American College of Surgeons Committee on Trauma verification level affects trauma center management of pelvic ring injuries and patient mortality

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BACKGROUND: Pelvic ring fractures represent a complex injury that requires specific resources and clinical expertise for optimal trauma patient management. We examined the impact of treatment variability for this type of injury at Level I and II trauma centers on patient outcomes.

METHODS: Trauma quality collaborative data (2011–2017) were analyzed. This includes data from 29 American College of Surgeons Committee on Trauma verified Level I and Level II trauma centers. Inclusion criteria were adult patients (≥16 years), Injury Severity Score of 5 or higher, blunt injury, and evidence of a partially stable or unstable pelvic ring fracture injury coding as classified using Abbreviated Injury Scale version 2005, with 2008 updates. Patients directly admitted, transferred out for definitive care, with penetrating trauma, or with no signs of life were excluded. Propensity score matching was used to create 1:1 matched cohorts of patients treated at Levels I or II trauma centers. Trauma center verification level was the exposure variable used to compare management strategies, resource utilization, and in-hospital mortality in univariate analysis.

RESULTS: We selected 1,220 well-matched patients, from 1,768 total patients, using propensity score methods (610 Level I and 610 Level II cohort). There were no significant baseline characteristic differences noted between the groups. Patients with pelvic ring fractures treated at Level I trauma centers had significantly decreased mortality (7.7% vs. 11.6%, $p = 0.02$). Patients treated at Level II trauma centers were less likely to receive interventional angiography, undergo complicated definitive orthopedic operative treatment, and to be admitted to an intensive care unit.

CONCLUSION: Admission with a partially stable or unstable pelvic ring injury to a Level I trauma center is associated with decreased mortality. Level II trauma centers had significantly less utilization of advanced treatment modalities. This variation in clinical practice highlights potential processes to emphasize in the appropriate treatment of these critically ill patients. (*J Trauma Acute Care Surg.* 2019;86: 1–10.

LEVEL OF EVIDENCE: Economic/Decision, Level II.

KEY WORDS: Trauma outcomes; trauma registry; quality improvement; collaborative quality improvement; complications.

Pelvic ring injuries represent a complex pattern of trauma and are a significant cause of morbidity and mortality in blunt trauma patients.[1–4] Diagnosis and treatment of pelvic ring injuries requires a systems approach for optimal care, consisting of a multidisciplinary clinical team along with timely availability of specific hospital resources.[5–8] American College of Surgeons Committee on Trauma (ACS-COT) verified Level I or Level II trauma centers are considered to be the most appropriate institutions to render this type of multi-specialty treatment.[9] The trauma center verification criteria outlined in the Resources for Optimal Care of the Injured Patient document states that the minimum standards for clinical care delivered to these patients should be identical at Level I or II trauma centers. However, despite these criteria, studies have demonstrated outcome differences between Level I and II trauma centers for complex injuries.[10–12]

Little is known about the potential differences between Level I and II trauma centers regarding the specific treatments delivered and resultant outcomes for patients with significant pelvic ring injuries. While there are studies that have examined processes of care and outcomes in pelvic injury patients, these studies have typically been confined to a single institution or Level I trauma centers and are not generalizable to the larger trauma system population.[13,14] Other studies have used national trauma registry data for pelvic ring injuries, but these studies do not compare differences in treatments and outcomes between Level I and II trauma centers.[15,16] In a recent study of high-grade liver injury we found that treatment at a Level II trauma center was associated with increased in-hospital mortality when compared to Level I trauma centers.[17] Level II trauma centers were less likely to use angiography or admit the patient to an intensive care unit (ICU) in the setting of a high-grade liver injury.

Our objective in this study is to compare outcomes for complex pelvic ring injury patients treated at ACS-COT verified Level I and II trauma centers and identify potential differences in treatment patterns. We used data from a statewide collaborative quality initiative for trauma to assess the care and results

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delivered for pelvic ring injury patients. Our goal is to inform trauma system stakeholders of these results and practices to drive process improvement and optimize future clinical outcomes.

MATERIALS AND METHODS

Data Collection

The Michigan Trauma Quality Improvement Program (MTQIP) is a collaborative quality initiative comprised of 29 ACS-COT verified Level I and II trauma centers in the state of Michigan.[18] Michigan Trauma Quality Improvement Program uses a data definitions dictionary, based upon the National Trauma Data Standard, which is published online and updated annually.[19] Trauma data abstractors from participating hospitals undergo training in MTQIP and National Trauma Data Standard data definitions.[20] Data are transmitted from the trauma registry at participating hospitals to the coordinating center at 2-month intervals. The inclusion criteria applied to form the MTQIP patient cohort are as follows:

-Age ≥ 16 years

-At least one valid trauma International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) code in the range of 800–959.9. Excluding the following isolated injuries, late effects (905–909.9), superficial injuries (910–924.9), and foreign bodies (930–930.9). Or at least one valid trauma International Classification of Diseases, 10th Revision, Clinical Modification (ICD-9-CM) code S00-S99 with 7th character modifiers of A, B, or C only *(injuries to specific body parts—initial encounter),* T07 *(unspecified multiple injuries),* T14 *(injury of unspecified body region), T79.A1-T79.A9 with 7th character modifier of A only (Traumatic Compartment Syndrome—initial encounter).* Excluding the following isolated injuries, S00 *(superficial injuries of the head)*, S10 *(superficial injuries of the neck)*, S20 *(superficial injuries of the thorax)*, S30 *(superficial injuries of the abdomen, pelvis, lower back and external genitals),* S40 *(Superficial injuries of shoulder and upper arm)*, S50 *(Superficial injuries of elbow and forearm)*, S60 *(Superficial injuries of wrist, hand and fingers)*, S70 *(Superficial injuries of hip and thigh)*, S80 *(Superficial injuries of knee and lower leg)*, S90 *(Superficial injuries of ankle, foot and toes),* T20-T28 with 7th character modifier of A only *(burns by specific body parts – initial encounter),* T30-T32 *(burn by TBSA percentages).* Late effect codes, which are represented using the same range of injury diagnosis codes but with the 7th digit modifier code of D through S, are also excluded.

-Primary mechanism of injury classified as either blunt or penetrating:

- Blunt is defined as an injury where the primary E-code is mapped to the following categories: fall, machinery, motor vehicle traffic, pedestrian, cyclist, and struck by against.
- Penetrating is defined as an injury where the primary E-code is mapped to the following categories: cut/pierce, and firearm.

-Calculated Injury Severity Score (ISS) ≥ 5.

-Emergency department (ED) discharge disposition and/or hospital discharge disposition must be known.

All ISS values were derived from registrar abstracted and recorded Abbreviated Injury Scale 2005 codes with 2008 updates (AIS 2005).

Analysis

Data were extracted from the MTQIP database, and the study cohort consists of patients admitted to participating trauma centers between January 1, 2011, and August 31, 2017.

Excluded patients, for the study, are those with no signs of life at initial evaluation (ED systolic blood pressure, 0; pulse, 0; Glasgow Coma Scale [GCS] score, 3), patients directly admitted from another hospital, transfers out to another acute care hospital, or patients missing critical data.[21] We selected patients with partially stable and unstable pelvic ring injuries using the following AIS 2005 codes (856161.3, 856162.4, 856163.4, 856164.5, 856171.4, 856172.4, 856173.5, 856174.5). These AIS 2005 pelvic injury codes are similar to the Tile classification system used by orthopedic surgeons.[22] The concept of stability is based on the integrity of the posterior osseoligamentous structures and is defined as stable, partially stable or unstable.[23] Both partially stable and unstable pelvic injuries were combined into one group for the purposes of outcome analysis. We did not include stable fracture patterns as these injuries are almost always treated nonoperatively. Also, we did not use ICD-9 or ICD-10 codes to identify pelvic ring injuries as they do not correspond well to orthopedic classification systems that define treatment.

We identified pelvic angiography procedures from hemorrhage control process measures data and/or ICD procedure codes. Hemorrhage control process measures data were collected on all patients who received any transfusion of red blood cells within the first 4 hours after trauma center arrival. Intervention timing and type data is collected on hemorrhage control procedures performed in the first 24 hours for angiography (none, angiogram only, or angiogram with embolization) and open operations. Within the ICD procedure code data, we selected pelvic angiographic procedures as defined by ICD-9 procedural codes (38.86, 88.4, 88.40, 88.47, 88.49, 39.79) or ICD-10 procedural codes (B40C0ZZ, B40C1ZZ, B40CYZZ, B41C010, B41C110, B41CY10, B41C0ZZ, B41C1ZZ, B41CYZZ, B41CZZZ, 04LC3CZ, 04LC3DZ, 04LC3ZZ, 04LC4DZ, 04LC4ZZ, 04LD3CZ, 04LD3DZ, 04LD3ZZ, 04LD4DZ, 04LD4ZZ, 04LE3CZ, 04LE3DZ, 04LE3ZZ, 04LE4DZ, 04LE4ZZ, 04LF3CZ, 04LF3DZ, 04LF3ZZ, 04LF4DZ, 04LF4ZZ, 04LH3CZ, 04LH3DZ, 04LH3ZZ, 04LH4DZ, 04LH4ZZ, 04LJ3CZ, 04LJ3DZ, 04LJ3ZZ, 04LJ4DZ, 04LJ4ZZ, 04VC3DZ, 04VC3ZZ, 04VC4DZ, 04VD3DZ, 04VD3ZZ, 04VD4DZ, 04VE3DZ, 04VE3ZZ, 04VE4DZ, 04VF3DZ, 04VF3ZZ, 04VF4DZ, 04VH3DZ, 04VH3ZZ, 04VH4DZ, 04VJ3DZ, 04VJ3ZZ, 04VJ4DZ). Operative procedures relating to an exploratory laparotomy or pelvic packing were defined by ICD-9 procedural codes (54.1, 54.11, 54.19) or ICD-10 procedural codes (0W3J0ZZ, 0DJW0ZZ). Orthopedic surgery procedures were defined as one of two groups: 1) Placement of an external fixator (Ex-Fix) or 2) open reduction internal fixation (ORIF) and/or closed reduction percutaneous pinning (CRPP). Ex-Fix was defined by ICD-9 procedural codes (78.1, 78.19, 84.71) or ICD-10 procedural codes (0QH205Z, 0QH235Z, 0QH245Z, 0QH305Z, 0QH335Z, 0QH345Z, 0QS205Z, 0QS235Z, 0QS245Z,

