were the time taken to perform MSA embolization, success rate of MSA selection, incidence of complications by embolization, and 30-day survival rate.

### Statistical analysis

IBM SPSS version 21 (IBM Corp., Armonk, NY, USA) was used to perform all statistical analyses. Continuous and categorical variables were analyzed using the Mann–Whitney U test and Fisher's exact test, respectively. In all statistical analyses,



**Figure 1.** Procedure for median sacral artery embolization in a 56-year-old female patient. The patient attempted suicide by jumping off the second floor of her house (approximately 3 m in height) and was transported by ambulance to our hospital. We identified (a) right and left pubic and ischial fractures, sacroiliac joint separation, and a sacral fracture in the sacral hiatus. Contrast extravasation (CE) was detected in the arterial phase (b) of contrast-enhanced computed tomography, and (c) the bleeding had lightly spread (circle) in the delayed phase. Transcatheter arterial embolization was then performed. (d) The median sacral artery (MSA) can be selected by pulling down a shepherd hook catheter, with this catheter facing the dorsal side at the level of aortic bifurcation. The MSA splits into the left and right fifth lumbar arteries and runs along the anterior sacrum. (e) Embolization is performed by advancing the microcatheter further to the MSA, while being careful that the embolic agent does not overflow into the aorta. (f) In this case, there was CE on the right side of the distal sacrum in the fifth lumbar artery bifurcation (arrow), and embolization using a gelatin sponge led to the resolution of CE.

a P value of  $<0.05$  was considered statistically significant.

### Ethics

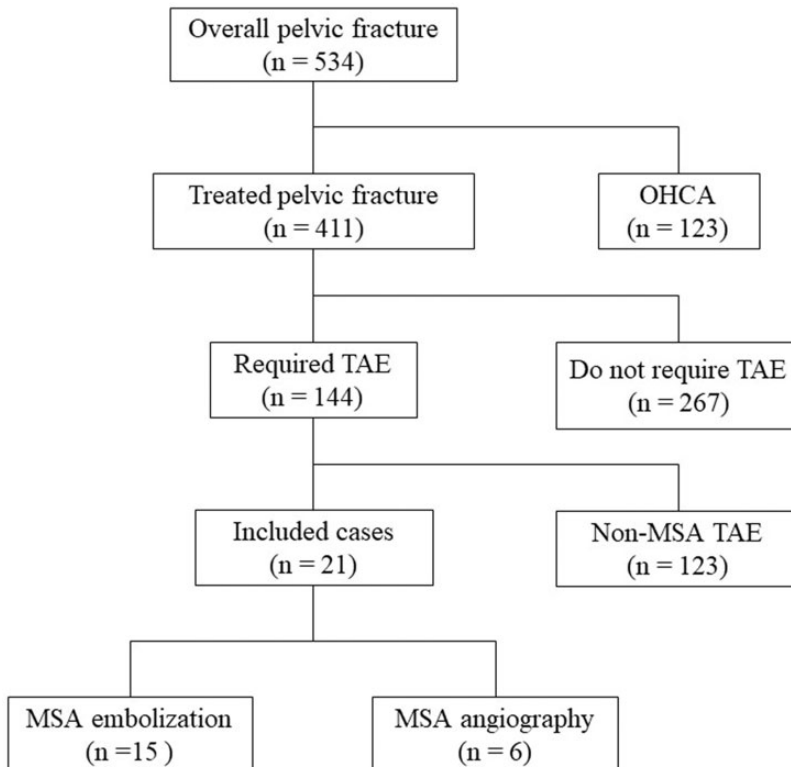
This retrospective, observational study involved human participants, and was conducted in conformance with the principles of the Declaration of Helsinki and its amendments. The reporting of this study also conforms to the STROBE guidelines.<sup>23</sup> The study protocol was approved by the Institutional Review Board for Observation and Epidemiological Study at our hospital (approval no. B19-253). This committee waived the need for informed consent because of the retrospective study design.

### Results

Among the 144 patients who underwent TAE for pelvic fractures, we examined 21 (14.6%) patients (Figure 2). Table 1 shows the patients' characteristics. Among the 21 patients, 15 underwent MSA embolization, and the other 6 underwent MSA angiography alone, during which time they showed no CE.

The main cause of injury was falls in 85.7% (18/21) of the patients. The median injury severity score was 38 (interquartile range, 34–57), and all patients had severe multiple traumas with an injury severity score of  $\geq 15$ .

All patients had pelvic fractures equivalent to a Type C unstable fracture



**Figure 2.** Flowchart of the patients. Among 534 patients with pelvic fractures observed during the study period, 123 had out-of-hospital cardiopulmonary arrest (OHCA) and were excluded. Among the remaining 411 patients, 144 patients underwent transcatheter arterial embolization. Among these, 21 patients underwent median sacral artery (MSA) contrast or embolization.

