Embolization in Trauma Patients: What Trauma Radiologists Should Know

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Abstract

Objectives

Limited information exists on embolization for trauma patients regarding arteries embolized, embolic materials used, and embolization duration. 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 six embolized body regions: cerebrovascular, chest, abdomen, pelvis, peripheral, and other. Patient demographics, trauma mechanism, physiology, trauma severity, embolization procedures, and 30-day mortality were examined. The primary outcome was identifying an embolized body region and arteries, and secondary outcome was procedure time.

Results

Embolization was mainly performed in pelvic fractures ($n = 96$, 59%) and abdominal organ injuries ($n = 57$, 35%) and extended to the chest ($n = 17$, 10%), cerebrovascular ($n = 8$, 4.9%), peripheral ($n = 5$, 3.1%), and other ($n = 7$, 4.3%) regions. Approximately 13% ($n = 21$) of patients underwent embolization in ≥ 2 regions. Embolization was more strictly performed in minor artery injuries, e.g. 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. Non-selective embolization for a pelvic fracture tended to show a shorter procedure time despite no statistically significant difference ($p = 0.056$). For a longer procedure time, the number of embolized arteries ($R = 0.357$) and embolized body regions ($R = 0.428$) correlated.

Conclusions

Embolizations 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.

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 a solid organ injuries¹ not requiring a laparotomy, and in pelvic fractures². In

addition to embolization in solid organ injuries and pelvic fractures, embolization has recently also been extended to chest³, cerebrovascular⁴, and peripheral vascular injuries⁵.

However, limited information exists on the clinical application of embolization for trauma patients, especially with regard to what arteries are embolized, what embolic materials are used, and how long did it take to finish the embolization. Such information is important for emergency physicians, trauma surgeons, and interventional radiologists who are involved in initial trauma care. Early hemostasis is important because of the time-critical nature of trauma. However, the factors associated with prolonged procedure times in embolization for trauma are unknown. Trauma providers need to understand therapeutic characteristics in order to implement an optimal management strategy for trauma patients. In addition, intervention radiologists who are involved in trauma care need to acquaint themselves with the body parts necessary for angioembolization in trauma patients. Therefore, this study aimed to clarify the clinical application of embolization in trauma patients and the factors associated with a prolonged procedure time.

Methods

Study Design

A single-center, retrospective, observational study was performed. The study protocol was approved by the institutional review board of — Hospital. The medical records of patients with severe trauma (severe trauma in a patient was 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. With approximately 200 annual severe trauma admissions, this trauma center is one of the largest in Japan.

Patient Selection

Patients who were transferred to our hospital and received emergent embolization were included. Emergent embolization was defined as therapeutic angioembolization within 24 hours 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 with 24 hours from arrival, procedures of embolization, other hemorrhagic procedures and 30-day mortality. 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, and an indication for angiography for the abdomen was a large amount of hemoperitoneum or retroperitoneal hematoma. A general indication for therapeutic embolization was the existence of arterial extravasation. Pre-emptive 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 performed with local anesthesia or general anesthesia by one of four interventional radiologists (–, –, –, and –, with 5, 5, 7, and 10 years of experience, 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 six embolized body regions: cerebrovascular – those who were embolized in head, face and cervical regions; chest; abdomen; pelvis; peripheral; and other. Patients in the other region were defined as those who could not be classified in the above five regions, such as patients who had an arterial hemorrhage from an inferior epigastric artery on the surface area or who had an arterial hemorrhage from a lumbar artery without a pelvic fracture. 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. 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 performed 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 multiple regression model to assess independent predictor of procedure time. This model was adjusted for age, vital signs at arrival (systolic blood pressure < 90mmHg and Glasgow Coma Scale = < 8), coagulopathy (international normalized ratio > 1.2), ISS > 15, number of embolized arteries and number of embolized regions. In addition, the association between selective embolization or non-selective embolization and procedure time was assessed, especially for pelvic fractures and

abdominal organ injuries. Regardless of whether selective or not selective embolization included abdominal and/or pelvic embolizations, selective embolization was defined as follows based on the previous literature^{6,7}: selective embolization for the pelvis was the embolization of branches of the internal or external iliac arteries⁶; and selective embolization of the abdomen was embolization of the segmental branches of an organ artery, such as liver, splenic, and renal arteries⁷. The statistical significance of all tests was set using a two-tailed p -value of < 0.05 . All analyses were conducted 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 male. 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) minutes, the time to angiography was 87 (59–123) minutes and the median procedure time was 70 (50–95) minutes. There was no significant difference between time to blood transfusion and time to angiography ($p = 0.583$). Approximate 28% (46/162) patients underwent no blood transfusion within 24 hours from arrival. Regarding mortality, a total of 17 deaths in the cohort (10.0%) as a result of severe head injury ($n = 10$, 59%) and hemorrhagic shock ($n = 7$, 41%).

