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Does time to angiography affect the survival of trauma patients with embolization to the pelvis? A retrospective study across trauma centers in the United States

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ABSTRACT

Introduction: Traumatic pelvic injuries can result in rapid exsanguination. Bleeding control interventions include stabilization, angiography, and possible embolization. Previous studies yielded conflicting results regarding the benefit of a shorter time to embolization.

Objectives: The aim of this study is to examine the impact of the time to angioembolization on the survival of patients presenting with pelvic injuries using a national database.

Materials and Methods: This was an observational retrospective study that used the National Trauma Data Bank 2017 dataset. Adult patients with pelvic injuries and who received angiography with embolization to the pelvis were included. Univariate and bivariate analyses (survival to hospital discharge yes/no) were done. This was followed by a multivariable logistic regression analysis to assess the impact of time to angiography on survival to hospital discharge after adjusting for potential confounders.

Results: A total of 1,057 patients were included. They were predominantly of male gender (69.3 %) with a median age of 50 years (IQR = [31–64]). The mean time to pelvic angiography was 264.0 ± 204.4 min. The overall survival rate at hospital discharge was 72.0 %. Time to angiography was not significantly associated with survival to hospital discharge before and after adjusting for clinically and statistically significant confounders (aOR = 1.000; 95 %CI=[0.999 – 1.001]; p = 0.866).

Conclusion: Time to angiography was not associated with survival to hospital discharge of patients with pelvic injuries who required embolization. Further research examining specific patterns of injuries and assessing the impact of early angioembolization is needed.

Introduction

Trauma remains the main cause of mortality within the age group 1 to 40 years with one-third of deaths directly related to exsanguination and more than half of them occurring within the first 24 h [1,2]. Blood loss is lethal unless it is managed promptly to prevent the lethal triad [3]. Different management techniques can be applied depending on the bleeding site including manual compression, blood transfusion, internal and external fixations, transarterial embolization, Resuscitative Endovascular Balloon Occlusion of the Aorta (REBOA), and surgery [4]. In the context of trauma, angioembolization helps to visualize internal bleeding and when coupled with embolization, allows to control it. Recent data from a US nationwide study reported a prevalence of 0.53 % for the use of angiography in trauma [5]. Angioembolization allows for detecting minor vessel abrasions possibly missed by computed tomography (CT) and instantly managing the bleeding [6].

Trauma to the pelvis can have devastating consequences. Many important vascular structures lie within the bony pelvis and become severely compromised following blunt and penetrating trauma. Injuries to the venous plexus, branches of the iliac arteries, and branches of the iliac veins can result in hemodynamic instability and rapid exsanguination [7] making the pelvis the most common site of embolization [5, 8]. The use of embolization in the management of pelvic injuries is already established [9] and is increasing with time [10]. The Eastern Association for the Surgery of Trauma (EAST) issued level I recommendations on the use of angiography and embolization in pelvic

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fractures with hemodynamic instability or with intravenous contrast extravasation on a pelvis CT. It also supported repeating embolization if bleeding persisted after the initial control intervention [11].

Time to bleeding control is important in managing pelvic fractures. Interventions usually start in the prehospital phase by applying temporary external fixations and establishing early intravenous access for suspected pelvic fractures with pelvic instability until definitive treatment can be instituted at the receiving facility [12,13]. Several studies previously demonstrated that a shorter time to angioembolization can help decrease mortality in patients with pelvic injuries [10,14–18] and reduce the need for blood transfusion [14,16,19]. Other studies advocated for a shorter time to embolization with a potential associated reduction in mortality [19,20]. Large multicenter studies assessing the impact of time to embolization on outcomes in patients with pelvic injuries are lacking. This study uses data from the US National Trauma Data Bank to examine angioembolization practices for patients with pelvic injuries and the impact of time to angioembolization on the outcomes of patients treated in US trauma centers. Its findings can help provide evidence for incorporating a time interval criterion in future angiography guidelines for pelvic injury.

Materials and Methods

This retrospective observational study utilized the 2017 NTDB (National Trauma Data Bank) dataset ($n = 997{,}970$). This dataset is issued by the American College of Surgeons (ACS) on a yearly basis and gathers information from over 900 trauma centers across the US. NTDB currently holds the largest aggregation of trauma-related data ever assembled in the United States. It incorporates patients' characteristics, injury data, clinical information, Emergency Department (ED), and hospital outcomes. ICD-10-CM (the International Classification of Diseases, Tenth Revision, and Clinical Modification) procedures were mapped to the multi-CCS level 1 (clinical classification Software) in order to present more manageable and meaningful categories, [21].

