Effect of door-to-angioembolization time on mortality in pelvic fracture: Every hour of delay counts

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INTRODUCTION: Angioembolization (AE) is widely used for hemorrhagic control in patients with pelvic fracture. The latest version of the *Resources for Optimal Care of the Injured Patient* issued by the American College of Surgeons Committee on Trauma requires interventional radiologists to be available within 30 minutes to perform an emergency AE. However, the impact of time-to-AE on patient outcomes remains unknown. We hypothesized that a longer time-to-AE would be significantly associated with increased mortality in patients with pelvic fracture.

METHODS: This is a 2-year retrospective cohort study using the American College of Surgeons Trauma Quality Improvement Program database from January 2013 to December 2014. We included adult patients (age ≥ 18 years) with blunt pelvic fracture who underwent pelvic AE within 4 hours of hospital admission. Patients who required any hemorrhage control surgery for associated injuries within 4 hours were excluded. Hierarchical logistic regression was performed to evaluate the impact of time-to-AE on in-hospital and 24-hour mortality.

RESULTS: A total of 181 patients were included for analysis. The median age was 54 years (interquartile range, 38–68) and 69.6% were male. The median injury severity score was 34 (interquartile range, 27–43). Overall in-hospital mortality rate was 21.0%. The median packed red blood cell transfusions within 4 and 24 hours after admission were 4 and 6 units, respectively. After adjusting for other covariates in a hierarchical logistic regression model, a longer time-to-pelvic AE was significantly associated with increased in-hospital mortality (odds ratio, 1.79 for each hour; 95% confidence interval, 1.11–2.91; $p = 0.018$).

CONCLUSION: The current study showed an increased risk of in-hospital mortality related to a prolonged time-to-AE for hemorrhagic control following pelvic fractures. Our results suggest that all trauma centers should allocate resources to minimize delays in performing pelvic AE. (*J Trauma Acute Care Surg.* 2018;84: 685–692. Copyright © 2018 American Association for the Surgery of Trauma. All rights reserved.)

LEVEL OF EVIDENCE: Therapeutic/care management, level IV.

KEY WORDS: Pelvic fracture; angioembolization; timing; outcome.

Hemorrhage control in hemodynamically unstable patients with severe pelvic fracture can be extremely challenging. Despite the introduction of a multispecialty approach, a recent multicenter study in the United States showed that the mortality rate associated with severe pelvic fractures remains as high as 32.0% in a shock cohort.[1,2] In addition to hemostatic resuscitation with aggressive use of blood products, there are currently several surgical and nonsurgical options available for the management of pelvic fracture hemorrhage.[3–6] While significant variations between trauma centers have been reported in managing unstable patients with severe pelvic fracture, angioembolization (AE) is most commonly used to control pelvic hemorrhage.[2,7]

Even in Level 1 trauma centers, time from hospital admission to pelvic AE (time-to-AE) can be prolonged, particularly during nights or on weekends.[8,9] The latest version of the *Resources for Optimal Care of the Injured Patient* issued by the American College of Surgeons Committee on Trauma (ACS-COT) stipulates that interventional radiologists should be available within 30 minutes to perform an emergency AE in Level 1 and Level 2 centers.[10] However, the interventional radiology team is not required to be in-house for 24 hours per day for trauma center verification by the ACS-COT or equivalent state agencies.

Reduction of time to therapeutic intervention is known to be associated with improved patient outcomes in a wide variety of surgical and medical conditions, particularly in setting of trauma.[11–13] However, the discrepancy between the recommendations and certification requirements by the ACS-COT may be due, in part, to the limited data regarding the impact of time-to-AE on patient outcomes in hemorrhage control for pelvic fracture. The current study, therefore, intended to evaluate the impact of a delay in performing pelvic AE on patients' survival. We hypothesized that a longer time-to-AE would be significantly associated with increased mortality in patients with pelvic fracture.