Table 1
Characteristics of study patients

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

AIS, abbreviated injury scale; BP, blood pressure; GCS, Glasgow Coma Scale; INR, international normalized ratio; ISS, injury severity score

Characteristic	Study patients (n = 162)
Blood transfusion within 24h	2 (0–9)
Mortality	17 (10)
30-day mortality, n (%)	
AIS, abbreviated injury scale; BP, blood pressure; GCS, Glasgow Coma Scale; INR, international normalized ratio; ISS, injury severity score	

Distributions of embolized regions are shown in Fig. 1 and the Supplemental Table. The frequency of embolized regions had the following order: pelvis (n = 96, 59%), abdomen (n = 57, 35%), chest (n = 17, 10%), cerebrovascular (n = 8, 4.9%), other (n = 7, 4.3%), and peripheral (n = 5, 3.1%). Overlapping of embolized regions among pelvis, abdomen, and other body regions, including cerebrovascular, chest, peripheral and other, is shown in Fig. 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 (90 [77–113]; $p = 0.036$) regions was associated with a longer procedure time compared with whole patients. Gelatin sponge particles were most often used in any body region.

Table 2
Procedural Data for Patients According to Embolized Body Regions

	Pelvis (n = 96)	Abdomen (n = 57)	Chest (n = 17)	Cerebrovascular (n = 8)	Peripheral (n = 5)
Physiology	32 (33)	13 (23)	6 (35)	3 (38)	1 (20)
Systolic BP < 90 mmHg, n (%)	42 (44)	13 (23)	11 (65)	4 (50)	1 (20)
INR > 1.2, n (%)					
Trauma score	29 (22–41)	29 (19–36)	33 (18–50)	43 (26–52)	42 (34–43)
ISS					
Procedure time, min	65 (47–94)	75 (55–100)	105 (60–120)	85 (74–110)	60 (60–112)
Embolic material	94 (98)	47 (83)	17 (100)	5 (63)	4 (80)
Gelatin, n (%)	0 (0)	5 (8.8)	1 (5.9)	1 (13)	0 (0)
Coils, n (%)	7 (7.3)	4 (7.0)	2 (12)	3 (38)	1 (20)
NBCA, n (%)					
Number of	3 (2–4)	2 (1–2)	3 (1–4)	3 (1–6)	2 (2–3)
Embolized arteries					
Other hemorrhagic procedures	6 (6.3)	2 (3.5)	2 (12)	2 (25)	2 (40)
Neurosurgery	9 (9.4)	2 (3.5)	6 (35)	0 (0)	0 (0)
Thoracotomy	23 (24)	20 (35)	7 (41)	2 (25)	1 (20)
Laparotomy	50 (52)	10 (18)	7 (42)	1 (13)	3 (60)
Orthopedic	3 (3.1)	1 (1.8)	0 (0)	1 (13)	0 (0)
OMFS	2 (2.1)	1 (1.8)	0 (0)	0 (0)	0 (0)
Vascular extremity					
BP, blood pressure; INR, international normalized ratio; ISS, injury severity score; NBCA, n-butyl cyanoacrylate; OMFS, oral and maxillofacial surgery					

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 performed in 64 patients (67%) and in the abdomen for 49 patients (86%). Regarding embolization for pelvic fractures, non-selective 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] minutes) compared with selective embolization (112 [80–137] mmHg and 69 [50–10] minutes); however, statistically significant differences in systolic blood pressure ($p = 0.092$) and procedure time ($p = 0.056$) were not observed.