We initially selected trauma patients who underwent angiography ($n = 5265$). Patients were excluded if they had: pediatric age group (defined as being under 16 years of age as per NTDB criteria) ($n = 113$), age was missing or not recorded ($n = 80$), ED disposition as unknown/not recorded ($n = 36$) /other ($n = 15$) /transferred to another hospital ($n = 25$), hospital discharge disposition as unknown or not recorded ($n = 2$), and those who had an inter-facility transfer ($n = 935$). Additionally, for the purpose of this study, patients who received an angiogram without embolization ($n = 1892$) were excluded. Finally, among those who were embolized, we excluded all embolization sites other than the pelvis ($n = 3185$). A total of 1057 patients were included in the final analysis. A flowchart of the participant selection is presented in Fig. 1.

An exemption was granted by the Institutional Review Board (IRB) for the use of this de-identified dataset.

Statistical Analysis

The statistical package for social sciences (SPSS, version 25.0; Inc, IBM Corp, Chicago, IL) was used to conduct all statistical analyses. Continuous variables (age and time to angiography) were described by their means ± standard deviations (SD), medians, and interquartile ranges (IQR) whereas all categorical variables were presented by their frequencies and percentages. Patients' demographic, injury, and clinical characteristics were stratified by the outcome (died/survived) using the Pearson's Chi-Square or the Fisher's exact tests. Because of the violation of the normality distribution, the Mann-Whitney test was carried out to

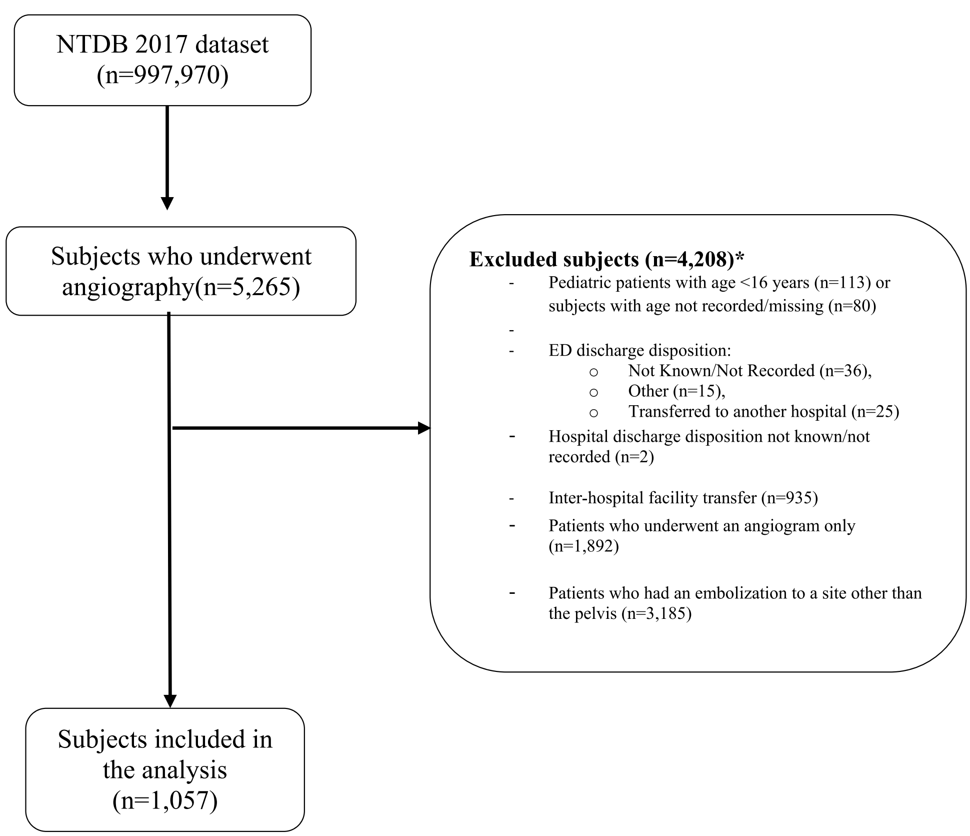

Fig. 1. Flow Diagram for participants selection from the National Trauma Data Bank 2017. ED = Emergency Department.
* There are overlaps among the categories of the excluded variables. More specifically, some patients who had inter-hospital facility transfer had as ED disposition one of the excluded categories. Also, some patients whose age was not recorded or were 15 years or younger were transferred or had as ED disposition one of the excluded categories. These overlaps explain why the final number on which the data analysis was conducted cannot be calculated just by subtracting the number of excluded patients from the selected sample.