METHODS

Study Design and Patient Selection

This is a retrospective cohort study using the American College of Surgeons Trauma Quality Improvement Program database. Our study period was 2 years, from January 2013 to December 2014. The study was approved by the Institutional Review Board of the University of Southern California. The American College of Surgeons Trauma Quality Improvement Program database is a subset of the National Trauma Databank consisting of trauma-related data submitted from more than 700 participating Level 1 and Level 2 trauma centers throughout the United States. To meet inclusion criteria for the TQIP, patients must be older than 16 years, with Abbreviated Injury Scale (AIS)score greater than 2 in at least one body region. For patients who received at least one unit of packed red blood cells (PRBC) within 4 hours of hospital admission, additional data concerning transfused blood products (PRBC, fresh frozen plasma, and platelets) within 4 and 24 hours, as well as the timing (first angiography or AE time) and target organs of AE, were collected and available for analysis.

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Blunt trauma patients (age ≥18 years) who underwent AE for pelvic fractures were included in the analysis (Fig. 1). Patients with pelvic fracture were identified using the *International Classification of Diseases, Ninth Revision* codes 808.0 to 808.9. We excluded patients who underwent pelvic AE 4 hours or more after admission, as these cases were likely nonemergency.[8,9] Patients who required hemorrhage control surgery (laparotomy; thoracotomy; sternotomy; peripheral vascular procedures; neck and mangled extremity/traumatic amputation) within 4 hours were also excluded, as the timing of pelvic AE could be significantly affected by associated injuries. Variables including patients' demographics, injury profile, hospital characteristics, transfusion requirements, and clinical outcomes were collected for analysis. Our primary outcome was in-hospital mortality; and secondary outcomes included 24-hour mortality, hospital length of stay (LOS), LOS in the intensive care unit, and days on mechanical ventilation.

Statistical Analysis

Study patients were divided into four groups by hours to pelvic AE (0–1 hour, 1–2 hours, 2–3 hours, and 3–4 hours). Univariate analysis was performed comparing patients' characteristics and hospital characteristics as well as study outcomes between these four groups. Chi-square or Fisher exact test was used for categorical variables, and Student *t*-test or Mann-Whitney test was used for continuous variables as appropriate. Hierarchical logistic regression was then performed to account for clustering effect within trauma centers. Patient- and hospital-level potential confounding factors were adjusted in a hierarchical regression model for in-hospital and 24-hour mortality. The results were reposted as odds ratios and 95% confidence intervals (CIs). Correlation between variables was tested with multicollinearity analysis. The area under the receiver operating characteristic curve with 95% CI was used to assess the accuracy of the test. Statistical significance was set as $p < 0.05$. All statistical analyses were performed using SPSS for Mac OS version 23.0 (SPSS Inc, Chicago, IL).

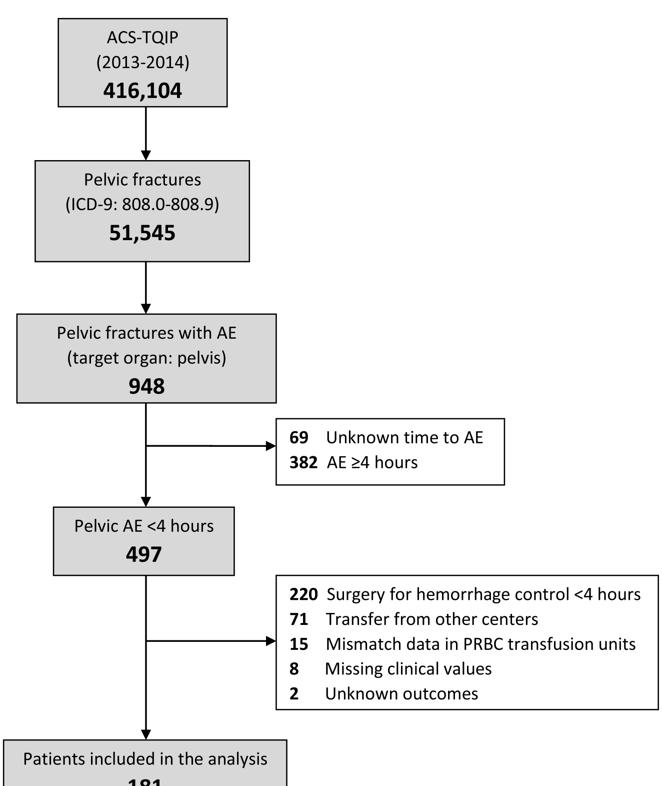

Figure 1. Patient flow diagram.