Table 3
Details of embolized arteries according to each region

Regions	Details of embolized arteries	Number of the cases with specific embolized arteries
Pelvis (n = 96)	Internal iliac artery (IIA)	76 (79%)
	Main trunk of IIA	43 (45%)
	Branches of IIA	13 (14%)
	Superior gluteal artery	12 (13%)
	Inferior gluteal artery	13 (14%)
	Internal pudendal artery	1 (1.0%)
	External pudendal artery	6 (6.3%)
	Obturator artery	4 (4.2%)
	Deep iliac circumflex artery	13 (14%)
	Iliolumbar artery	6 (6.3%)
	Lateral sacral artery	1 (1.0%)
	Vesical artery	15 (16%)
	Branches of external iliac artery	8 (8.3%)
	Inferior epigastric artery	3 (3.1%)
	Medial circumflex femoral artery	7 (7.3%)
	Lateral circumflex femoral artery	3 (3.1%)
	Deep femoral artery	4 (4.2%)
	Median sacral artery	22 (23%)
	Lumber artery	
Abdomen (n = 57)	Splenic artery	28 (49%)
	Hepatic artery	23 (40%)
	Renal artery	11 (19%)
	Adrenal artery	2 (3.5%)
	Inferior phrenic artery	2 (3.5%)

Categorical variables are presented as a number (%).

Regions	Details of embolized arteries	Number of the cases with specific embolized arteries
Chest (n = 17)	Intercostal artery	9 (53%)
	Internal mammary artery	8 (47%)
	Lateral thoracic artery	2 (12%)
	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%)
	Maxillary artery	2 (25%)
	Middle meningeal artery	2 (25%)
	Vertebral artery	1 (13%)
	Transverse cervical artery	1 (13%)
	Superficial cervical artery	1 (13%)
Peripheral (n = 5)	Deep femoral artery	5 (100%)
Other (n = 7)	Lumbar artery	4 (57%)
	Deep iliac circumflex artery	2 (29%)
	Inferior epigastric artery	1 (14%)
	Iliolumbar artery	1 (14%)
	Lateral femoral circumflex artery	1 (14%)
	Internal pudendal artery	1 (14%)
Categorical variables are presented as a number (%).		

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). Multiple regression model demonstrated number of embolized arteries ($p = 0.021$) and number of embolized regions ($p < 0.001$) were independently associated with procedure time, respectively (Table 4).

Table 4
Multiple regression model of predictor of procedure time

Variables	Partial regression coefficient	<i>p</i> -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
OR, odds ratio; CI, confidence interval; BP, blood pressure; GCS, Glasgow Coma Scale; INR, international normalized ratio; ISS, injury severity score			

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 performed in pelvic fractures and abdominal organ injuries. However, embolization was more strictly performed in minor artery injuries, such as those of branches of external iliac and lumbar arteries in pelvic fractures, and those of the inferior phrenic artery in liver injuries. 2. Embolization was extended to other body regions, such as in chest, cerebrovascular and peripheral regions. 3. Regarding time courses, there was no significant difference between time to blood transfusion and angiography. As for procedure time, the number of embolized arteries and embolized body regions were independently associated.

Embolization in pelvic fractures and abdominal organ injuries

In this study, embolization was mainly performed in 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. A similar frequency was previously reported by an interventional radiology team at the University of Washington Medical Center, with the frequency of external iliac artery branch injury associated with pelvic fracture being 17%⁸. Regarding the frequency of complicated injury of the lumbar artery, reports from Chang Gung Memorial Hospital

described how approximately 50% of patients who underwent a lumbar artery injury had a pelvic fracture⁹. In this study, 25 patients underwent lumbar artery embolization and 92% had a pelvic fracture. In addition to internal iliac arteries, angiography for suspected external iliac artery branches and lumbar arteries were thought also to be needed.

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 the US¹⁰. 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 be various bleeding sites¹¹ and needed to be contrast in liver injury especially posterior segment injury¹².

Of embolizations in the chest region, that 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 thoracotomy¹³. 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 embolization¹⁴.

Regarding injuries of the peripheral arteries, all patients underwent deep femoral artery embolization. The causes of trauma were a penetrating mechanism (n = 2), contusion (n = 2), and femoral fracture (n = 2). Prior literature had reported the efficacy of embolization for the deep femoral artery following a penetrating injury¹⁵.

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 the literature^{5,16}; however, prior literature reporting on the procedure time itself is scarce^{17,18}. In this study, there was no delay to angiography compared with time to blood transfusion, and the time to angiography was earlier by previous literatures^{17,18}. Earlier time to angiography could contribute comparable high rate of patients (28%) who underwent no blood transfusion and less total amount of blood transfusion [median 2 (interquartile range 0–9) units] within 24 hours from arrival¹⁸. 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. Though 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 are housed in a trauma center and have techniques comparable to interventional radiologists are desirable. Overall, procedure time in this study (70 [25] minutes) was comparable to an IRS in Morrison's study (102 [60] minutes)¹⁸. 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 arteries, and number of embolized regions were associated with a longer procedure time. Multiple regression model demonstrated number of embolized arteries and number of embolized regions were independently associated with procedure time. To the best of our knowledge, this is first report to assess the association between number of embolized arteries, number of embolized regions and procedure time. The previous report from Japan reported the time to angiography did not differ by hemodynamic instability¹⁹. Our finding reported procedure time was not statistically significantly associated with hemodynamic instability, disturbance of consciousness and coagulopathy. Regarding pelvic fracture, non-selective embolization had a tendency for a shorter procedure time ($p = 0.056$). If embolization is limited to pelvic region, non-selective 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.