**Table 1.** Baseline characteristics of the patients included in this study.

MSA angiography/embolization (n = 21)	Median or number	IQR or %
Age (years)	44	25–62
Male sex, n (%)	6	28.6
Mechanism		
Fall, n (%)	18	85.7
Traffic accident, n (%)	3	14.3
Vital signs at arrival		
Respiratory rate (breaths/minute)	24	21–30
Saturation (%)	100	100–100
Systolic blood pressure (mmHg)	90	80–124
Pulse rate (beats/minute)	105	90–126
Glasgow coma scale (points)	14	12–15
Modified shock index < 1 at arrival, n (%)	6	28.6
Time from arrival to TAE (minutes)	54	40–100
Time for TAE for pelvic fractures (minutes)	50	34–69
Time for bilateral IIA embolization (minutes)	29	15–46
Time for MSA embolization (minutes)	18	9–29
Technical success of MSA selection, n (%)	21	100
Embolization agents, n (%)		
Gelatin sponge	11	52.4
n-butyl-2-cyanoacrylate	3	14.3
Other	1	4.8
None (only angiography)	6	28.6
Another treatment (non-TAE), n (%)		
Pelvic gauze packing	2	9.5
Pelvic binder	21	100
External fixation	11	52.4
REBOA	2	9.5
Type of pelvic fracture*, n (%)		
Type C	21	100
Type of sacral fracture (Dennis classification), n (%)		
Zone I	6	28.6
Zone II	5	23.8
Zone III	10	47.6
Open fracture (%)	0	0
Pelvis AIS	4	4–5
Injury severity score	38	34–57
Complications associated with MSA embolization, n (%)		
Gluteal necrosis	0	0
Neurogenic bladder	1	4.8
Erectile dysfunction (only male patients: n = 6)	0	0
30-day survival, n (%)	18	85.7

\*Classification of Arbeitsgemeinschaft für Osteosynthesefragen/Orthopedic Trauma Association. MSA, median sacral artery; IQR, interquartile range; TAE, transcatheter arterial embolization; IIA, internal iliac artery; REBOA, resuscitative endovascular balloon occlusion of the aorta; AIS, abbreviated injury scale.

according to the Arbeitsgemeinschaft für Osteosynthesefragen-Orthopedic Trauma Association classification, also involving sacral fractures. In addition to TAE, treatment involved pelvic EF in 11 (52.4%) patients and retroperitoneal gauze packing in 2 (9.5%) patients. The success rate of MSA selection was 100%. The most common embolizing agent used for the 15 patients who underwent MSA embolization was a gelatin sponge, followed by n-butyl-2-cyanoacrylate and other agents.

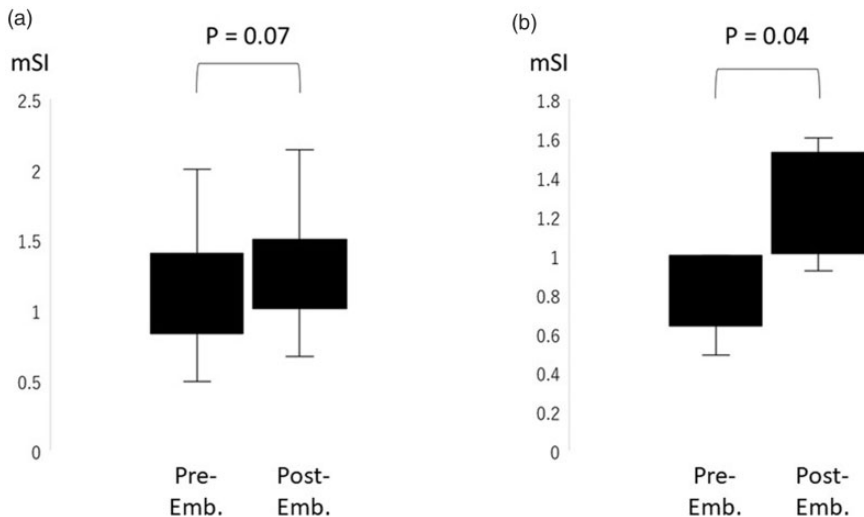
Hemodynamically unstable patients (i.e., those who showed a modified shock index of  $<1$ ) represented 52.4% (11/21) of all cases. Among the 15 patients who underwent MSA embolization, 6 showed a modified shock index of  $<1$ , which indicated prolonged unstable hemodynamics, even after bilateral IIA embolization. There was no significant difference in the modified shock index value between before and after MSA embolization in the 15 patients

who underwent MSA embolization. However, when the analysis was limited to only the six patients who showed a modified shock index of  $<1$  even after IIA embolization, the modified shock index in all patients was  $\geq 1$  after MSA embolization, which indicated that significant stabilization of hemodynamics was achieved ( $P = 0.04$ ) (Figure 3).