0QS305Z, 0QS335Z, 0QS345Z). Open reduction internal fixation was defined by ICD-9 procedural codes (79.10, 79.19, 79.30, 79.39, 78.50, 78.59) or ICD-10 procedural codes (0QH204Z, 0QH234Z, 0QH244Z, 0QH304Z, 0QH334Z, 0QH344Z, 0QS204Z, 0QS234Z, 0QS244Z, 0QS304Z, 0QS334Z, 0QS344Z, 0QH104Z, 0QH134Z, 0QS104Z, 0QS134Z, 0SS704Z, 0SS734Z, 0SS7X4Z, 0SS804Z, 0SS834Z, 0SS8X4Z, 0SH704Z, 0SH734Z, 0SH744Z, 0SH804Z, 0SH834Z, 0SH844Z).

We stratified our study population into two groups based on the ACS-COT verified level of trauma center (Level I vs. Level II). Propensity scores were then generated to allow for matching in a 1:1 ratio based on demographics (age, gender, race, insurance status), injury severity parameters (GCS motor, ISS, > 4 units packed red blood cells (PRBC) in first 4 hours, AIS head and neck, AIS chest, AIS abdomen, AIS extremity, intubation status, need for prehospital cardiopulmonary resuscitation), admission vital sign parameters (blood pressure, pulse), preinjury anticoagulant use and transfer in status using a logistic regression model. Based on the calculated propensity scores, two evenly matched groups were formed regarding admission to a Level I versus Level II trauma center with the common caliper set at 0.003. Caliper is the maximum distance or difference that is acceptable for a propensity score match. This matching approach technique of using propensity scores, as opposed to stratification or regression adjustment, was chosen because it is the closest approximation to a randomized clinical trial and provides the greatest balance between cases in two groups of treatment.[24] This data set is referred to as the "propensity-matched cohort." The matched cohorts were then evaluated for balance between both levels of trauma centers.

Differences in outcomes were explored using univariate analysis. Outcomes of interest included hospital mortality, early death (<48 hours), initial management strategy (nonoperative, angiography, or operative), orthopedic surgical treatment (nonoperative, Ex-Fix, or ORIF), ICU length of stay (LOS), hospital LOS, ICU admission status, any complication, and failure to rescue. Complications were defined based on the MTQIP data dictionary.[19] Major complications were defined as systemic sepsis, pulmonary embolism, pneumonia, acute renal failure, acute respiratory distress syndrome (ARDS), or the presence of a cardiovascular complication (cardiac arrest, myocardial infarction, or cerebrovascular accident). Failure to rescue was defined as a death following the occurrence of a complication.[25]

Statistical Methods

Statistical analyses were performed using Stata MP, version 14 (StataCorp, College Station, TX). Statistical significance was defined as a p value less than 0.05. Data are expressed as the mean ± standard deviation for continuous descriptive variables and proportions for categorical variables. We performed Student's t test to explore differences in the two groups for continuous variables. We used χ^2 tests to identify differences in outcomes for categorical variables. Approval for this study was obtained from the Michigan Medicine Institutional Review Board.

RESULTS

From a total database population of 141,148 patients, we identified 1,768 specific patients with partially stable or unstable pelvic ring injuries that met inclusion criteria for this study (Table 1). There were significant baseline differences in patient characteristics between Level I and II trauma centers. Propensity score matching was used to adjust for these differences. After matching, 1,220 patients were included in the cohort used for the final analysis (610 patients treated at Level I trauma centers and 610 treated at Level II centers). There were no differences identified in patient characteristics after propensity score matching (Table 1).

There was a significantly higher rate of in-hospital mortality at Level II trauma centers (7.7% vs. 11.6%, $p = 0.02$) (Table 2). Additionally, patients treated in Level II centers experienced higher mortality within the first 48 hours following admission (3.4 vs. 6.2%, $p = 0.04$). Examining complications, Level I trauma centers had a higher rate of ARDS ($p = 0.009$) while Level II centers had a higher rate of unplanned intubation ($p = 0.03$). There were no other significant differences in specific individual complications, major complications, or failure to rescue rates between the level of trauma center groups. Lengths of stay, both in the hospital and ICU, were not different between the groups. Level I centers also treated a higher average yearly volume of all pelvic ring injuries than Level II centers (67 vs. 27, $p < 0.001$). While not significantly different, almost twice as many patients died in the ED at Level II centers than Level I (9 vs. 17) (Table 3).

There were significant differences in processes of care between the two levels of trauma center (Table 4). Patients treated at Level I centers were more likely to be admitted to the ICU while patients at Level II centers were frequently admitted to stepdown type patient care units ($p < 0.001$). Of the 289 patients that experienced a complication, patients treated in an ICU during their admission (at both Level I and Level II trauma centers) were more likely to be rescued and to not die than those not treated in an ICU at all (13% vs. 40%, $p < 0.001$).

During initial treatment, patients admitted to a Level I trauma center were more likely to undergo pelvic angiography, either alone or in conjunction with an exploratory laparotomy (10.8% vs. 6.1%), while those cared for at Level II trauma centers had a higher rate of exploratory laparotomies ($p = 0.001$). Twice as many patients at Level I centers underwent therapeutic angioembolization (n = 38 vs. n = 18).