RESULTS

Patients' and Hospital Characteristics

A total of 181 patients met inclusion criteria (Fig. 1). Patients' and hospital characteristics are summarized in Table 1. While pelvic AE was most commonly performed between 2 and 3 hours after admission (43.6%), 10.5% of study patients underwent pelvic AE within 1 hour. There were no significant differences in median age, sex, or preexisting medical conditions between the four study groups, whereas 36.8% and 42.6% were elderly patients (age > 65 years) in the zero- to 1-hour and 3- to 4-hour groups, respectively ($p = 0.049$). Approximately one quarter of patients presented with hypotension (systolic blood pressure < 90 mm Hg), and more than half of patients were tachycardic (heart rate > 100 beats per minute) upon arrival. Nearly 50% of patients in the 1-hour group presented with decreased mental status, defined as Glasgow Coma Scale score of less than 9 ($p = 0.032$). Injury severity score was greater than 15 in 92.3% of patients, and many of them had associated severe injuries (AIS score > 2) in other body regions. Patients were admitted and underwent pelvic AE in 80 unique trauma centers, of which 77.9% were Level 1 centers and 22.1% were Level 2 centers. The trauma center with the highest volume admitted 20 patients (11.1%). Otherwise, a median case volume per center during the study period was 2 (interquartile range, 1–3). Most of the patients in the zero- to 1-hour group were managed at a university hospital, whereas pelvic AE was performed after 1 hour primarily at nonteaching and community hospitals.

Transfusion Requirements and Outcomes

Table 2 summarizes the results of statistical analyses on blood transfusions and clinical outcomes. Overall, PRBC and fresh frozen plasma were transfused in a ratio of 1:1:2 or greater within 24 hours after admission. No significant differences in transfusion requirements within 4 hours were identified between the groups. Additionally, the total number of units administered and the ratio of transfused blood products within 24 hours were similar in all study groups. Of note, in all four groups, only 1 to 2 units of blood products were required between 4 and 24 hours following pelvic AE.

No patient died in the first 24 hours of hospital admission, and only one patient (5.3%) died before hospital discharge in the zero- to 1-hour group. In the other groups, the 24-hour mortality rate was as high as 11.1%. In-hospital mortality was 25.3% and 23.4% in the 2- to 3-hour and 3- to 4-hour groups, respectively. No significant differences were observed in hospital LOS, LOS in the intensive care unit,