compare the time to angiography between deceased and surviving patients. A multivariable logistic regression analysis was performed to determine the impact of time to angiography on the patients' survival to hospital discharge by adjusting for all clinically and statistically significant factors (age (years), sex, race, ethnicity, primary method of payment, transport mode, facility level (Hospital teaching Status - Hospital type - Bed size), trauma designation level, comorbidity, Injury Severity Score (ISS), Glasgow Coma Scale (GCS), Systolic Blood Pressure (SBP), injury intentionality, mechanism of injury, alcohol and drug screens, nature of the injury, body region, signs of life, time to angiography (minutes), hospital complications, embolization sites, and procedures. It is worth noting that some variables were not controlled for in the multivariable regression analysis due to having one of their categories as being fully distributed in the survived group, that is, a zero percent was detected among the deceased patients [body region: torso, hospital complications: alcohol withdrawal syndrome – osteomyelitis - superficial incisional surgical site infection]. Moreover, the trauma type was not taken into consideration while running the logistic regression model because almost all patients sustained blunt injuries. A p-value of ≤ 0.05 was used to denote statistical significance.

Results

Patients included in the study (1057) had a median age of 50 years (IQR = [31–64]). The majority were males (69.3 %). Most had either private/commercial insurance (42.2 %) or Medicare/Medicaid (36.5 %) as the primary method of payment rather than self-pay (11.4 %). Patients were mainly transported by ambulance (ground or helicopter) to university hospitals (60.2 %) and level I centers (70.3 %). Other general characteristics of patients (compared by outcome) are presented in Table 1. Patients were mostly admitted to the intensive care unit (ICU) ($n = 353$; 50.6 %) or to the operation room (OR) ($n = 430$; 40.7 %) rather than admitted to a regular floor /observation unit ($n = 45$; 4.3 %), telemetry/step-down unit ($n = 16$; 1.5 %) or discharged home (n = 26; 2.5 %). A total of 296 patients died (28 %) and the overall survival to hospital discharge rate in was 72.0 % ($n = 761$).

Pelvic injuries were mostly blunt (95.6 %), unintentional (91.7 %), and resulting from MVTs (70.5 %). Most patients had concomitant fractures (98.0 %) and more than half had blood vessel injuries (52.8 %). All patients in both groups received blood transfusions. Patients who survived were more likely to have injury severity score (ISS) ≤ 15 (9.2 % vs 3.7 %; $p = 0.003$), mild Glasgow Coma Scale (GCS 13 – 15) scores (73.6 %vs 37.9 %), and systolic blood pressure (SBP) ≥ 90 compared to those who died (72.4 %vs 62.8 %; $p = 0.003$). They were also less likely to have internal organ injuries (83.8% vs 94.3 %; $p < 0.001$) and head and neck injuries (64.5% vs 75.3 %; $p = 0.001$) (Table 2).

The hospital-related complications of embolized pelvic injured patients are presented in Table 3. While cardiac arrest, acute respiratory distress syndrome, and acute kidney injury were significantly higher in the group of patients who died (27.7 % vs 3.0 %; $p < 0.001$, 7.8 % vs 3.4 %; $p = 0.003$ and 16.9 % vs 6.7 %; $p < 0.001$ respectively), unplanned ICU admission was more common in the survived group (5.4 % vs 1.4 %; $p = 0.004$). Subsequent complications were more prevalent in the group that survived and included: deep and superficial surgical site infections, deep vein thrombosis, and catheter-associated urinary tract infection (Table 3).

The mean time to angiography was 264.0 ± 204.4 minutes, with an IQR ranging from 140 to 300 (data not shown). In addition to the pelvis, the two most common sites of concurrent embolization were the spleen (3.1 %) and the retroperitoneum (2.2 %). Patients who survived had significantly fewer embolization procedures in the retroperitoneum than those who died (1.6 % vs 3.7 %; $p = 0.032$). Concurrent embolization to the spleen or to the liver was similar in both groups ($p = 0.924$ and $p = 0.117$ respectively) (Table 3).

