Original Article

Factors associated with prolonged procedure time of embolization for trauma patients

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Aim: Limited information exists on the factors associated with prolonged procedural time in embolization for trauma patients. We clarified the clinical application of embolization in trauma patients and factors associated with a prolonged procedure time.

Methods: Medical records of 162 trauma patients who underwent embolization between January 2007 and December 2020 at a regional trauma care center were reviewed retrospectively. Patients were divided into four embolized body regions: chest, abdomen, pelvis, and other. Patient demographics, trauma mechanism, physiology, trauma severity, embolization procedures, and 30-day mortality were examined. The outcomes were identifying an embolized body region, embolized arteries, and procedure time. Multiple regression model was created to investigate the factors associated with prolonged procedural time in embolization.

Results: Embolization was mainly undertaken in pelvic fractures (n = 96, 59%) and abdominal organ injuries (n = 57, 35%) and extended to the chest (n = 17, 10%), and other (n = 20, 12%). Approximately 13% (n = 21) of patients underwent embolization in two or more regions. Embolization was more strictly performed in minor artery injuries, for example, external iliac (n = 15, 16%) and lumbar artery (n = 22, 23%) branches in pelvic fractures, and inferior phrenic artery (n = 2, 3.5%) branches in liver injuries. Multiple regression model indicated that the number of embolized arteries (P = 0.021) and number of embolized regions (P < 0.001) were associated with prolonged procedural time in embolization.

Conclusions: Embolization for trauma patients extended to various trauma regions. In time-sensitive embolization, emergency interventional radiologists showed superior knowledge of expected embolizing arteries and factors associated with procedure time.

Key words: embolization, multiple regression analysis, procedure time, time to hemostasis, trauma

INTRODUCTION

HEMORRHAGE IS A significant problem following traumatic injury and early hemorrhage control is vital to rescue trauma patients. Traditionally, operative management has been the only method used to control bleeding. However, an endovascular approach, such as embolization, was recently adopted to manage traumatic vascular lesions in solid organ injuries[1] not requiring a laparotomy, and in pelvic fractures.[2] In addition to embolization in solid organ injuries and pelvic fractures, embolization has recently also been extended to chest,[3] cerebrovascular,[4] and peripheral vascular injuries.[5]

Early hemostasis is important because of the time-critical nature of trauma and trauma providers need to understand therapeutic characteristics in order to implement an optimal management strategy for trauma patients. However, limited information exists on the factors associated with prolonged procedure time. The associations between details of embolization, such as number of embolized arteries, embolized regions, and embolic materials and procedural time, were unknown. Such information is important for emergency physicians, trauma surgeons, and interventional radiologists who are involved in initial trauma care. Therefore, this study aimed to clarify the factors associated with a prolonged procedure time.

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METHODS

Study design

A single-center, retrospective, observational study was undertaken. The study protocol was approved by the institutional review board of Saiseikai Yokohamashi Tobu Hospital. The medical records of patients with severe trauma (defined as a patient who had an Abbreviated Injury Scale >2 in least one body region), who received emergent angioembolization between January 2007 and December 2020, were reviewed.

Patient selection

Patients who were transferred to our hospital and received emergent embolization were included. Emergent embolization was defined as therapeutic angioembolization within 24 h of admission. We did not include trauma patients who received diagnostic angiography only.

Analytic variables

The following variables were obtained from medical records: patient demographics, trauma mechanism, Abbreviated Injury Scale for each region, Injury Severity Score (ISS), time courses (time to blood transfusion, time to angiography, and procedure time), blood transfusion within 24 h of arrival, procedures of embolization, other hemorrhagic procedures, and 30-day mortality. Procedural time was collected from medical records and the definition was declaration of start and finish angiography by operator. Regarding the embolization procedure, we collected information on the identity of embolized arteries and the embolic materials used.