Patients treated at Level I trauma centers were more likely to undergo orthopedic operative intervention (50% vs. 45%). In addition, patients treated at Level I trauma centers underwent complex orthopedic surgical procedures such as ORIF or CRPP at an increased rate. Level II trauma centers were more likely to use external fixation as part of their overall construct, either alone or in conjunction with other orthopedic surgical procedures ($p = 0.003$).

DISCUSSION

In this study, treatment of complex pelvic ring injuries at Level I trauma centers was associated with reduced mortality, more aggressive utilization of angiography and ICU care, and higher rates of more complicated orthopedic operations. Patients treated at Level II trauma centers tended to die earlier, were less likely to receive angiographic intervention, and admission to an ICU. At Level II trauma centers, these pelvic ring injuries were

TABLE 1. Patient Characteristics

	Entire Sample			Propensity-Matched Cohort		
	Level I	Level II		Level I	Level II	
Characteristics	**n = 1105**	**n = 663**	***p* value**	**n = 610**	**n = 610**	***p* value**
Age, n (%)			0.6			0.98
16–25	213 (19)	94 (14)		95 (15)	88 (14)	
26–45	280 (25)	177 (27)		161 (26)	163 (27)	
46–65	364 (33)	219 (33)		199 (33)	206 (34)	
66–75	89 (8)	58 (9)		53 (9)	54 (9)	
>75	159 (15)	115 (17)		102 (17)	99 (16)	
Male sex, n (%)	607 (55)	364 (55)	0.99	333 (55)	341 (56)	0.6
Race, n (%)			0.003			0.6
White	879 (80)	514 (78)		487 (80)	473 (78)	
Black	164 (15)	129 (19)		104 (17)	117 (19)	
Other	62 (5)	20 (3)		19 (3)	20 (3)	
Private insurance, n (%)	722 (65)	423 (64)	0.5	387 (63)	390 (64)	0.9
Transfer in, n (%)	372 (34)	122 (18)	<0.001	116 (19)	120 (20)	0.8
ED GCS motor score, n (%)			0.2			0.4
6	858 (78)	534 (81)		507 (83)	486 (80)	
5–2	88 (8)	55 (8)		48 (8)	53 (9)	
1	122 (11)	60 (9)		45 (7)	57 (9)	
Missing	37 (3)	14 (2)		10 (2)	14 (2)	
ISS, n (%)			0.001			0.5
5–15	266 (24)	207 (31)		182 (30)	172 (28)	
16–24	352 (32)	218 (33)		204 (34)	207 (34)	
25–35	252 (23)	137 (21)		143 (23)	133 (22)	
>35	235 (21)	101 (15)		81 (13)	98 (16)	
4+ Units PRBC in 4 h, n (%)	362 (33)	228 (34)	0.5	204 (33)	205 (34)	0.95
AIS head/neck score >2, n (%)	212 (19)	98 (15)	0.02	97 (16)	96 (16)	0.9
AIS chest score >2, n (%)	423 (38)	223 (34)	0.05	207 (34)	215 (35)	0.6
AIS abdomen score >2, n (%)	245 (22)	124 (19)	0.08	118 (19)	119 (20)	0.9
AIS extremity score >2, n (%)	1105 (100)	663 (100)	0.99	610 (100)	610 (100)	0.99
Intubated, n (%)	747 (68)	460 (69)	0.4	404 (66)	425 (70)	0.2
Prehospital CPR, n (%)	13 (1)	10 (2)	0.6	6 (1)	9 (1)	0.4
ED systolic blood pressure, n (%)			0.02			0.7
>90 mm Hg	972 (88)	565 (85)		535 (88)	527 (87)	
61–90 mm Hg	95 (9)	78 (12)		62 (10)	66 (11)	
≤60 mm Hg	11 (1)	12 (2)		5 (1)	9 (1)	
Missing	27 (2)	8 (1)		8 (1)	8 (1)	
ED pulse, n (%)			0.6			0.97
51–120 bpm	925 (84)	568 (85)		526 (86)	522 (86)	
>120 bpm	156 (14)	85 (13)		76 (12)	78 (12)	
0–50 bpm	7 (1)	4 (1)		3 (1)	4 (1)	
Missing	17 (1)	6 (1)		5 (1)	6 (1)	
Anticoagulant use, n (%)	146 (13)	100 (15)	0.3	85 (14)	87 (14)	0.9

more likely to be treated either nonoperatively or by external fixation instead of with more complex open reduction and internal fixation procedures.

Hemorrhage control is considered a key factor in the survival of patients with complex pelvic ring injuries.[26] Prior investigations have focused on the timing of treatment for these injuries. Initial treatment in a patient hemorrhaging from pelvic ring fractures can consist of one or more of the following interventions: angiography, preperitoneal packing, and temporary pelvic fracture stabilization (binder, c-clamp, or external fixator).[27] The most effective treatment regimen is a point of controversy and often depends upon the availability, timing, and experience with these different treatment modalities.[28] However, reduced times to angiography have been associated with decreased overall mortality.[29,30] While our study did not find a difference in the average time to angiography, we did find evidence that Level I trauma centers used interventional radiology procedures more often in their treatment of these patients.