Patients who died were more likely to undergo operations related to the nervous system (17.6 vs 11.6; $p = 0.010$), respiratory system (57.4 vs

Table 1
General characteristics of the total sample and after stratification by the outcome (died/survived)

	Total N=1057	Died No (N=761)	Yes (N=296)	p-value
Age (years)				
16 – 25	165 (15.6%)	136 (17.9%)	29 (9.8%)	<0.001
26 – 35	156 (14.8%)	121 (15.9%)	35 (11.8%)	
36 – 45	138 (13.1%)	103 (13.5%)	35 (11.8%)	
46 – 55	164 (15.5%)	130 (17.1%)	34 (11.5%)	
56 - 65	193 (18.3%)	134 (17.6%)	59 (19.9%)	
≥ 66	241 (22.8%)	137 (18.0%)	104 (35.1%)	
Sex				
Male	733 (69.3%)	520 (68.3%)	213 (72.0%)	0.251
Female	324 (30.7%)	241 (31.7%)	83 (28.0%)	
Race				
Black	176 (16.7%)	129 (17.2%)	47 (16.5%)	0.273
White	710 (67.2%)	505 (67.5%)	205 (71.9%)	
Other Race[1]	147 (13.9%)	114 (15.2%)	33 (11.6%)	
Not Known/Not Recorded	24 (2.3%)			
Ethnicity				
Hispanic or Latino	137 (13.0%)	110 (15.0%)	27 (9.7%)	0.027
Not Hispanic or Latino	875 (82.8%)	623 (85.0%)	252 (90.3%)	
Not Known/Not Recorded	45 (4.3%)			
Primary method of payment				
Medicaid / Medicare	386 (36.5%)	261 (35.0%)	125 (43.3%)	<0.001
Self-Pay	120 (11.4%)	73 (9.8%)	47 (16.3%)	
Private/Commercial Insurance	446 (42.2%)	354 (47.5%)	92 (31.8%)	
Not Billed (for any reason) & Other Government & Other	83 (7.9%)	58 (7.8%)	25 (8.7%)	
Not Known/Not Recorded	22 (2.1%)			
Transport Mode				
Ground Ambulance	808 (76.4%)	572 (75.5%)	236 (80.0%)	0.250*
Helicopter Ambulance	228 (21.6%)	174 (23.0%)	54 (18.3%)	
Other[2]	17 (1.6%)	12 (1.6%)	5 (1.7%)	
Not Known/Not Recorded	4 (0.4%)			
Facility level: Hospital Teaching Status				
Community	330 (31.2%)	236 (31.0%)	94 (31.8%)	0.695
Non-Teaching	91 (8.6%)	69 (9.1%)	22 (7.4%)	
University	636 (60.2%)	456 (59.9%)	180 (60.8%)	
Trauma Designation Level				
I	743 (70.3%)	527 (69.7%)	216 (73.0%)	0.393*
II	304 (28.8%)	226 (29.9%)	78 (26.4%)	
III	5 (0.5%)	3 (0.4%)	2 (0.7%)	
Not Known/Not Recorded	5 (0.5%)			

* indicates that the Fisher's exact test was used to calculate the p-value.
[1] Other race is the combination of the following categories: Asian & Pacific Islander & American Indian & Other
[2] Other transport mode includes: Private/Public Vehicle/Walk-in & Police & Other

Table 2
Clinical characteristics of the total sample and after stratification by the outcome (died/survived)