TABLE 1. Patient's and Hospital Characteristics

		Hours to Pelvic AE				
Variable	**Total (n = 181)**	**0–1 (n = 19)**	**1–2 (n = 36)**	**2–3 (n = 79)**	**3–4 (n = 47)**	***p***
Patients' characteristics						
Age, median (IQR)	54 (38–68)	59 (43–75)	51 (33–59)	53 (37–63)	54 (34–73)	0.11
Age > 65, n (%)	52 (28.7)	7 (36.8)	7 (19.4)	18 (22.8)	20 (42.6)	0.049
Male sex, n (%)	126 (69.6)	12 (63.2)	27 (75.0)	52 (65.8)	35 (74.5)	0.59
Comorbidities						
Diabetes, n (%)	26 (14.4)	4 (21.1)	3 (8.3)	11 (13.9)	8 (17.0)	0.57
Hypertension, n (%)	44 (24.3)	4 (21.0)	4 (11.1)	24 (30.4)	12 (25.5)	0.16
Obesity, n (%)	21 (11.6)	3 (15.8)	7 (19.4)	8 (10.1)	3 (6.4)	0.27
Smoking, n (%)	30 (16.6)	2 (10.5)	7 (19.4)	14 (17.7)	7 (14.9)	0.83
Respiratory disease, n (%)	12 (6.6)	2 (10.5)	4 (11.1)	4 (5.1)	2 (4.3)	0.50
SBP < 90 mm Hg, n (%)	49 (27.1)	5 (26.3)	8 (22.2)	24 (30.4)	12 (25.5)	0.82
HR > 100 bpm, n (%)	109 (60.2)	10 (52.6)	23 (63.9)	47 (59.5)	29 (61.7)	0.87
GCS, median (IQR)	14 (4–15)	10 (3–15)	14 (3–15)	15 (11–15)	14 (6–15)	0.19
GCS < 9, n (%)	53 (29.3)	9 (47.4)	14 (38.9)	15 (19.0)	15 (31.9)	0.032
AIS head > 2, n (%)	74 (40.9)	6 (31.6)	15 (41.7)	34 (43)	19 (40.4)	0.84
AIS spine > 2, n (%)	28 (15.5)	4 (21.1)	6 (16.7)	15 (19)	3 (6.4)	0.24
AIS thorax > 2, n (%)	110 (60.8)	11 (57.9)	22 (61.1)	45 (57)	32 (68.1)	0.66
AIS abdomen > 2, n (%)	113 (62.4)	8 (42.1)	22 (61.1)	53 (67.1)	30 (63.8)	0.25
ISS, median (IQR)	34 (27–43)	38 (24–43)	34 (27–43)	34 (22–43)	34 (27–48)	0.84
ISS > 15, n (%)	167 (92.3)	16 (84.2)	35 (97.2)	73 (92.4)	43 (91.5)	0.39
Hospital characteristics						
Trauma center level						
Level 1, n (%)	141 (77.9)	14 (73.7)	29 (80.6)	60 (75.9)	38 (80.9)	0.86
Level 2, n (%)	40 (22.1)	5 (26.3)	7 (19.4)	19 (24.1)	9 (19.1)	
Teaching status						
University, n (%)	113 (62.4)	16 (84.2)	19 (52.8)	48 (60.8)	30 (63.8)	0.10
Nonteaching, n (%)	17 (9.4)	1 (5.3)	4 (11.1)	11 (13.9)	1 (2.1)	
Community, n (%)	51 (28.2)	2 (10.5)	13 (36.1)	20 (25.3)	16 (34.0)	

ACS-TQIP, American College of Surgeons Trauma Quality Improvement Program; GCS, Glasgow Coma Scale; HR, heart rate; ICD, International Classification of Diseases; IQR, interquartile range; ISS, injury severity score; SBP, systolic blood pressure.

and ventilator days. In the hierarchical logistic regression analysis (Table 3) adjusted for both patient- and hospital-level covariates, the hours-to-pelvic AE was not significantly associated with 24-hour mortality (odds ratio, 1.39; 95% CI, 0.76–2.55; $p = 0.28$). In contrast, every hour of delay in pelvic AE was significantly associated with an increased risk of in-hospital mortality (odds ratio, 1.79; 95% CI, 1.11–2.91; $p = 0.018$).

DISCUSSION

This study, using a large nationwide trauma database, demonstrates that the mortality associated with pelvic fractures remains high in patients receiving pelvic AE despite other resuscitative measures, such as transfusion therapy, meeting current standard of care. Most importantly, we found that every hour of delay in pelvic AE is associated with an increased risk of in-hospital death by 79%. Although our sample size is relatively small, study patients were admitted and managed in various types of trauma centers. Thus, we believe that our study results are applicable to any trauma center in the United States, and may support the current requirement by the ACS-COT that interventional radiologists must be available within 30 minutes to perform an emergency AE.

The adverse effects associated with a delay in pelvic AE were previously described in a few single-center retrospective studies.[8,9,14] Tanizaki et al.[14] reported a small series of pelvic AE in hemodynamically unstable patients. The mean time from hospital admission to pelvic AE was 76 minutes. Although the time-to-AE in their study was shorter compared to our study, in-hospital mortality was 50%, likely because a more severely injured cohort was included. They suggested that a 60-minute delay could negatively impact patients' survival (16% mortality rate within 60 minutes vs 64% after 60 minutes), but no clear explanation was provided as to the use of a 60-minute cutoff. Time-to-AE is often prolonged at night or on weekends, a well-known phenomenon in other catheter-based interventions, including percutaneous coronary intervention for acute coronary syndrome and thrombolysis for acute ischemic stroke.[15,16] Similarly, significant discrepancies in time-to-AE in pelvic fracture were reported at a high-volume Level 1 trauma center.[8] While we were unable to capture the data on the time of hospital admission in the current study, a retrospective study by Schwartz et al. showed that time-to-AE in patients admitted at night and on weekends was significantly longer than in patients admitted during the day on weekdays (193 vs 301 minutes, $p < 0.001$). Admissions at night or on weekends