Angioembolization procedure

During the study period, indications for embolization in trauma patients remained unchanged. A general indication for angiography in a body region was whether arterial extravasation existed on enhanced computed tomography. A specific indication of angiography for a pelvic fracture was the presence of a massive retroperitoneal hematoma and/or hemodynamic instability,[6] and an indication for angiography for the abdomen was a large hemoperitoneum or retroperitoneal hematoma.[7,8] A general indication for therapeutic embolization was the existence of arterial extravasation. Preemptive therapeutic embolization included truncation of the vessel, a questionable arterial extravasation, and sluggish flow during angiography. The necessity of therapeutic embolization was judged by emergency physicians and an interventional radiologist who took charge of the procedure based on the findings of angiography. Digital subtraction angiography and embolization were carried out with local anesthesia or general anesthesia by one of four interventional radiologists (M.A., Y.T., S.S., and T.F., with 5, 5, 7, and 10 years of experience in interventional radiology, respectively). All four interventional radiologists in our angiographic suite were certified by the Japanese Society of Interventional Radiology.

Definitions

The primary outcome of this investigation was an embolized body region and embolized arteries, and a secondary outcome was procedure time.

Anatomic categories of embolized regions

First, we divided the included patients into four embolized body regions: chest, abdomen, pelvis, and other. Other regions mainly involved the cerebrovascular region, that is, those who were embolized in head, face and cervical regions, and peripheral regions. If a patient had an embolization in two regions, this patient was counted two times.

Statistical analysis

Continuous variables were expressed as medians and interquartile ranges. Categorical variables were expressed as counts and percentages. First, we descriptively analyzed the distributions of embolized regions and revealed the duplication of embolized regions by Venn diagram. Second, we descriptively summarized the procedural data and details of embolized arteries according to embolized regions. We classified other embolized regions into cerebrovascular, peripheral, and other regions in more detail. Third, we assessed the association between embolized regions (whole patient cohorts were referenced) and procedure time by univariate analysis. A comparison of continuous variables was carried out using a Mann–Whitney *U*-test. Fourth, we calculated Pearson correlation coefficients between the number of embolized arteries and procedure time, and between the number of embolized regions and procedure time. Finally, we created a multiple regression model to assess independent predictors of procedure time and created the equation of estimated procedural time. This model was adjusted for age, vital signs at arrival (systolic blood pressure <90 mmHg and Glasgow Coma Scale ≤8), coagulopathy (international normalized ratio >1.2), ISS >15, number of embolized arteries, and number of embolized regions. An equation of estimated procedural time was constructed from the number of arteries and targeted regions. In addition, the association between selective embolization or nonselective embolization and procedure time was assessed, especially for pelvic fractures and abdominal organ injuries. Regardless of whether selective or nonselective embolization included abdominal and/or pelvic embolizations, selective embolization was defined as follows, based on previous reports:[9,10] selective embolization for the pelvis was the embolization of branches of the internal or external iliac arteries,[9] and selective embolization of the abdomen was embolization of the segmental branches of an organ artery, such as liver, splenic, and renal arteries.[10] The statistical significance of all tests was set using a two-tailed *P*-value of less than 0.05. All analyses were undertaken using statistics software (R version 4.0.3; R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

DURING THE STUDY period, 162 patients with severe trauma were studied. The characteristics of study patients are shown in Table 1. The median age was 54 (36–71) years and 62% were men. The most frequent trauma mechanism was a motor vehicle collision (49%) and the second most frequent mechanism was a fall (41%). The median ISS was 27 (18–38). The median time to blood transfusion was 79 (29–135) min, the time to angiography was 87 (59–123) min, and the median procedure time was 70 (50–95) min. There was no significant difference between time to blood transfusion and time to angiography ($P = 0.583$). Approximately 28% (46/162) of patients did not undergo a blood transfusion within 24 h of arrival. Regarding mortality, a total of 17 deaths occurred in the cohort (10.0%) as a result of severe head injury ($n = 10$, 59%) and hemorrhagic shock ($n = 7$, 41%).