TABLE 2. Primary and Secondary Outcomes

Outcomes	Level I n = 610	Level II n = 610	*p* value
Mortality, n (%)	47 (7.7)	71 (11.6)	0.02
Early mortality (<48 h), n (%)	21 (3.4)	38 (6.2)	0.04
Complications			
ARDS, n (%)	19 (3)	6 (1)	0.009
Pneumonia, n (%)	51 (8)	52 (9)	0.9
C. difficile colitis, n (%)	7 (1)	11 (2)	0.3
Incisional SSI, n (%)	16 (3)	12 (2)	0.4
Organ space SSI, n (%)	5 (1)	2 (1)	0.3
Wound disruption, n (%)	1 (1)	1 (1)	0.99
Pulmonary embolism	8 (1)	8 (1)	0.99
Acute renal failure, n (%)	10 (2)	9 (1)	0.8
UTI, n (%)	33 (5)	38 (6)	0.5
CVA, n (%)	1 (1)	5 (1)	0.1
Cardiac arrest, n (%)	20 (3)	26 (4)	0.4
MI, n (%)	1 (1)	6 (1)	0.06
Lower DVT, n (%)	20 (3)	27 (4)	0.3
Upper DVT, n (%)	2 (1)	0 (0)	0.2
Sepsis, n (%)	8 (1)	11 (2)	0.5
Compartment syndrome (extremity), n (%)	1 (1)	1 (1)	0.99
CLABSI, n (%)	1 (1)	3 (1)	0.3
Unplanned return to OR, n (%)	10 (2)	15 (2)	0.3
Unplanned return to ICU, n (%)	15 (2)	14 (2)	0.9
Unplanned intubation, n (%)	10 (2)	22 (4)	0.03
Any complication, n (%)	137 (22)	152 (25)	0.3
Major complication, n (%)	88 (14)	95 (16)	0.6
Failure to rescue, n (%)	23 (17)	29 (19)	0.6

C. diff, *Clostridium difficile* colitis; SSI, surgical site infection; UTI, urinary tract infection; CVA, cerebrovascular accident; MI, myocardial infarction; DVT, deep venous thrombosis; CLABSI, central line associated blood stream infection.

Our finding of a lower early mortality rate in Level I trauma centers is consistent with other investigations demonstrating effective hemorrhage control and interventional radiology intervention as being critical toward decreasing morbidity and mortality in complex pelvic fracture patients.[31–34]

The ability to appropriately monitor and treat seriously injured patients at risk for complications after admission is also critical. We found that Level I trauma centers admitted more of their patients to ICUs, whereas stepdown units were favored by Level II centers. While the overall failure to rescue rate was not different between centers, patients treated in an ICU were more likely to be rescued than those treated elsewhere in the hospital. This is similar to Haas' findings that trauma centers with lower mortality were better at rescuing their patients.[35] Our results suggest that the severely injured patients are optimally managed and observed in the ICU. Intensive care units have a more favorable nurse to patient ratio and are equipped to rapidly detect and respond to acute changes in a patient's condition.

TABLE 3. ED Disposition of Patients that Died

ED Disposition	Level I n = 47	Level II n = 71
Floor, n (%)	1 (2)	3 (4)
Stepdown, n (%)	0 (0)	1 (2)
Died in ED, n (%)	9 (19)	17 (23)
Operating room, n (%)	18 (38)	25 (35)
ICU, n (%)	19 (41)	24 (34)
Missing, n (%)	0 (0)	1 (2)

TABLE 4. Process Measures

Process Measures	Level I n = 610	Level II n = 610	*p* value
Initial treatment			0.001
Nonoperative, n (%)	511 (84)	512 (84)	
Angiography, n (%)	51 (8)	30 (5)	
Exploratory laparotomy, n (%)	33 (6)	61 (10)	
Angiography + exploratory laparotomy, n (%)	15 (2)	7 (1)	
Interventional radiography			0.008
No angiography, n (%)	544 (89)	573 (94)	
Angiography, n (%)	28 (5)	19 (3)	
Angiography + therapeutic embolization, n (%)	38 (6)	18 (3)	
Orthopedic treatment			0.003
Nonoperative, n (%)	302 (50)	332 (55)	
External fixation (Ex-Fix), n (%)	16 (2)	16 (2)	
ORIF, n (%)	250 (41)	195 (32)	
Ex-Fix + ORIF, n (%)	42 (7)	67 (11)	
ED Disposition			<0.001
Floor, n (%)	209 (34)	159 (26)	
ICU, n (%)	269 (44)	218 (36)	
Stepdown Unit, n (%)	35 (6)	93 (15)	
Operating Room, n (%)	88 (15)	123 (20)	
Died, n (%)	9 (1)	17 (3)	
ICU LOS, mean ± SD	8.1 ± 10.2	7.1 ± 8.5	0.1
Hospital LOS, mean ± SD	11.4 ± 11.1	10.9 ± 18.4	0.5

While there is known variability in the orthopedic treatment of pelvic ring injuries, our findings in this study warrant further investigation to determine why this occurs.[8,23,36] We found that Level I trauma centers were more likely to perform more complicated open procedures like ORIF while Level II centers incorporated external fixation more often into their overall construct. For example, a significant lateral compression type pattern (partially stable) could be treated with posterior fixation supported by anterior ring stabilization. This anterior fixation could be in the form of an external fixator or with an InFix device (an anterior subcutaneous bar construct).[37] Alternatively, this injury pattern could be treated solely by internal fixation in the form of a LC2 type percutaneous screw. The InFix or LC2 type percutaneous screw treatments require significantly more surgical expertise and system support to implement than application of an external fixator. Given these differences in operative approach, additional examination of the orthopedic surgeon training level and experience with operating around the pelvis at Level I and II trauma centers is merited.