	Total N=1057	Died No (N=761)	Yes (N=296)	p-value
Comorbidity				
No	451 (42.7%)	314 (41.3%)	137 (46.3%)	0.138
Yes	606 (57.3%)	447 (58.7%)	159 (53.7%)	
ISS				
≤ 15	81 (7.7%)	70 (9.2%)	11 (3.7%)	0.003
≥ 16	976 (92.3%)	691 (90.8%)	285 (96.3%)	
GCS				
Severe ≤ 8	293 (27.7%)	143 (18.9%)	150 (51.2%)	<0.001
Moderate 9 – 12	88 (8.3%)	56 (7.4%)	32 (10.9%)	
Mild 13 – 15	667 (63.1%)	556 (73.6%)	111 (37.9%)	
Not Known/Not Recorded	9 (0.9%)			
SBP				
< 90	315 (29.8%)	207 (27.6%)	108 (37.2%)	0.003
≥ 90	724 (68.5%)	542 (72.4%)	182 (62.8%)	
Not Known/Not Recorded	18 (1.7%)			
Transfusion blood (4 hours)				
Yes	1057 (100%)	761 (100%)	296 (100%)	-
Trauma type Blunt	1010 (95.6%)	722 (95.1%)	288 (97.3%)	0.141*
Penetrating	43 (4.1%)	36 (4.7%)	7 (2.4%)	
Burn & Other/unspecified	2 (0.2%)	1 (0.1%)	1 (0.3%)	
Not Known/Not Recorded	2 (0.2%)			
Injury Intentionality				
Unintentional	969 (91.7%)	692 (91.1%)	277 (93.6%)	0.333*
Self-inflicted	42 (4.0%)	30 (3.9%)	12 (4.1%)	
Assault	38 (3.6%)	32 (4.2%)	6 (2.0%)	
Undetermined & Other	7 (0.7%)	6 (0.8%)	1 (0.3%)	
Not Known/Not Recorded	1 (0.1%)			
Mechanism of Injury Fall	134 (12.7%)	100 (13.3%)	34 (11.9%)	0.601
Firearm	35 (3.3%)	28 (3.7%)	7 (2.4%)	
MVT	745 (70.5%)	532 (70.8%)	213 (74.5%)	
Other[1]	123 (11.6%)	91 (12.1%)	32 (11.2%)	
Not Known/Not Recorded	20 (1.9%)			
Nature of injury: Fracture				
No	21 (2.0%)	16 (2.1%)	5 (1.7%)	0.665
Yes	1036 (98.0%)	745 (97.9%)	291 (98.3%)	
Nature of injury: Blood Vessel				
No	499 (47.2%)	377 (49.5%)	122 (41.2%)	0.015
Yes	558 (52.8%)	384 (50.5%)	174 (58.8%)	
Nature of injury: Internal organ injury				
No	140 (13.2%)	123 (16.2%)	17 (5.7%)	<0.001
Yes	917 (86.8%)	638 (83.8%)	279 (94.3%)	
Nature of injury: Superficial and contusion				
No	420 (39.7%)	302 (39.7%)	118 (39.9%)	0.957
Yes	637 (60.3%)	459 (60.3%)	178 (60.1%)	
Nature of injury: Open wound				
No	479 (45.3%)	342 (44.9%)	137 (46.3%)	0.694
Yes	578 (54.7%)	419 (55.1%)	159 (53.7%)	
Nature of injury: Other specified injury				
No	801 (75.8%)	571 (75.0%)	230 (77.7%)	0.363
Yes	256 (24.2%)	190 (25.0%)	66 (22.3%)	
Nature of injury: Dislocation				
No	765 (72.4%)	538 (70.7%)	227 (76.7%)	0.050
Yes	292 (27.6%)	223 (29.3%)	69 (23.3%)	
Nature of injury: Other[2]				
No	977 (92.4%)	708 (93.0%)	269 (90.9%)	0.234
Yes	80 (7.6%)	53 (7.0%)	27 (9.1%)	
Body Region: Torso				
No	4 (0.4%)	4 (0.5%)	0 (0%)	0.581*
Yes	1053 (99.6%)	757 (99.5%)	296 (100%)	
Body Region: Extremities				
No	143 (13.5%)	105 (13.8%)	38 (12.8%)	0.682
Yes	914 (86.5%)	656 (86.2%)	258 (87.2%)	
Body Region: Head and Neck				
No	343 (32.5%)	270 (35.5%)	73 (24.7%)	0.001
Yes	714 (67.5%)	491 (64.5%)	223 (75.3%)	
Body Region: Spine and Back				
No	244 (23.1%)	171 (22.5%)	73 (24.7%)	0.448
Yes	813 (76.9%)	590 (77.5%)	223 (75.3%)	
Body Region: Unclassifiable by body region				
No	1000 (94.6%)	732 (96.2%)	268 (90.5%)	<0.001
Yes	57 (5.4%)	29 (3.8%)	28 (9.5%)	
Signs of Life				
Arrived with no signs of life	12 (1.1%)	2 (0.3%)	10 (3.4%)	<0.001*
Arrived with signs of life	1045 (98.9%)	759 (99.7%)	286 (96.6%)	

* indicates that the Fisher's exact test was used to calculate the p-value.
[1] Other mechanism of injury includes: Cut/pierce & Fire/flame & Machinery & Pedal cyclist, other & Pedestrian, other & Transport, other & Natural/environmental, Other & Struck by, against & Other specified and classifiable & Other specified, not elsewhere classifiable
[2] Other nature of injury includes: Amputation & Burns and corrosions & Crushing & Other effects of external causes & Unspecified injury

48.8 %; $p = 0.011$), and digestive system (56.8 s 48.5 %; $p = 0.016$) while those who survived were more likely to undergo operations to the musculoskeletal (83.2 % vs 43.9 %; p<0.001) and integumentary systems (50.9 % vs 28.4 %; $p < 0.001$) (Table 4).

Time to angiography was not associated with survival to hospital discharge in trauma patients with embolization to the pelvis before and after adjusting for clinically and statistically significant confounders (OR = 1.000; 95 %CI=[0.999–1.001];$p = 0.866$) (Table 5).