Distributions of embolized regions are shown in Figure 1 and Table S1. The frequency of embolized regions had the following order: pelvis ($n = 96$, 59%), abdomen ($n = 57$, 35%), chest ($n = 17$, 10%), and other ($n = 20$, 12%). Overlapping of embolized regions among pelvis, abdomen, and other body regions, including cerebrovascular, chest, peripheral and other, is shown in Figure 1. Approximately 13% ($n = 21$) of patients underwent embolization in two or more regions.

Procedural data according to embolized body regions is shown in Table 2. Embolization in the chest (105 [60–120]; $P = 0.004$) and other (85 [69–113]; $P = 0.009$) regions was associated with a longer procedure time compared with whole patients. Gelatin sponge particles were most often used in any body region.

Table 1. Characteristics of study patients who underwent embolization for trauma

Characteristic	Study patients (n = 162)
Age, years	54 (36–71)
Sex, male	100 (62)
Trauma mechanism	
Motor vehicle collision	79 (49)
Fall	67 (41)
Penetrating	6 (3.7)
Other blunt mechanism	9 (5.5)
Unknown	1 (0.6)
Admission physiology	
Systolic BP, mmHg	113 (88–141)
GCS	14 (9–15)
INR	1.1 (1.0–1.3)
Systolic BP <90 mmHg	45 (28)
GCS <9	35 (21)
INR >1.2	58 (36)
Injury data	
Head AIS	4 (3–5)
Chest AIS	3 (3–4)
Abdomen AIS	3 (2–4)
Pelvis AIS	3 (2–4)
ISS	27 (18–38)
ISS >15, n (%)	141 (87)
Time to blood transfusion	79 (29–135)
Time to angiography	87 (59–123)
Procedure time	70 (50–95)
Blood transfusion within 24 h	2 (0–9)
Mortality	
30-day mortality	17 (10)

Data are shown as median (interquartile range) or n (%).
Abbreviations: AIS, Abbreviated Injury Scale; BP, blood pressure; GCS, Glasgow Coma Scale; INR, international normalized ratio; ISS, Injury Severity Score.

The number of embolized arteries did not differ between body regions. Approximately 64% (103/162) of patients underwent concomitant surgery in most orthopedic procedures. Embolized arteries of each region are shown in Table 3. Selective embolization in the pelvis was carried out in 64 patients (67%) and in the abdomen for 49 patients (86%). Regarding embolization for pelvic fractures, nonselective embolization (60 [39–83]) had a tendency to be associated with a lower systolic blood pressure (94 [71–125] mmHg) and shorter procedure time (60 [39–83] min) compared with selective embolization (112 [80–137] mmHg and 69 [50–10] min); however, statistically significant differences in systolic blood pressure ($P = 0.092$) and procedure time ($P = 0.056$) were not observed.