Patients at Level II trauma centers were more likely to be treated either nonoperatively or with an external fixator as part of their overall care. However, we were limited in that the granularity within the data available to us did not allow for discrimination between operative versus nonoperative partially stable injuries. While use of an external fixator is considered a key component of treatment in a damage control scenario, it is unlikely that Level II centers treated more patients in extremis as the two groups were well matched for injury, bleeding, and hemodynamics in our study.[27] Decisions on which treatment to use for a pelvic ring injury requires a thorough understanding of complex injury patterns and ability to tailor the most appropriate and safe intervention in the surgeons armamentarium to the individual patient.

We were unable to fully investigate preperitoneal pelvic packing along with external fixation usage in this study. The principal reason for this limitation was that the preponderance of the data was collected using ICD9 procedure codes. Preperitoneal packing is only identifiable with ICD10 coding used at the very end of this study. Future studies will need access to better fracture pattern data and all of the different interventions used must be recognizable in the procedure coding.

Finding outcome differences along with variability in pelvic injury treatment patterns in verified Level I and 2 trauma centers is concerning as a potential quality gap.[9] Interventional radiology procedures require a well-trained, highly specialized staff to mobilize in a timely fashion and may not have the same availability as a trauma surgeon and an operating room in all trauma centers. In addition, there are likely discrepancies in the ability of interventional radiology suites at different levels of trauma center to handle hemodynamically unstable patients who may also require operative intervention. Preperitoneal pelvic packing is often suggested as a timely and viable option in these patients resulting in similar or better outcomes when compared to angiography.[5,28,38–41] However, effective utilization of the preperitoneal packing technique requires familiarity with the procedure and repetitive volume to optimize results. In our study, Level I trauma centers cared for higher volumes of all pelvic ring injuries ($p < 0.001$). The volume of exposure to complex injuries can become diminished within inclusive trauma systems where there may be many Level II trauma centers. Trauma center volume has been correlated with better outcomes.[42–44]

According to the Resources for Optimal Care of the Injured Patient document, the orthopedic surgical care at Level I trauma centers must be "overseen" by a surgeon who has completed an approved orthopedic trauma fellowship. However, at Level II traumas centers the recommended criteria is that orthopedic surgical care should be "overseen" by a surgeon who is "highly experienced." The exact staffing breakdown of orthopedic surgeons (traumatologists and nontraumatologists) who take call and treat patients likely varies between trauma centers. While these differences may appear slight, they could potentially explain some of the results in our study regarding treatment patterns.

Strengths of this study are that it uses a large sample size across multiple institutions. A large sample size provides statistical power that allows subtle differences present in processes and outcomes, which can be masked at the hospital level, to become apparent when aggregated across levels of trauma center. The utilization of a comparative effectiveness study method in a allowed us to lessen the risk of a type 2 error by examining a large population in a pragmatic fashion. Our findings can be used to guide further inquiry into process and structure differences that need to be modified and monitored to decrease preventable deaths in trauma patients. We have identified differences in outcomes and treatment patterns between Levels I and II trauma centers for two complex injury patterns (Liver and Pelvis).[17] We advocate for considerate and judicious addition of data elements to the trauma registry to assist in elucidating why these differences are occurring.

This was not a prospective randomized study and there are several limitations. We used propensity scoring to match patients into cohorts while minimizing confounding variables. However, there could be unmeasured differences in unmeasured confounders that affected the results of our study. The classification of pelvic ring injuries in the trauma registry is a concern. Significant disagreement between trauma registrar and orthopedic traumatologist coding of these injury patterns has been demonstrated.[45] To mitigate this effect, we combined the partially stable and unstable pelvic ring injuries into one group. This allowed us to analyze these injury patterns together regardless of fracture coding so that we could examine multidisciplinary approaches used at different levels of trauma center. However, because we used the AIS 2005 classification system and not an orthopedic injury classification system, we were unable to distinguish between operative and nonoperative partially stable injury patterns.[14] Within existing trauma registry data, the AIS coding system is most closely aligned to current orthopedic injury classification systems and future studies should aim to improve capture of operative and nonoperative injury patterns. We were unable to assess the appropriateness of the timing of orthopedic fixation as we could not discern whether an intervention was performed in an emergent/urgent damage control typesetting or whether it was for definitive fixation. Our inability identify preperitoneal pelvic packing as procedure is troubling, however it should be noted that our groups were well balanced for presence of intra-abdominal injuries. Lastly, our study did not have enough recent volume to examine the impact of resuscitative endovascular balloon occlusion of the aorta.[46] The resuscitative endovascular balloon occlusion of the aorta technique is relatively new and may enhance the operative and interventional radiology treatment of these patients in hemodynamically unstable situations.

CONCLUSION

In conclusion, admission of patients with partially stable and unstable pelvic ring injuries to Level I trauma centers is associated with decreased in-hospital and early mortality. Level II trauma centers were less likely to use angiography, admit patients to the ICU or perform more complex open orthopedic procedures. Level II trauma centers were more likely to treat partially stable and unstable pelvic ring injuries nonoperatively or with external fixation. An examination of why the process differences found in this study are occurring in different levels of trauma centers is necessary to optimize trauma system care.

