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Time to definitive fixation of pelvic and acetabular fractures

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BACKGROUND:	The timing of definitive surgical stabilization is a controversial topic of pelvic and acetabular fracture (PAF) management. Historically, staged care with delayed definitive fixation was recommended; however, more recently, some centers have shown early definitive fixation to be feasible in most patients. We hypothesized that time to definitive fixation of PAF decreased without adverse outcomes.
METHODS:	A level 1 trauma center's prospective pelvic fracture database was retrospectively analyzed. A total of 341 of the 1,270 consecutive PAF patients had surgery between January 2009 and December 2018. Demographics, polytrauma status, hemodynamic stability, time to definitive operation, length of intensive care unit stay, hospital length of stay, mortality were recorded. Data is presented as mean ± SD, percentages. Statistical significance was determined at $p < 0.05$.
RESULTS:	There were 34 ± 8 per year operatively treated PAF patients during the study period. The demographics (age, 44.1 ± 18 years; 74.5% males) and injury severity (Injury Severity Score, 20; interquartile range, 16–29) did not change. Time to definitive fixation on average was 85 ± 113 hours (range, 0.8–1286 hours). Linear regression analysis demonstrated a decrease in time to definitive fixation considering all patients ($\beta = -0.186$, $p = 0.003$). pelvic ring fractures with polytrauma ($\beta = -1.404$, $p = 0.03$). and hemodynamically unstable patients ($\beta = -1.428$, $p = 0.037$). There was no significant change in mortality, length of stay, or intensive care unit length of stay for the overall cohort or any subgroup.
CONCLUSION:	Time to definitive fixation in PAF has decreased during the last decade, with the largest decrease in time to fixation occurring in the hemodynamically unstable and pelvic fracture with polytrauma cohorts. The timely definitive internal fixation is achievable without increased length of stay. (*J Trauma Acute Care Surg.* 2020;89: 730–735. Copyright © 2020 The Author(s). Published by Wolters Kluwer Health, Inc. on behalf of the American Association for the Surgery of Trauma.)
LEVEL OF EVIDENCE:	Therapeutic/care management, level IV.
KEY WORDS:	Pelvic fracture; early fixation; acetabulum fracture; damage control; polytrauma.

Pelvic and acetabular fractures require complex multidisciplinary care in trauma centers lead by fellowship-trained specialist orthopedic trauma surgeons. For the optimal recovery of these frequently polytraumatized patients, the timely anatomical reduction and stabilization of the pelvic ring and acetabulum are crucial. Restoration of the bony pelvic and acetabular anatomy facilitates patient positioning in the intensive care unit (ICU), allows early mobilization, and prevents immobilization-associated complications.[1–3]

The timing of definitive fixation is controversial, and optimal timing for definitive management is frequently debated. Further to this, "early" fixation has been variably defined and rages from 8 hours to 1 week.[2,4–7] Traditionally, without strong evidence, definitive internal fixation was recommended after 72 hours to prevent major intraoperative blood loss[1]; for polytrauma-associated pelvic ring injuries, staged care with initial external fixation followed by delayed definitive fixation was recommended.[8,9] During the last decade, there are convincing data available that timely surgery (well before 72 hours) is feasible, safe, and advantageous in well resuscitated, physiologically uncompromised patients.[2–5,10–13] Our institution was a pioneer in the concept of early definitive internal fixation of these injuries by introducing the concept since 2005.[7]

We hypothesized that pelvic and acetabular fracture (PAF) patients' time to definitive surgery decreased without any adverse outcomes during the last 10 years.

PATIENTS AND METHODS

Ethics approval was obtained from the Hunter New England Human Research Ethics Committee. Informed consent was waived because the data were collected from existing patient records with deidentification protocols followed to ensure confidentiality of personal information.

This study was performed at the John Hunter Hospital (University of Newcastle–affiliated level 1 trauma center), New South Wales, Australia. Our institution manages more than 4,500 trauma admissions per year including approximately 550 patients with an Injury Severity Score (ISS) of greater than 12.[14] The majority of these admissions initially present to the

trauma center; however, many are transferred from one of five regional trauma hospitals within the trauma referral network. Acute pelvic fractures are managed according to the Advanced Trauma Life Support principles and our own local pelvic fracture management guidelines. Depending on the fracture pattern and patient condition, early definitive internal fixation is advocated.[7]

Our trauma service has maintained a prospective database on all patients presenting with PAFs since 2005. This study is a retrospective review of this prospective database over the last 10 years, from January 2009 to December 2018. All patients within this database were reviewed for eligibility in this study. All patients presenting with a PAF within that period and who had documented definitive fixation for that pelvic or acetabular fracture were included.

For all patients who met the inclusion criteria, demographics (age and sex), ISS, body region–specific Abbreviated Injury Scale (AIS), emergency department physiologic parameters and resuscitative interventions (systolic blood pressure, blood gases, transfusion requirements), and anatomical fracture description were extracted from the database.

Further information was retrieved from the local electronic patient record system to determine time to definitive fixation for each patient. This period was defined as the time between documented arrival at the initial hospital (either the referral trauma center or a regional hospital) and the documented operation start time at our trauma center. In cases where patients had multiple operations, definitive fixation was defined as open reduction and internal fixation (ORIF) of the pelvis or acetabulum, or external fixation that was not subsequently followed by an ORIF. In cases where the patient received external fixation followed by an ORIF, definitive fixation was defined as the concluding ORIF. Outcomes of interest including in-hospital mortality, hospital length of stay (LOS), ICU LOS, and number of operations for pelvic fixation.