TABLE 2. Blood Transfusion Requirements and Patient Outcomes

	Hours to Pelvic AE					
	Total	0–1	1–2	2–3	3–4	*p*
Transfusion (units)*						
Within 4 hours						
PRBC, median (IQR)	4 (2–8)	4 (3–8)	6 (3–9)	4 (2–6)	4 (2–7)	0.15
FFP, median (IQR)	2 (0–4)	3 (0–5)	2 (0–4)	2 (0–4)	3 (1–5)	0.56
Platelets, median (IQR)	0 (0–1)	1 (0–1)	0 (0–1)	0 (0–1)	1 (0–1)	0.26
Within 24 hours						
PRBC, median (IQR)	6 (4–10)	7 (3–12)	7 (4–14)	6 (3–9)	7 (4–13)	0.27
FFP, median (IQR)	4 (1–7)	4 (0–7)	4 (0–7)	3 (0–5)	5 (2–9)	0.30
Platelets, median (IQR)	1 (0–2)	1 (0–2)	1 (0–2)	1 (0–2)	1 (0–2)	0.39
Between 4 and 24 hours						
PRBC, median (IQR)	1 (0–4)	1 (0–4)	1 (0–2)	1 (0–4)	2 (0–5)	0.28
FFP, median (IQR)	0 (0–2)	0 (0–2)	0 (0–4)	0 (0–2)	0 (0–4)	0.47
Platelets, median (IQR)	0 (0–1)	0 (0–1)	0 (0–1)	0 (0–1)	0 (0–2)	0.71
Outcome						
24-hour mortality, n (%)	15 (8.3)	0 (0)	4 (11.1)	6 (7.6)	5 (10.6)	0.48
In-hospital mortality, n (%)	38 (21.0)	1 (5.3)	6 (16.7)	20 (25.3)	11 (23.4)	0.23
Hospital LOS, median (IQR)	15 (8–28)	26 (10–45)	16 (9–34)	14 (6–23)	18 (8–31)	0.11
ICU LOS, median (IQR)	7 (4–14)	8 (5–15)	8 (4–15)	7 (3–13)	8 (4–16)	0.81
Ventilator days, median (IQR)	5 (2–11)	4 (2–9)	3 (2–6)	6 (2–11)	6 (3–12)	0.86

*Patients who survived more than 24 hours were included.
FFP, fresh frozen plasma; ICU, intensive care unit; IQR, interquartile range.

were associated with a nearly two-fold increased 30-day mortality rate. Of note, their study included a relatively heterogeneous group of patients, and the results may be biased as more than half of study patients did not undergo pelvic AE and died within 24 hours. Additionally, diagnostic pelvic angiography without therapeutic arterial embolization was performed in 23 of 88 patients. In contrast, the strength of our study using the TQIP database was the ability to identify specific patients who underwent AE, and not angiography only. Another study at a Level 1 trauma center by Tesoriero et al.[9] also showed a prolonged time-to-AE (median, 286 minutes) in pelvic fracture. Although they showed the highest mortality rate in patients who received pelvic AE less than 90 minutes, their study population was, again, not limited to those who required hemorrhagic control solely for pelvic fracture. An optimal time cutoff for pelvic AE is yet to be determined; thus, further studies are still warranted.

Our results suggest that trauma programs need to review resource allocations and protocols for emergency pelvic AE and

TABLE 3. Hierarchical Logistic Regression Analysis for 24-Hour and In-Hospital Mortality