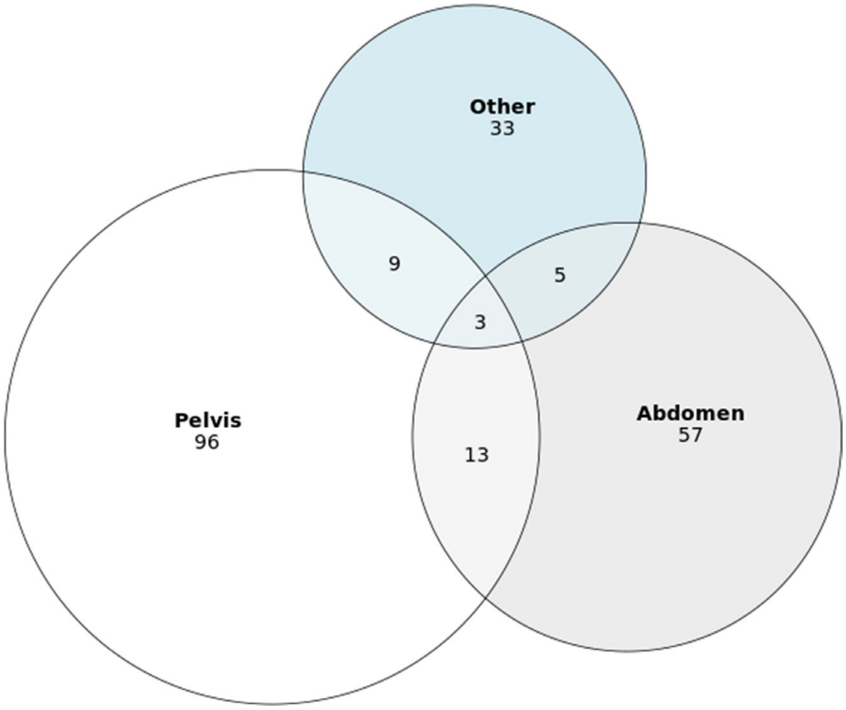

Fig. 1. Venn diagram of the distribution of embolized regions in 162 trauma patients who underwent embolization at a regional trauma care center in Japan. Overlapping of embolized regions among pelvis, abdomen and the other body regions, including cerebrovascular, chest, peripheral, and other.

The Pearson correlation coefficient between the number of embolized arteries and procedure time was $r = 0.357$ ($P < 0.001$; Fig. 2), and between the number of embolized regions and procedure time was $r = 0.428$ ($P < 0.001$; Fig. 3). The multiple regression model showed that the number of embolized arteries ($P = 0.021$) and number of embolized regions ($P < 0.001$) were independently associated with procedure time (Table 4). The equation of estimated procedural time was: Procedural time = 25 × number of embolized regions + 4.5 × number of embolized arteries + 34.5 min.

DISCUSSION

Brief summary

THE FACTORS ASSOCIATED with prolonged procedure times in embolization for trauma are unknown. This study clarified the clinical practice of embolization in trauma patients. Overall, the findings of this study were as follows:

1. Embolization was mainly carried out in pelvic fractures and abdominal organ injuries. Embolization was also extended to other body regions, including chest.
2. The number of embolized arteries and embolized body regions were independently associated with prolonged procedure time.

Embolization in pelvic fractures and abdominal organ injuries

In this study, embolization was mainly used for pelvic fractures and abdominal organ injuries, with the percentage being approximately 86% (140/163). Regarding pelvic fractures, approximately 80% of patients underwent an embolization in the internal iliac artery and its branches. In addition to embolization in internal iliac arteries, 16% of patients needed embolization in branches of the external iliac arteries and 23% needed embolization in lumbar arteries. The necessity of angiography of the external iliac arteries was reported to have existence of ipsilateral intertrochanteric fracture or ipsilateral ilium fracture[11] and of lumbar arteries was reported to have existence of multiple pelvic injury.[12]

As for injury in abdominal organs, the frequency of such embolized organs in decreasing order were spleen, liver, and kidney. These frequencies were consistent with those in a report by the National Trauma Data Bank in

Table 2. Procedural data for trauma patients according to embolized body regions

	Pelvis (n = 96)	Abdomen (n = 57)	Chest (n = 17)	Other (n = 20)
Physiology				
Systolic BP <90 mmHg	32 (33)	13 (23)	6 (35)	4 (20)
INR >1.2	42 (44)	13 (23)	11 (65)	7 (35)
Trauma score				
ISS	29 (22–41)	29 (19–36)	33 (18–50)	34 (20–44)
Procedure time, min	65 (47–94)	75 (55–100)	105 (60–120)	85 (69–113)
Embolic material				
Gelatin	94 (98)	47 (83)	17 (100)	15 (75)
Coils	0 (0)	5 (8.8)	1 (5.9)	2 (10)
NBCA	7 (7.3)	4 (7.0)	2 (12)	5 (25)
Number of embolized arteries	3 (2–4)	2 (1–2)	3 (1–4)	2 (1–3)
Other hemorrhagic procedures				
Neurosurgery	6 (6.3)	2 (3.5)	2 (12)	5 (25)
Thoracotomy	9 (9.4)	2 (3.5)	6 (35)	1 (5)
Laparotomy	23 (24)	20 (35)	7 (41)	3 (15)
Orthopedic	50 (52)	10 (18)	7 (42)	8 (40)
OMFS	3 (3.1)	1 (1.8)	0 (0)	1 (5)
Vascular extremity	2 (2.1)	1 (1.8)	0 (0)	0 (0)