Discussion

In this multicenter study of trauma patients who underwent embolization to the pelvis, time to angiography was not found to be associated

Table 3
Angiography characteristics and hospital complications of the total sample and after stratification by the outcome (died/survived)

	Total N=1057	Died No (N=761)	Yes (N=296)	p-value
Angiography procedure				
Angiography with embolization	1057 (100%)	761 (100%)	296 (100%)	-
Hospital Complication: Deep Vein Thrombosis (DVT)				
No	986 (93.3%)	700 (92.0%)	286 (96.6%)	0.007
Yes	71 (6.7%)	61 (8.0%)	10 (3.4%)	
Hospital Complication: Alcohol Withdrawal Syndrome				
No	1041 (98.5%)	745 (97.9%)	296 (100%)	0.009*
Yes	16 (1.5%)	16 (2.1%)	0 (0%)	
Hospital Complication: Cardiac Arrest with CPR				
No	952 (90.1%)	738 (97.0%)	214 (72.3%)	<0.001
Yes	105 (9.9%)	23 (3.0%)	82 (27.7%)	
Hospital Complication: Catheter-Associated Urinary Tract Infection (CAUTI)				
No	1027 (97.2%)	733 (96.3%)	294 (99.3%)	0.008
Yes	30 (2.8%)	28 (3.7%)	2 (0.7%)	
Hospital Complication: Acute Kidney Injury				
No	956 (90.4%)	710 (93.3%)	246 (83.1%)	<0.001
Yes	101 (9.6%)	51 (6.7%)	50 (16.9%)	
Hospital Complication: Acute Respiratory Distress Syndrome (ARDS)				
No	1008 (95.4%)	735 (96.6%)	273 (92.2%)	0.003
Yes	49 (4.6%)	26 (3.4%)	23 (7.8%)	
Hospital Complication: Superficial Incisional Surgical Site Infection				
No	1042 (98.6%)	746 (98.0%)	296 (100%)	0.009*
Yes	15 (1.4%)	15 (2.0%)	0 (0%)	
Hospital Complication: Pressure Ulcer				
No	1007 (95.3%)	715 (94.0%)	292 (98.6%)	0.001
Yes	50 (4.7%)	46 (6.0%)	4 (1.4%)	
Hospital Complication: Unplanned Admission to the ICU				
No	1012 (95.7%)	720 (94.6%)	292 (98.6%)	0.004
Yes	45 (4.3%)	41 (5.4%)	4 (1.4%)	
Embolization Site: Liver				
No	1039 (98.3%)	751 (98.7%)	288 (97.3%)	0.117
Yes	18 (1.7%)	10 (1.3%)	8 (2.7%)	
Embolization Site: Spleen				
No	1024 (96.9%)	737 (96.8%)	287 (97.0%)	0.924
Yes	33 (3.1%)	24 (3.2%)	9 (3.0%)	
Embolization Site: Kidneys				
No	1050 (99.3%)	757 (99.5%)	293 (99.0%)	0.407*
Yes	7 (0.7%)	4 (0.5%)	3 (1.0%)	
Embolization Site: Retroperitoneum (lumbar, sacral)				
No	1034 (97.8%)	749 (98.4%)	285 (96.3%)	0.032
Yes	23 (2.2%)	12 (1.6%)	11 (3.7%)	
Embolization Site: Peripheral vascular (neck, extremities)				
No	1049 (99.2%)	756 (99.3%)	293 (99.0%)	0.693*
Yes	8 (0.8%)	5 (0.7%)	3 (1.0%)	
Embolization Site: Aorta (thoracic or abdominal)				
No	1051 (99.4%)	756 (99.3%)	295 (99.7%)	1.000*
Yes	6 (0.6%)	5 (0.7%)	1 (0.3%)	
Embolization Site: Other				
No	1033 (97.7%)	746 (98.0%)	287 (97.0%)	0.295
Yes	24 (2.3%)	15 (2.0%)	9 (3.0%)	

* indicates that the Fisher's exact test was used to calculate the p-value.

The following hospital complications were not shown in the table because they were not significantly different between the two groups: Central Line-Associated Bloodstream Infection (CLABSI), Deep Surgical Site Infection, Pulmonary Embolism, Extremity Compartment Syndrome, unplanned intubation, Myocardial infarction, Organ/Space Surgical Site Infection, Osteomyelitis, Unplanned Return to the OR, Severe sepsis, Stroke / CVA, Ventilator-Associated Pneumonia (VAP).

with survival to hospital discharge. Delays in time to the angiography procedure (median time of 264 min) were observed. To our knowledge, this study is the largest multicenter study to examine this topic. Other studies used national databases to examine pelvic injuries addressing specific subpopulations or ethnic groups [22,23], different aims [9], or different exposures [23]. Despite the proven benefit of early hemorrhage control in patients with pelvic injuries using different techniques, including but not limited to embolization, the findings of this study highlight the need for further research to provide a more evidence-based timelines for embolization in the management of pelvic injuries.