	24-hour Mortality*		In-hospital Mortality**	
Variable	**Odds Ratio (95% CI)**	*p*	**Odds Ratio (95% CI)**	*p*
Patients' characteristics				
Age, increased 10 years	1.27 (0.93–1.71)	0.12	1.24 (0.995–1.55)	0.056
SBP, increased 10 mm Hg			0.87 (0.77–0.99)	0.034
GCS, increased 1 point	0.90 (0.81–0.996)	0.04	0.88 (0.81–0.96)	0.003
ISS, increased 10 points			1.96 (1.34–2.85)	<0.001
Hours to pelvic AE, increased 1 hour	1.39 (0.76–2.55)	0.28	1.79 (1.11–2.91)	0.018
Trauma center level				
Level 1 (ref)				
Level 2			0.18 (0.03–1.24)	0.08
Teaching status				
University hospital (ref)	1		1	
Nonteaching hospital	1.08 (0.30–3.83)	0.91	1.82 (0.59–5.59)	0.30
Community hospital	2.00 (0.37–10.81)	0.42	5.66 (0.49–65.79)	0.17

*Hosmer-Lemeshow goodness-of-fit test: $p = 0.11$; AUROC,0.69 (95% CI, 0.59–0.83).
**Hosmer-Lemeshow goodness-of-fit test: $p = 0.20$; AUROC,0.81 (95% CI, 0.74–0.89).
AUROC, area under a receiver operation curve; GCS, Glasgow Coma Scale; ISS, injury severity score; SBP, systolic blood pressure.

then formulate quality improvement plans to shorten time-to-AE. For example, a large success in reducing door-to-balloon time has been reported in the management of patients with an ST-segment elevation myocardial infarction.[17] A nationwide quality improvement program sponsored by the American College of Cardiology and other organizations involved more than 1,000 hospitals to achieve significant improvement in door-to-balloon times since 2006.[18] A subsequent study using a large database supported the positive impact of shorter door-to balloon time on patients' survival.[19] As each trauma center has unique barriers to and resources for performing pelvic AE without a significant delay, critical evaluations and assessments in each step of patient care, from the prehospital setting to the interventional radiology suite, are crucial to develop a successful program. In the United States, pelvic AE is usually performed by interventional radiologists who often take at-home calls at nights and on weekends. To successfully perform an emergency pelvic AE, not only interventional radiologists but also the entire procedure team, including nursing staff and radiology technicians, need to be mobilized. A single-call activation system using a clear protocol can be used to expedite the mobilization process. Similarly, the interventional radiology suite has to be open and available at all times for emergency cases. If not, alternative options such as hybrid operating rooms or hybrid emergency rooms with fluoroscopic capabilities should be used.[20–22]

Another potential solution to minimize the negative impact of a delay in pelvic AE is to use other temporizing measures for hemorrhage control. Preperitoneal pelvic packing (PPP) has been frequently used for this indication, as it can be quickly performed by trauma surgeons in the operating room. Burlew et al.[3] reported their own experiences of PPP with external fixation incorporated in their protocol as alternatives and/or adjuncts to pelvic AE. A short time to operation was emphasized (median, 44 minutes), and they reported a lower mortality rate compared to other studies, including in the sickest group of pelvic fracture patients. After PPP with external fixation, only 13% of patients required pelvic AE for active arterial bleeding (mean time, 10 hours after presentation). While indications for resuscitative endovascular balloon occlusion of the aorta remain unclear, it is suggested that occlusion of the abdominal aorta just below the renal arteries (Zone III) can be effective in temporizing pelvic fracture hemorrhage.[23] The patient, in theory, can tolerate a longer balloon occlusion time as long as the balloon is inflated in Zone III. In addition, temporary occlusion of the distal abdominal aorta would potentially allow thrombosis of arterial bleeding sources, and subsequent pelvic AE may not always be necessary. Although future prospective studies are warranted, subgroup analysis of a retrospective study using the Japanese Trauma Data Bank did not find a significant survival benefit by using resuscitative endovascular balloon occlusion of the aorta in patients with AIS scores 4 and 5 in pelvic and lower extremity region.[24]