Only one patient presented with urinary retention because of bladder and rectal disorders after MSA embolization. None of the patients showed gluteal necrosis or necrosis of the bladder and rectum. The 30-day survival rate was 85.7%.

## Discussion

This study suggested that MSA embolization in patients who did not achieve stable hemodynamics after bilateral IIA embolization helped stabilize their hemodynamics. Most patients who stabilize after additional



**Figure 3.** Exploratory subgroup analyses of primary outcomes. The modified shock index (mSI) after bilateral internal iliac artery embolization and after additionally performing median sacral artery (MSA) embolization is shown. (a) The median mSI at post-MSA embolization was not significantly different to that at pre-MSA embolization ( $n = 15$ ). (b) In six patients with an mSI of  $<1$  after bilateral internal iliac artery embolization, the median mSI at post-MSA embolization was significantly higher than that at pre-MSA embolization.

embolization of MSA have trauma secondary to falls or crashes, and have fractures crossing the sacrum (suicidal jumper's fractures<sup>24</sup>). These patients can also have fractures near the center of the sacrum, such as the sacral hiatus corresponding to Zone II to III, according to the Dennis classification. Generally, many facilities perform peritoneal pelvic packing for pelvic fractures with hemodynamical instability. However, in case of bleeding of the anterior sacrum caused by MSA injury, making the gauze reach the anterior sacrum by peeling is difficult, and the effect of a striction may be inadequate in these sites. Therefore, in patients who have fractures such as those mentioned above, and certainly for those showing CE in the anterior sacrum by contrast CT, involvement of the MSA should be considered. In such cases, MSA embolization can be effective. Selection of the MSA is not difficult for well-trained interventionalists. However, selecting the MSA may be difficult when patients have a meandering aorta, such as that found in elderly patients. In these patients, a method to select only the MSA is required, such as slow injection of a cutting gelatin sponge, with bilateral common iliac artery balloons occluded just below the aortic bifurcation, to ensure flow only to the MSA.

Because the MSA is partly a feeding vessel in the lower lumbar and sacral medulla, there is a risk of developing bladder and rectal disorders owing to embolization at the same site. In fact, experiments in dogs reported that embolization of the MSA in addition to bilateral IIAs increased the incidence of necrosis in the bladder and rectum.<sup>25</sup> Even though we did not observe necrosis of the bladder or rectum in this study, we did identify one case of bladder and rectal disorder where the chief complaint was a neurogenic bladder. Pelvic fractures are associated with complications, such as bladder and rectal disorders or

sexual dysfunction, especially in patients with suicidal jumper's fracture who show severe neurological injuries (rate of 80%).<sup>26</sup> Therefore, we are unable to declare definitively that MSA embolization was associated with these conditions. However, the permanent embolic agent n-butyl-2-cyanoacrylate was used in the patient in whom a bladder and rectal disorder occurred. Previous reports have also suggested that ingenuity in the method of embolization during bilateral IIA embolization reduces the incidence of gluteal necrosis.<sup>13-15,17</sup> Additionally, the embolizing agents and the technique used determine the success of MSA embolization. More of these cases need to be accumulated, and methods of MSA embolization with fewer complications should be considered in the future.

## **Limitations**

There are several limitations to this study. First, this was a retrospective study conducted in a single center; therefore, the sample size was small, and the differences in therapeutic strategy for pelvic fractures may have affected the results. Second, we performed resuscitation, such as blood transfusion in parallel with bilateral IIAs or MSA embolization. The stabilization of hemodynamics may have been influenced by factors other than MSA embolization. Finally, because many of the surviving patients had been transferred to this hospital for rehabilitation, we were not able to study long-term complications, such as buttock claudication, and bladder and rectal disorders. The long-term safety of MSA embolization also needs to be evaluated with a focus on functional aspects in the future. Further details of patients who require MSA embolization need to be examined using prospective studies involving more patients.



## Conclusion

MSA angiography was required in 14.6% of cases of pelvic fractures requiring TAE in this study. Severe pelvic fractures, such as Dennis Zone III and suicidal jumper's fracture due to falls, may require MSA embolization. Although there were no short-term complications of MSA embolization in this study, long-term complications need to be further investigated.

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## Declaration of conflicting interest

The authors declare that there is no conflict of interest.

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