Patients with traumatic injuries and who required embolization to the pelvis were noted to have a high mortality rate (28.0 %). This was expected since they are usually severely injured and display worse baseline clinical characteristics with high ISS scores, and a high likelihood of blood vessel injuries, hemodynamic instability, and need for blood transfusion. This mortality rate is higher than rates reported in previous studies examining embolization in pelvic injuries [9,14,24]. Kim et al examined trauma patients with complex pelvic injuries undergoing transarterial embolization and reported an overall mortality rate of 14.6 % (vs 28.0 %) [14]. Their study examined patients from a single center, used different inclusion criteria, and reported improved outcomes from a facility that is highly equipped for interventional angiography with a shorter time to embolization and bleeding control. Another NTDB nationwide study explored the management of pelvic injuries and reported a lower mortality rate (20.5 %) despite being conducted in a similar setting (US Trauma Centers) [9]. It however adopted different inclusion criteria for pelvic injuries and selected specific trauma centers, leading to different outcomes. Similarly, Bou Saba et al. examined trauma patients who underwent angiography with or without embolization from the same database and reported a mortality rate of 20 % [5] which is consistent with the fact that patients with

Table 4
Distribution of the multi-CCS level 1 procedures of the total sample and after stratification by the outcome (died/survived)

	Total N=1057	Died No (N=761)	Died Yes (N=296)	p-value
Operations on the nervous system				
No	917 (86.8%)	673 (88.4%)	244 (82.4%)	0.010
Yes	140 (13.2%)	88 (11.6%)	52 (17.6%)	
Operations on the respiratory system				
No	516 (48.8%)	390 (51.2%)	126 (42.6%)	0.011
Yes	541 (51.2%)	371 (48.8%)	170 (57.4%)	
Operations on the hemic and lymphatic system				
No	967 (91.5%)	706 (92.8%)	261 (88.2%)	0.016
Yes	90 (8.5%)	55 (7.2%)	35 (11.8%)	
Operations on the digestive system				
No	520 (49.2%)	392 (51.5%)	128 (43.2%)	0.016
Yes	537 (50.8%)	369 (48.5%)	168 (56.8%)	
Operations on the musculoskeletal system				
No	294 (27.8%)	128 (16.8%)	166 (56.1%)	<0.001
Yes	763 (72.2%)	633 (83.2%)	130 (43.9%)	
Operations on the integumentary system				
No	586 (55.4%)	374 (49.1%)	212 (71.6%)	<0.001
Yes	471 (44.6%)	387 (50.9%)	84 (28.4%)	
Miscellaneous diagnostic and therapeutic procedures				
No	36 (3.4%)	19 (2.5%)	17 (5.7%)	0.009
Yes	1021 (96.6%)	742 (97.5%)	279 (94.3%)	

The following hospital procedures were not shown in the table because they were not significantly different between the two groups: Operations on the eye, ear, nose; mouth; and pharynx, the cardiovascular system, the urinary system, the male and female genital organs, and obstetrical procedures.

Table 5
Crude and adjusted odds ratios of survived patients who underwent angiography with embolization procedure in the pelvic site.

	Crude OR	Crude 95 % CI	Crude p-value	Adjusted* OR	Adjusted* 95 % CI	Adjusted* p-value
Time to angiography (minutes)	1.000	0.999 – 1.001	0.849	1.000	0.999 – 1.001	0.866

* Variables entered into the model: Age (years) – Sex – Race – Ethnicity - Primary method of payment - Transport Mode- Facility level: Hospital Teaching Status - Facility level: Hospital type - Facility level: Bed size – Trauma designation level - Comorbidity – ISS – GCS – SBP - Injury Intentionality - Mechanism of Injury - Alcohol Screen - Drug Screen - Nature of injury [Fracture; Blood Vessel; Internal organ injury; Superficial and contusion; Open wound; Other specified injury; Dislocation; Other] - Body Region [Extremities; Head and Neck; Spine and Back; Unclassifiable by body region] - Signs of Life – Time to angiography (minutes)- Hospital Complications [Central Line-Associated Bloodstream Infection (CLABSI); Deep Surgical Site Infection; Deep Vein Thrombosis (DVT); Cardiac Arrest with CPR; Catheter-Associated Urinary Tract Infection (CAUTI); Pulmonary Embolism; Extremity Compartment Syndrome; Unplanned Intubation; Acute Kidney Injury; Myocardial Infarction; Organ/Space Surgical Site Infection; Acute Respiratory Distress Syndrome (ARDS); Unplanned Return to the OR; Severe Sepsis; Stroke / CVA; Pressure Ulcer; Unplanned Admission to the ICU; Ventilator-Associated Pneumonia (VAP); Other] - Embolization Sites [Liver; Spleen; Kidneys; Retroperitoneum (lumbar, sacral);Peripheral vascular (neck, extremities);Aorta (thoracic or abdominal);Other]-Procedures [Operations on the nervous system; Operations on the eye; Operations on the ear; Operations on the nose; mouth; and pharynx; Operations on the respiratory system; Operations on the cardiovascular system; Operations on the hemic and lymphatic system; Operations on the digestive system; Operations on the urinary system; Operations on the male genital organs; Operations on the female genital organs; Obstetrical procedures; Operations on the musculoskeletal system; Operations on the integumentary system; Miscellaneous diagnostic and therapeutic procedures].