There are several limitations to the current study. First, our inclusion criterion for the time-to-AE (within 4 hours) was determined based on data from previous studies as well as clinical observations at our institution. A recent study from a major Level 1 trauma center reported that a median time to pelvic AE in patients with pelvic fracture was 5 hours.[9] We felt that results may be biased by including patients who underwent nonemergency pelvic AE. In addition, with our other inclusion criteria, we attempted to examine our hypothesis in a limited group of patients who did not have any other sources of significant hemorrhage. Thus, this study does not answer questions about the impact of time-to-AE in patients with more complex injury characteristics (e.g., pelvic fracture with associated intraabdominal injuries).[25] Similarly, our sample size might not be large enough to eliminate the risk of a Type II error. Therefore, the results of our hierarchical logistic regression analysis should be interpreted with caution owing to a small number of outcome events (i.e., in-hospital and 24-hour mortality). Second, we were not able to identify patients who received other hemorrhage control procedures for pelvic fracture. Preperitoneal pelvic packing may have been performed in some of our study patients before or after pelvic AE. Unfortunately, no specific *International Classification of Diseases, Ninth Revision* code is assigned to PPP. Additionally, accurate data for prehospital transport time were not available in TQIP and therefore could not be adjusted for in our analysis. Furthermore, because of the retrospective nature of our study, we were unable to specify the time when the interventional radiologists were notified and the team was mobilized. Certainly, more extensive diagnostic workup and therapeutic interventions may have been required in sicker patients before pelvic AE could be performed. However, our results suggest that physiological profiles upon presentation were similar across the four study groups. Finally, owing to the retrospective nature of our study, we were unable to capture the data on causes of death. The hours-to-pelvic AE was significantly associated with in-hospital mortality, but not with 24-hour mortality in our study. Although there was no significant difference in the severity of injuries between our study groups, associated severe injuries, particularly traumatic brain injury, could have affected the incidence of mortality after 24 hours of admission.

CONCLUSIONS

This study showed that a shorter time-to-AE is significantly associated with improved survival among patients with pelvic fractures. Our results suggest that time-to-AE may be a key quality metric in trauma and supports the recent ACS-COT requirements.

AUTHORSHIP

K.M., A.P., M.S., V.C., P.H., A.S., E.B., K.I., and D.D. conceptualized and designed the study. K.M., A.P., M.S., and V.C. collected and analyzed the data. KM, AP, and MS wrote the manuscript. V.C., P.H., A.S., E.B., K.I., and D.D. critically revised the manuscript.

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DISCLOSURE

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DISCUSSION

Dr. Bruce A. Crookes (Charleston, South Carolina): So good afternoon, colleagues. I want to begin by thanking the members of the American Association for the Surgery of Trauma for the privilege of discussing this interesting and well-presented study.

I would also like to thank Dr. Matsushima for providing me with a copy of the manuscript well in advance of the meeting. I was provided with the gift of time, which is a rarity in academic medicine.

I will be brief with my discussion in an attempt to provide Dr. Matsushima with as much time as possible to answer our questions regarding this elegant study.

Dr. Matsushima and colleagues have attempted to ask a question which, I am certain, all of our attendees at this meeting have asked themselves at one time or another: does the time that it takes to mobilize our interventional radiology team make a difference in the bleeding pelvic fracture patient. Or, to put it more succinctly, does door-to-needle time matter?

To answer this question the authors turned to TQIP, and ultimately identified 181 patients that met their inclusion criteria for this study.

They then divided these patients into groups according to their hours to pelvic angioembolization, and looked at their chosen outcome measures.

Based upon their statistical analysis the authors concluded that "time to AE is significantly associated with improved survival among patients with pelvic fractures."

Personally, I love papers that feed into my own personal bias and this one is no exception. Personal bias, however, aside, however, I am left with several nagging questions. I do have the advantage of having reviewed the full manuscript and some of my questions are directed at the manuscript, as well.

Taking into account that this is a large data base study with its inherent limitations I would be thrilled if the authors could address the following questions.

Number 1. Did you conduct an a priori sample size calculation prior to conducting your study? I ask because the total number of included patients is 181. It appears as though larger numbers may have shown significant differences in the portion of your analysis in which centers are differentiated by teaching status.

Number 2. While the authors in their manuscript suggest that there were no significant differences in "age, gender, or preexisting medical conditions between the four groups," the P value for age was 0.049, making a statistically significant value.

In addition, there was a statistically significant difference in GCS scores across the groups. And the authors did not address this in the manuscript. How does these statistically significant differences in your group change your conclusions?

Number 3. Why isn't your outcome variable time to death as opposed to 24-hour mortality versus in-hospital mortality? Was it that you did not have enough deaths to differentiate the time of death?