Other hemorrhagic procedures and Causes of mortality.

Approximate 65% (106/162) patients had multiple severe injury and 64% had concomitant other hemorrhagic procedures, and this procedure rate was higher than previous rate (47.1%) because of comparable high rate of pelvic fracture. To note, the hemodynamic instability was 28% and this was higher than the rate of R Adams Cowley Shock Trauma Center's population (9.2%). On the other hands, the mortality of our population (10%) was comparable to previous population (7.6%). The major cause of mortality of our population was severe head injury (59%, 10/17). The other cause of mortality was hemorrhagic shock, and 85% (6/7) had severe pelvic fracture and 5 cases were cardiac pulmonary arrest on arrival. The other one case had severe liver injury had resuscitative thoracotomy with aortic cross clamping and laparotomy with following adjunct embolization. Though 5 cases of hemorrhagic shock patients were admitted to intensive care unit after embolization, they deceased with 24hours from admission.

Our study has several limitations. First, this was a single centered observational study. Embolized arteries were judged from emergent interventional radiologists and the practice may be different from other institutional practice. Second, any causal relationship was not determined from the nature of retrospective study.

Conclusion

This study described an embolization profile in trauma patients. Embolization was applied to pelvic fractures, abdominal organ, chest, cerebrovascular and peripheral injuries. 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.

Declarations

Ethics approval and consent to participate: This study was approved by the medical ethics committee of Saiseikai Yokohamashi Tobu Hospital. Because of the anonymous and retrospective nature of the study, the need for informed consent was waived.

Consent for publication: Not applicable

Availability of supporting data and material: Not applicable

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Author's contributions: MA and SM conceived of and designed this study, interpreted the data, drafted the manuscript, and revised the manuscript for important intellectual content. YT, SS, YI, MY, TF, and TF interpreted the data and revised the manuscript for important intellectual content.

References

1. Martin JG, Shah J, Robinson C, et al. Evaluation and management of blunt solid organ trauma. *Tech Vasc Interv Radiol*. 2017;20(4):230–6.
2. Adnan SM, Wasicek PJ, Crawford A, et al. Endovascular control of pelvic hemorrhage: Concomitant use of resuscitative endovascular balloon occlusion of the aorta and endovascular intervention. *J Trauma Acute Care Surg*. 2019;86:155–9.
3. Mac New HG, Hyslop R, Bromberg W, Britt P. Submammary intercostal arterial injury treated with angioembolization: a case report. *J Trauma*. 2009;66(1):264–6.
4. Kim DY, Biffl W, Bokhari F, Brakenridge S, Chao E, Claridge JA, Fraser D, Jawa R, Kasotakis G, Kerwin A, Khan U, Kurek S, Plurad D, Robinson BRH, Stassen N, Tesoriero R, Yorkgitis B, Como JJ. Evaluation and management of blunt cerebrovascular injury: A practice management guideline from the Eastern Association for the Surgery of Trauma. *J Trauma Acute Care Surg*. 2020;88(6):875–87.
5. Kobayashi L, Coimbra R, Goes AMO Jr, Reva V, Santorelli J, Moore EE, Galante J, Abu-Zidan F, Peitzman AB, Ordonez C, Maier RV, Di Saverio S, Ivatury R, De Angelis N, Scalea T, Catena F, Kirkpatrick A, Khokha V, Parry N, Civil I, Leppaniemi A, Chirica M, Pikoulis E, Fraga GP, Chiarugi M, Damaskos D, Cicuttin E, Ceresoli M, De Simone B, Vega-Rivera F, Sartelli M, Biffl W, Ansaloni L, Weber DG, Coccolini F. American Association for the Surgery of Trauma-World Society of Emergency Surgery guidelines on diagnosis and management of peripheral vascular injuries. *J Trauma Acute Care Surg*. 2020;89(6):1183–96.
6. Hymel A, Asturias S, Zhao F, Bliss R, Moran T, Marshall RH, Benjamin E, Phelan HA, Krause PC, Marecek GS, Ldonardi C, Stuke L, Hunt JP, Mooney JL. Selective versus nonselective embolization versus no embolization in pelvic trauma: A multicenter retrospective cohort study. *J Trauma Acute Care Surg*. 2017;83(3):361–7.