Data are shown as median (interquartile range) or n (%).
Abbreviations: BP, blood pressure; INR, international normalized ratio; ISS, Injury Severity Score; NBCA, n-butyl cyanoacrylate; OMFS, oral and maxillofacial surgery.

the United States.[13] In this study, two patients underwent embolization in an injury of the inferior phrenic artery and one patient underwent an embolization of the adrenal gland artery in a liver injury. Inferior phrenic artery was reported to involve various bleeding sites[14] and needed to be contrast in liver injury, especially posterior segment injury.[15]

In the chest region, embolization in the intercostal artery was the most frequent. A dual-centered study from Italy and Spain described patients who underwent embolization of an intercostal artery injury and those who could be managed with an embolization obviating a thoracotomy.[16] As for injury of the internal mammary artery, two patients showed a penetrating mechanism. Operative management is principally needed for a penetrating thoracic injury; however, a few patients may obviate a thoracotomy with embolization.[17]

All patients with injuries of the peripheral arteries underwent deep femoral artery embolization. The causes of trauma were a penetrating mechanism (n = 2), contusion (n = 2), and femoral fracture (n = 2). Prior studies had reported the efficacy of embolization for the deep femoral artery following a penetrating injury.[18]

Procedure time according to injured body region and factors associated with a longer procedure time

From a time-critical perspective, the shortest hemostasis is desirable in trauma patients. A decreased time to angioembolization has been much debated in published works,[5,19] however, previous reporting on the procedure time itself is scarce.[20,21] In this study, there was no delay to angiography compared with time to blood transfusion, and the time to angiography was shorter than in previous reports.[20,21] Shorter time to angiography could be related to the comparatively high proportion of patients (28%) who did not undergo blood transfusion and the lower total amount of blood transfused (median, 2 [interquartile range, 0–9] units) within 24 h from arrival.[21] Regarding procedure time itself, an investigation at the R Adams Cowley Shock Trauma Center evaluated the effect of an endovascular trauma service (ETS) made up of two surgeons. Although an ETS contributed to a shorter time to the procedure, the overall procedure time was longer compared to an interventional trauma service (IRS) composed of interventional radiologists. Ideally, emergency physicians or trauma surgeons who

Table 3. Details of embolized arteries in trauma patients according to anatomical region

Region	Details of embolized arteries	Number of cases with specific embolized arteries, *n* (%)
Pelvis (*n* = 96)	Internal iliac artery (IIA)	
	Main trunk of IIA	76 (79.0)
	Branches of IIA	43 (45.0)
	Superior gluteal artery	13 (14.0)
	Inferior gluteal artery	12 (13.0)
	Internal pudendal artery	13 (14.0)
	External pudendal artery	1 (1.0)
	Obturator artery	6 (6.3)
	Deep iliac circumflex artery	4 (4.2)
	Iliolumbar artery	13 (14.0)
	Lateral sacral artery	6 (6.3)
	Vesical artery	1 (1.0)
	Branches of external iliac artery	15 (16.0)
	Inferior epigastric artery	8 (8.3)
	Medial circumflex femoral artery	3 (3.1)
	Lateral circumflex femoral artery	7 (7.3)
	Deep femoral artery	3 (3.1)
	Median sacral artery	4 (4.2)
	Lumber artery	22 (23.0)
Abdomen (*n* = 57)	Splenic artery	28 (49.0)
	Hepatic artery	23 (40.0)
	Renal artery	11 (19.0)
	Adrenal artery	2 (3.5)
	Inferior phrenic artery	2 (3.5)
Chest (*n* = 17)	Intercostal artery	9 (53.0)
	Internal mammary artery	8 (47.0)
	Lateral thoracic artery	2 (12.0)
	Subscapular artery	1 (5.9)
	Thoracoacromial artery	1 (5.9)
	Unknown branch of subclavian artery	1 (5.9)
Cerebrovascular (*n* = 8)	Facial artery	3 (38.0)
	Maxillary artery	2 (25.0)
	Middle meningeal artery	2 (25.0)
	Vertebral artery	1 (13.0)
	Transverse cervical artery	1 (13.0)
	Superficial cervical artery	1 (13.0)
Peripheral (*n* = 5)	Deep femoral artery	5 (100.0)
Other (*n* = 7)	Lumbar artery	4 (57.0)
	Deep iliac circumflex artery	2 (29.0)
	Inferior epigastric artery	1 (14.0)
	Iliolumbar artery	1 (14.0)
	Lateral femoral circumflex artery	1 (14.0)
	Internal pudendal artery	1 (14.0)