In my clinical mind, an in-hospital death on Day 21 is less likely to be attributable to a longer door-to-needle time than the death in the first six hours. Is in-hospital mortality a valid outcome variable?

Number 4. If increasing the time to angioembolization by one hour has no effect on 24-hour mortality, why does it have a significant effect on in-hospital mortality?

Number 5. I did notice in the manuscript that an increase in the patient's systolic blood pressure by a single millimeter or mercury provides a statistically significant improvement in in-hospital mortality but had no effect on 24-hour mortality. Can the authors explain this finding?

If I was the prototypical radiologist at home in bed, I would demand that the authors augment the patient's blood pressure by a single point and tell you that it will have the exact same effect of my getting my derriere out of bed in the middle of the night. I would then subsequently roll over, hit the snooze button, and sleep peacefully while my trauma colleagues work their tails off.

Again, I'd like to thank the AAST for the privilege of the podium, and I look forward to your answers to my questions. Thank you very much.

Dr. Babak Sarani (Washington, D.C.): Babak Sarani from George Washington University. Excellent study. Very provocative. Just a couple of quick questions.

One, in follow-up to what Dr. Crookes said, you only included one year of the TQIP data base. And that dropped your number of patients dramatically. If you were going to do the data analysis why not just include all years?

Secondly, how do you know about door-to-needle time? With the ACS orange book requirement that you alluded to, many trauma centers are using surrogates like when the fellow shows up, when the person goes to IR, but it could be easily another hour before the IR tech and the nurse show up to actually implement and start the procedure. It's a work-around the orange book requirement which is wholly arbitrary.

And then, lastly, did you control for any other injuries in your analysis of mortality?

Dr. Daniel Margulies (Los Angeles, California): Dan Margulies, Los Angeles.

Can you explain why it appeared that the transfusion requirements between each of the time intervals was not different?

Presumably, the sooner they get to angio, the less bleeding they will have as the cause of the improved mortality. But if there is no difference in transfusion requirements, I'm puzzled as to why there is a difference in mortality.

Could it be that the time to angiography is a surrogate for some other process happening in the hospital? Time to angiography may reflect other hospital system differences. Thank you.

Dr. Kazuhide Matsushima (Los Angeles, California): Thank you so much, Dr. Crookes, for all valuable comments and questions, as well as the other members.

Let me first try to respond to Dr. Crookes questions. Unfortunately, because this is a retrospective study with very limited amount of data – this is also an answer for Dr. Sarani's question – unfortunately, when we did design this study, only 2013 and 2014 TQIP database were available so we didn't have any other option to extend the study period.

I apologize for the unclearness in my manuscript regarding age and GCS. There is no significant difference in the median age and median GCS. But once you dichotomize by using a cut-off 65 years and GCS 9, there is significant difference. These variables were included in our multivariate analysis.

In terms of outcomes, I agree with Dr. Crookes. If the patient died weeks/months after the trauma, it's probably not affected by a time to pelvic angiography.

We are still in the process of additional analyses to figure out why there is no difference in the 24 mortality but there is a significant difference in the in-hospital mortality. But I can tell you that there is no significant difference in the rate of associated significant injuries using AIS.

In regards to systolic blood pressure, again, I apologize for the unclearness in my manuscript. I should have described the odds ratio for each ten point increase of systolic blood pressure instead of one point.

But, again, this can be due to a Type II error. We didn't see any significant difference between systolic blood pressure for the 24-hour mortality but we saw significant association for the in-hospital mortality.

For Dr. Guo's question, unfortunately, there is no way we could capture how many of our study patients received a massive transfusion protocol. I can tell how much patient received but I cannot tell how many of them the trauma team activated the protocol, itself.

For the question regarding associated intraabdominal injury requiring exploratory laparotomy. That is a very good point. That's why we excluded all patients who required hemorrhagic control surgery within four hours, to minimize those confounding factors.

In terms of a transfusion requirement, when we designed this study, we expected to see some significant difference in the transfusion requirement, as being pointed out. But, surprisingly enough for us, we didn't see any significant difference in the transfusion requirement. Again, we are still in the process of additional analyses to explore why these results came out.

Again, I would like to thank the AAST for the opportunity of the podium.