pelvic injuries requiring embolization who were selected for our study are expected to be sicker than other trauma patients and should benefit most from timely bleeding control procedures such as embolization.

Our study also looked at complications associated with patients undergoing embolization to the pelvis. It is worth noting that some complications were more prevalent in the group of patients who survived. Complications such as superficial surgical site infections, deep vein thrombosis (DVT), catheter-associated urinary tract infections (CAUTI), and pressure ulcers are generally expected with longer ICU stays [25]. It is possible that the latter group did not survive long enough to develop these complications. Relevant complications in the group who died included acute kidney injury (AKI), acute respiratory distress syndrome (ARDS), and cardiac arrest; all of which can be associated with imminent risks of death.

The median time-to-angiography was relatively long (264 minutes). Previous single-centered and small-scale studies reported both shorter door-to-embolization times and door-to-angiography times ranging from 76 to 106 minutes on average [14,18,26]. However, prior larger series reported similarly extended time intervals ranging from 193–286 minutes [17,20,27,28]. These findings reflect relative delays in achieving angiography and embolization even when examined at a national level, mainly across Level I and Level II trauma centers in the US, and despite the supporting evidence of the potential positive impact of this intervention on survival [10,14–18]. This time interval was also not associated with survival to hospital discharge. This contradicts previous studies that reported an association with worse outcomes with delays in angiography of more than 90 minutes [15,16,18]. More so, a study by Kim et al examined door-to-embolization time and clinical outcomes after transarterial embolization in trauma patients with complex pelvic fracture and reported that an increase of one hour in the door-to-embolization time resulted in a two-fold increase in mortality in the first 24 h [14]. Their median door-to-angiography time was 106 min IQR (78–134), less than half the median time reported in our study. It is possible that with a shorter median time to angiography, a positive impact on overall survival might be detected. Another potential explanation for this finding might be related to the selected outcome: Our study examined survival to hospital discharge rather than survival at 24 h. It is also worth noting that our study included patients from different trauma centers and adjusted for important factors including surgical procedures and complications in addition to other general, clinical, and injury characteristics which might have not been adjusted for in other studies.

Current angiography guidelines in patients with pelvic injuries do not incorporate specific timeframes for angiography or embolization. Efforts should therefore focus on improving access to timely angiography and embolization and on examining the impact of such reduction on overall mortality through evidence-based research to possibly incorporate the time criterion in future angiography guidelines.

Limitations

This study has some limitations related to its retrospective nature. Despite adequate yearly monitoring, inconsistencies in reporting between trauma centers to NTDB might still exist. Additionally, clinically important factors such as time of injury, prehospital transport time, prehospital interventions, and the volume of blood administered were not adjusted for in the multivariable analysis due to their unavailability in NTDB. "Time to angiography" was used in our study as the main variable. An alternative "Time to embolization" would have been a more precise measurement but was not available in the NTDB. One recommendation would be to include this variable in future NTDB datasets. Despite these limitations, NTDB remains the largest clinical database available in the United States and the study findings are representative of current angiography practices across US trauma centers and of impact on outcomes of trauma patients with embolization to pelvis.

Conclusions

Time to angiography was not significantly associated with survival to hospital discharge in patients embolized to the pelvis. Significant delays were noted in the current use of angiography in managing pelvic injuries across US trauma centers. Timely angioembolization should be encouraged through protocol implementation and better resource utilization.

Authors' contributions

RR AS and RB acquired, analyzed, and drafted the work. ME conceived, designed, and substantively revised the study. RR AS, RB, and ME approve the submitted version.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Declaration of Competing Interest

The authors declare that they have no competing interests.

Ethics approval and consent to participate

The Institutional Review Board (IRB) at the American University of Beirut approved this study.

Consent for publication

Not applicable.

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