AUTHORSHIP

B.W.O. participated in the study design, data collection, data analysis, data interpretation, writing, and critical revision. C.J.T. participated in the study design, data collection, data analysis, data interpretation, writing, and critical revision. J.A.G. participated in the data interpretation, writing, critical revision. L.N. participated in the data interpretation, writing, and critical revision. M.R.H. participated in the study design, data collection, data analysis, data interpretation, writing, and critical revision.

DISCLOSURE

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DISCUSSION

Todd W. Costantini, MD (San Diego, California): Thank you, and good morning Dr. Rotondo, Dr. Reilly. I would first like to thank the AAST for the privilege of discussing this paper today, and congratulations to Dr. Oliphant on completing this very interesting paper and for an excellent presentation this morning.

As you all know, pelvic fracture management can be challenging and requires both a multidisciplinary team and prompt resource availability in order to provide optimal care.

Despite improvements in resuscitation and the development of novel hemorrhage control interventions such as pre-peritoneal pelvic packing and REBOA, mortality remains high for patients with severe pelvic fractures.

Previous studies in severe pelvic fracture management have demonstrated that treatment strategies vary significantly between Level 1 trauma centers, with several hemorrhage control interventions and pelvic stabilization techniques utilized alone, or in combination.

Here, Dr. Oliphant and colleagues evaluate the impact on treatment variability between Level 1 and Level 2 centers on patient outcome.

The authors performed a retrospective review of statewide collaborative data from 29 ACS-verified Level 1 and Level 2 Trauma Centers in Michigan in order to assess the effects of Verification Level on outcomes for patients with pelvic fracture.

Their main findings are that there was increased mortality in patients treated at Level 2 trauma centers. They also found that patients treated at Level 1 trauma centers were more likely to undergo angiography and more likely to receive more complex orthopedic repair.

They concluded that Level 2 trauma centers utilize less advanced treatment modalities that may account for this increased mortality compared to Level 1 trauma centers.

The author should be congratulated on utilizing statewide collaborative data to assess the effect of Verification Level on outcomes for patients with pelvic fracture. These collaborative studies are important as they can identify areas for performance improvement within a trauma system.

There are some limitations to this analysis, however, based on the data that was available for this retrospective review. I have a few questions.

First, by including patients with both partially stable and unstable fractures, the authors are left to analyze a heterogeneous group of patients with pelvic fracture.

I am concerned that the patients included have a wide spectrum of pelvic injury severity. Approximately 85 percent of the patients in this study presented with normal vital signs. In this group, you would expect mortality to be very low – somewhere between 2 and 4 percent.

This is compared to only a small fraction of patients that presented with abnormal vital signs or signs of shock. You might expect a mortality of up to 30 percent for these patients.

Did the authors consider a sub-group analysis based on admission vital signs or evidence of shock on admission? This would make findings related to hemorrhage control and mortality more meaningful by studying only those patients at the highest risk.

The authors utilized ICD-9 and ICD-10 codes to collect hemorrhage control procedures. Unfortunately, there is no ICD-9 code for pelvic packing.

They appropriately attempt to capture these patients using exploratory laparotomy as a surrogate. How are the authors able to determine whether patients are being treated with pelvic packing for isolated pelvic hemorrhage versus laparotomy for treatment of a severe intra-abdominal injury?

Finally, not presented here but in the manuscript, there was a difference in early death in the emergency department between Level 1 and Level 2 trauma centers.

This may relate to differences in the initial resuscitation and evaluation rather than their pelvic fracture management and pelvic fracture stabilization techniques. Does your data provide any insights into this difference?

Once again, congratulations to Dr. Oliphant and his co-authors on this study, and for their continued work with the MTQIP project. Thank you.

Donald H. Jenkins, MD (San Antonio, Texas): I have one question for you. Did you use the risk-adjusted function within the TQIP to look and observed versus expected mortality, because if all of those that died in the Level 2s were expected to die, it's hard to come to a good conclusion here that there's a difference.

Avery V. Nathens, MD, MPH, MBA (Toronto, Canada): This was an excellent presentation. I have two questions, one of which pertains to laparotomies. Did you adjust for the presence of intra-abdominal injuries, because it isn't possible to determine that these are laparotomies are solely for pre-peritoneal packing?

And my second question: If you were to rewrite the Resources for Optimal Care of the Injured Patient – and had an opportunity to create new standards that would elevate the quality of care of these patients across Level 1 and 2 centers, what new standards would you create? Thank you.

David P. Blake, MD, MPH (Hartford, Connecticut): So, my question is regarding the systems in the decision-making.

Number one, who was the primary decision-maker in terms of management and whether or not this patient is truly a candidate to remain at the Level 2 hospital, with maybe somewhat limited high-tech resources.

Secondly, do we have any kind of idea what the skill level or the experience level of the angiography suite might be that may be contributing to some of these decision changes? Thank you.

Kevin M. Dwyer, MD (Stamford, Connecticut): We have a Level 2, and I would like to think that we run it fairly well and our mortality rate for our pelvic fractures – the few that we get – is decent.