7. Adam Wallis MD, Kelly LJ. Angiography and embolisation for solid abdominal organ injury in adults - a current perspective. *World J Emerg Surg.* 2010;5:18.
8. Johnson GE, Sandstrom CK, Kogut MJ, Ingraham CR, Stratil PG, Valji K, Vo NJ, Glickerman D, Hippe DS, Padia SA. Frequency of external iliac artery branch injury in blunt trauma: improved detection with selective external iliac angiography. *J Vasc Interv Radiol.* 2013;24(3):363–9.
9. Yuan KC, Hsu YP, Wong YC, Fang JF, Lin BC, Chen HW. Management of complicated lumbar artery injury after blunt trauma. *Ann Emerg Med.* 2011;58(6):531–5.
10. Chehab M, Afaneh A, Bible L, Castanon L, Hanna K, Ditillo M, Khurram M, Asmar S, Joseph B. Angioembolization in intra-abdominal solid organ injury: Does delay in angioembolization affect outcomes? *J Trauma Acute Care Surg.* 2020;89(4):723–9.
11. Aoki M, Shibuya K, Kaneko M, Koizumi A, Murata M, Nakajima J, Hagiwara S, Kanbe M, Koyama Y, Tsushima Y, Oshima K. Massive hemothorax due to inferior phrenic artery injury after blunt trauma. *World J Emerg Surg.* 2015;10:58.
12. Mizobata Y, Yokota J, Yajima Y, Sakashita K. Two cases of blunt hepatic injury with active bleeding from the right inferior phrenic artery. *J Trauma.* 2000;48(6):1153–5.
13. Tamburini N, Carriel N, Cavallesco G, Molins L, Galeotti R, Guzmán R, Salviato E, Sánchez-Lorente D, Maietti E, Maniscalco P, Boada M. Technical results, clinical efficacy and predictors of outcome of intercostal arteries embolization for hemothorax: a two-institutions' experience. *J Thorac Dis.* 2019;11(11):4693–9.
14. Whigham CJ Jr, Fisher RG, Goodman CJ, Dodds CA, Trinh CC. Traumatic injury of the internal mammary artery: embolization versus surgical and nonoperative management. *Emerg Radiol.* 2002;9(4):201–7.
15. Naouli H, Jiber H, Bouarhroum A. False aneurysm of perforating branch of the deep femoral artery- Report of two cases. *Int J Surg Case Rep.* 2015;14:36–9.
16. Matsushima K, Piccinini A, Schellenberg M, Cheng V, Heindel P, Strumwasser A, Benjamin E, Inaba K, Demetriades D. Effect of door-to-angioembolization time on mortality in pelvic fracture: Every hour of delay counts. *J Trauma Acute Care Surg.* 2018;84(5):685–92.
17. Olthof DC, Sierink JC, van Delden OM, Luitse JS, Goslings JC. Time to intervention in patients with splenic injury in a Dutch level 1 trauma centre. *Injury.* 2014;45(1):95–100.
18. Morrison JJ, Madurska MJ, Romagnoli A, Ottochian M, Adnan S, Teeter W, Kuebler T, Hoehn MR, Brenner ML, DuBose JJ, Scalea TM. A Surgical Endovascular Trauma Service Increases Case Volume and Decreases Time to Hemostasis. *Ann Surg.* 2019;270(4):612–9.
19. Adnan SM, Romagnoli AN, Elansary NN, Martinson JR, Madurska MJ, Dubose JJ, Scalea TM, Morrison JJ. Radial versus femoral arterial access for trauma endovascular interventions: A noninferiority study. *J Trauma Acute Care Surg.* 2020;89(3):458–63.

Figures

Figure 1

Figure 1

Venn diagram of the distribution of embolized regions. Overlapping of embolized regions among pelvis, abdomen and the other body regions, including cerebrovascular, chest, peripheral, and other.

Figure 2

Pearson correlation coefficient between the number of embolized arteries and procedure time.

Figure 3

Pearson correlation coefficient between the number of embolized regions and procedure time.

Supplementary Files

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