are housed in a trauma center and have techniques comparable to interventional radiologists are desirable. Overall, procedure time in this study (70 [25] min) was comparable to an IRS in Morrison's study (102 [60] min).[21] This short procedure time was explained by the presence of emergency physicians who specialized in interventional radiology.

In addition, we evaluated factors associated with procedure time. The embolized region, number of embolized

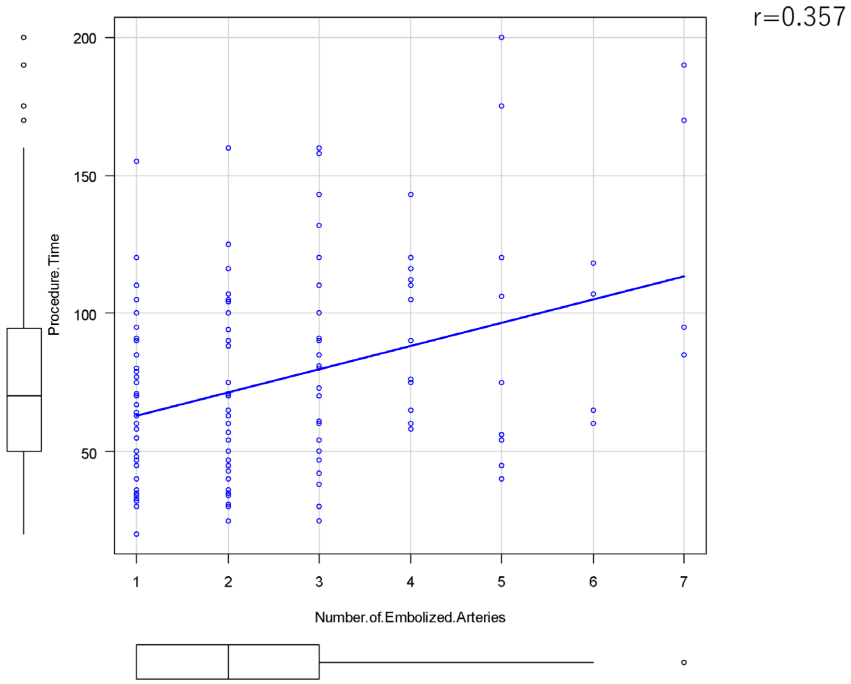

Fig. 2. Pearson correlation coefficient between the number of embolized arteries and procedure time in 162 trauma patients who underwent embolization at a regional trauma care center in Japan.