What we do, though, is we stabilize the patient, make sure we take care of all their other injuries, make sure they are completely stable, and then transfer the patient to Level 1 for orthopedic traumatologist, which we do not have at Stamford Hospital, but we have this relationship with them.

So my question is: How is that patient handled in the database? Does that look like non-operative in our hospital and an operation in their hospital? How is that patient handled?

Elkbuli Adel, MD : It is a pleasure to discuss this paper on the association of Trauma Center Verification level and management of pelvic injuries. The authors have conducted a well-conceived and thoughtful study and are to be congratulated on explicating the somewhat debatable question: do trauma patients have better outcomes at level I and II trauma centers.

My questions are:

1. Of the 29 trauma centers enrolled in this review can you detail how many were Level I and how many were Level II? Also how many were both ACS vs State verified or both?

2. What was the average patient volume for the Level I and Level II centers? I would like to know if they were comparable, so we know that they evaluating data pooled from similar high volume/high performance trauma centers.

3. The authors mention that they extracted data from NTDB 2011-2017, it is my understanding that data from NTDB 2017 is still not publically available. Did they use another substitute resource for the 2017 data i.e. State of Michigan TC registries?

4. Would it have been more clinically relevant to look at Observed/Expected (O/E) mortality rates rather than crude mortality rates? Given that the ACS-COT verification level affects trauma center management of pelvis ring injuries and patient mortality

Clay Cothren Burlew, MD (Denver, Colorado): Very nicely presented. I have 3 questions. First, was there a pelvic fracture management protocol at each of the individual institutions.

Secondly, how did you control for whether a patient had multiple pelvic operations – in other words, if they underwent external fixation first, and then underwent definitive internal fixation at a later date.

Finally, I would echo Todd's concern about using exploratory laparotomy as a surrogate for pelvic packing. Nicely done.

Bryant Oliphant, MD, MBA, MSC (Ann Arbor, Michigan): Thank you very much for these great questions. These are all things that we have considered and looked at.

First, hemorrhage control is important. We did not specifically create a subgroup of patients in shock for analysis. I know a lot of work from people here have demonstrated that and looked at that in previous studies.

However, we used the propensity score method, such that the patients were matched based on certain parameters – shock-type parameters – such as ED blood pressure, pulse rate, and also if they were transfused more than 4 units of packed red blood cells during the first 4 hours of their admission. And so the differences in outcomes reflect more of the management factors, and not patient factors, so no, we did not do a sub-group analysis.

In terms of ICD-9, I think this was echoed before in the reviews of our paper as well as today. Yes, there is no specific ICD-9 procedure code for pelvic packing, and thus it was a proxy or surrogate to use exploratory laparotomy. However, the patients were grouped together well and there were no differences in the cohorts in regards to intra-abdominal injuries between them. We also only looked at exploratory laparotomy within the first 24 hours to help avoid capturing operations that might be unrelated.

In terms of ED death, or what might go on in the emergency department, that's a very good question. While there were more deaths in emergency departments in Level 2 centers, this difference was not significant. We don't know the reasons for this. We're having a meeting next month with orthopedic surgeons of our state in this collaborative and hopefully, we can dive, deeper into some of these reasons. Some of this could be differences in resuscitation protocols, or the use of adjunct measures, such as pelvic binders or sheets, etc.

We did not use the risk-adjusted function within ACS TQIP to look at observed versus expected mortality.

In terms of the laparotomy, the groups were well-balanced for other intra-abdominal injuries based on AIS coding. Using exploratory-laparotomy as a surrogate for pelvic packing is a limitation, however we felt that if these groups were balanced in terms of these injuries that this would lessen this issue. If I was to rewrite the orange book – I think about that a lot actually throughout the day and on multiple days. I think – probably not to get off on a rant but – the use of the words "should" and "must" is interesting.

From an orthopedic standpoint, I would love to take a deeper dive in terms of what actually happens at these trauma centers. I have had the opportunity to work in multiple institutions and have seen a lot of different staffing models that will adhere to the protocols in the orange book and not violate them, but at the same time create huge variability in the clinical actual coverage. I think that's something that we should take a look at further if we really want to hone in on why we're having these differences.

In terms of who is the primary decision-maker, I think that's usually the trauma surgeon or the general surgeon running the code or the resuscitation who is in charge of the overall management and hopefully in discussion with the orthopaedic surgeons at that hospital.

We did not parse out patients that were transferred out and essentially captured information about those that each center chose to keep and treat. Interestingly in Michigan we have no-fault auto insurance, and so we are not sure about any possible latent incentives that might exist to keep patients at their institutions.

We don't have any information regarding the specific protocols of each institution in regards to how they handle pelvic ring injuries. In terms of the second question, before I close, thank you for bringing up external fixation versus operative fixation. It was an examination of the overall use of external fixation in the patient's construct. I think we need to be careful with evaluating the use external fixation from databases. It's not always in a damage-control setting; sometimes it's in the definitive management of these injuries.

Thank you very much for allowing us to present. It's been a great conference, and thank you very much.

In the state of Michigan at the time of this study, there were 8 Level 1 centers and 21 Level 2 centers. The average volume of all pelvic ring injuries treated at Level 1 centers was 67 per year and 27 per year at Level 2 centers. We used data from the MTQIP registry. We did not consider using observed versus expected mortality for this study but this is something to consider for future projects.