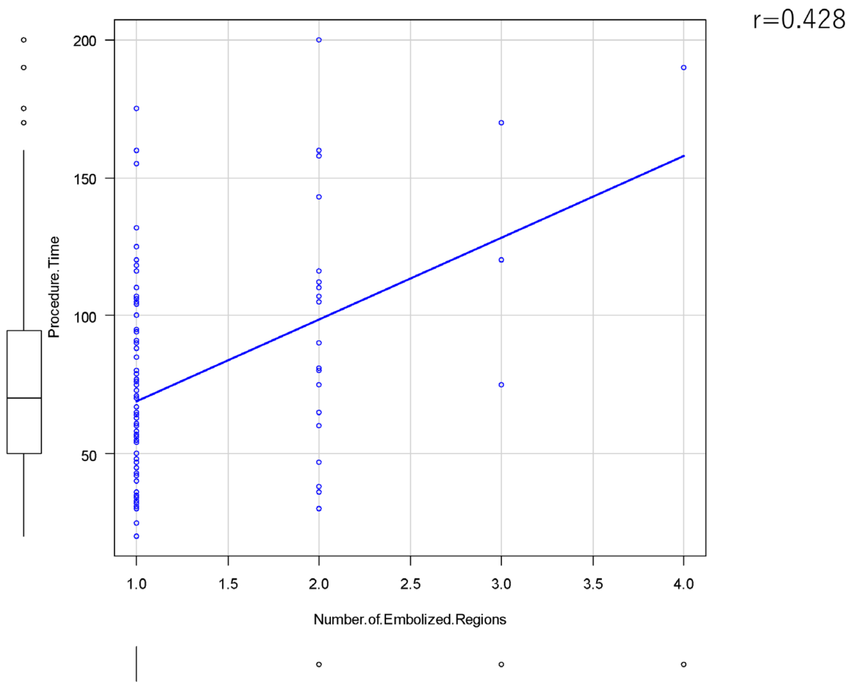

Fig. 3. Pearson correlation coefficient between the number of embolized regions and procedure time in 162 trauma patients who underwent embolization at a regional trauma care center in Japan.

Table 4. Multiple regression model of predictor of procedure time in trauma patients who underwent embolization

Variable	Partial regression coefficient	*P*-value	95% CI
Age	−0.013	0.915	−0.247–0.222
Systolic BP <90 mmHg	−7.303	0.246	−19.701–5.095
GCS < 9	−0.443	0.949	−14.221–13.335
INR > 1.2	1.284	0.822	−9.954–12.521
ISS > 15	−4.675	0.556	−20.321–10.972
Number of embolized arteries	4.770	0.021	0.724–8.817
Number of embolized regions	25.373	<0.001	13.051–37.694

Abbreviations: BP, blood pressure; CI, confidence interval; GCS, Glasgow Coma Scale; INR, international normalized ratio; ISS, Injury Severity Score.

arteries, and number of embolized regions were associated with a longer procedure time. Multiple regression model indicated that the number of embolized arteries and number of embolized regions were independently associated with procedure time. To the best of our knowledge, this is the first report to assess the association between number of embolized arteries, number of embolized regions, and procedure time. A previous report from Japan showed the time to angiography did not differ by hemodynamic instability.[22] Our findings showed that procedure time was not statistically significantly associated with hemodynamic instability, disturbance of consciousness, or coagulopathy. Regarding pelvic fracture, nonselective embolization had a tendency for a shorter procedure time ($P = 0.056$). If embolization is limited to the pelvic region, nonselective embolization could be associated with shorter procedure time. In addition, an emergency interventional radiologist was shown to have a better focus with regard to these points to achieve time-sensitive interventional radiology.

Our study has several limitations. First, this was a single centered observational study. Embolized arteries were judged from emergent interventional radiologists and the practice could be different from other institutional practices. Second, any causal relationship was not determined from the nature of the retrospective study. Finally, procedure time was retrospectively gathered from medical records, which might not be accurate.

CONCLUSION

THIS STUDY DESCRIBED an embolization profile in trauma patients. Embolization was applied to pelvic fractures, abdominal organs, chest, and other regions. To achieve time-sensitive embolization, it was found that an emergency interventional radiologist had better knowledge of expected embolizing arteries and factors associated with the procedure time. This information might be helpful in guiding the development of optimal management strategies for trauma patients.

DISCLOSURE

Approval of the research protocol: This study was approved by the medical ethics committee of Saiseikai Yokohamashi Tobu Hospital.

Informed consent: Because of the anonymous and retrospective nature of the study, the need for informed consent was waived.

Registry and registration no. of the study/trial: N/A.

Animal studies: N/A.

Conflict of interest: None.

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DATA AVAILABILITY STATEMENT

NOT APPLICABLE.

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SUPPORTING INFORMATION

Additional Supporting Information may be found in the online version of this article at the publisher's web-site:

Table S1. Distributions of embolized regions