Patients were nonexclusively categorized into groups according to their injury and physiological status at their hospital of initial presentation. Patients were stratified according to presence of polytrauma, defined as AIS of >2 in two or more body regions,[14] and hemodynamic instability, defined as physiological parameters prompting the administration of two or more units of blood products within the initial emergency department resuscitation.

Data are presented as mean ± SD in the text and tables, unless otherwise specified, with ISS presented as median ± interquartile range. Statistical analysis was performed using linear regression of the outcome against the patient series. Significance was established at $p < 0.05$.

RESULTS

Patient Characteristics

A total of 1,270 PAFs were managed by our trauma service in the 10-year period of 2009 to 2018. Of these, 341 patients receiving surgical fixation were identified for this study, averaging 34.1 ± 8.1 fixations per year. Mean ± SD age was 44.1 ± 18.3 years, and 74.5% were male. Median ISS across all patients receiving fixation was 20 (16–29). There was no significant change in ISS over time ($p = 0.551$).

Patients were nonexclusively subclassified into the following groups as per Table 1.

Time to Definitive Fixation

Considering all patients during the study period, the mean ± SD time to definitive fixation for PAF was 84.7 ± 113 hours, ranging between 0.8 and 1,286 hours. The mean yearly time to definitive fixation for all patients is represented in Figure 1.

Linear regression analysis across consecutive patients concluded that time to definitive fixation decreased for all patients as a consecutive patients continuum from 116 to 54 hours ($\beta = -0.186$, $p = 0.003$). Subgroup analysis revealed that time to definitive fixation decreased significantly for pelvic ring fractures as a whole, from 125 to 38 hours ($\beta = -0.349$, $p = 0.001$), and in the context of polytrauma, from 160 to 33 hours ($\beta = -1.404$, $p = 0.030$). Time to fixation also decreased for hemodynamically normal patients, from 98 to 56 hours ($\beta = -0.170$, $p = 0.012$); hemodynamically unstable patients, 172 to 41 hours ($\beta = -1.428$, $p = 0.037$); and for nonpolytrauma patients, from 100 to 51 hours ($\beta = -0.209$, $p = 0.004$). There was no statistically significant change in the PAF with polytrauma, acetabular fracture, or acetabulum fractures with polytrauma cohorts. Trends are presented in Figures 2–4 as a representation of the linear regression equations for each subgroup.

TABLE 1. Patient Groups and Demographics

Group	n	Total PAF, %	Age, Mean ± SD, y	Male, %	ISS, Median (IQR)
All fixations for PAF	341	100.0	44.1 ± 18.3	74.5	20 (16–29)
Hemodynamically normal PAF	249	73.0	43.4 ± 17.9	74.3	17 (12–25)
Hemodynamically unstable PAF	92	27.0	45.7 ± 19.3	75.0	33.5 (24–43)
PAF with polytrauma	109	32.0	43.5 ± 18.1	72.5	43 (28–57)
PAF without polytrauma	232	68.0	44.3 ± 18.4	75.4	17 (10–22.5)
AF	91	26.7	46 ± 18.1	72.5	13 (8–20)
AF with polytrauma	18	5.3	43.7 ± 14.6	72.2	28 (22–34)
PRF	250	73.3	43.4 ± 18.3	75.2	24 (17–33)
PRF with polytrauma	91	26.7	43.4 ± 18.8	72.5	34 (26–45)

AF, acetabular fracture; PRF, pelvic ring fracture; IQR, interquartile range.

Secondary Outcomes

Of the 341 patients who received definitive fixation for PAFs, 29 patients had a head AIS of ≥3 and 85 patients had a chest AIS of ≥3. Considering all patients, the median head AIS was 0 (0–2) and the median chest AIS was 0 (0–2). Among polytrauma patients, the median head AIS was 2 (0–2.25) and the chest AIS was 3 (0–3). Transfusion requirements according to subgroup are displayed in Table 2. Linear regression demonstrated no significant change in transfusion requirements for any blood products over the study period. As expected, increased packed red blood cell requirements were associated with an increased ISS ($p < 0.001$) and increased length of ICU stay ($p < 0.001$). An increased time to fixation was also associated with increased packed red blood cell requirements ($p < 0.001$); however, hemodynamic instability is one of the main reasons definitive fixation is delayed.

There were eight in-hospital deaths during the study period, representing an in-hospital mortality of 2.3% for those receiving fixation for PAFs. There was no statistically significant change in mortality over time ($\beta = 0.000047$, $p = 0.575$). Seven of the eight deaths occurred in the hemodynamically unstable cohort, equating to a mortality rate of 7.6%, with no change over time in this subgroup ($\beta = 0.00038$, $p = 0.720$). Causes of death were traumatic brain injury (n = 3), multiorgan failure (n = 3), postinjury myocardial infarction/pulseless electrical activity arrest (n = 1), and complication of nonorthopedic procedure (n = 1). There were no deaths directly attributed to exsanguination from hemorrhage of any source.

Median length of hospital stay for all patients was 16 (11–29) days. There was no change in length of stay for the overall cohort or within any of the subgroups.

A total of 122 patients (35.8%) were admitted to the ICU. The majority of those admitted to ICU were hemodynamically unstable at presentation (n = 74), classified as polytrauma (n = 78), and had sustained injuries involving the pelvic ring (n = 96). For patients requiring ICU admission, median length of ICU stay was 5 (2–10) days. Length of ICU stay increased

for the nonpolytrauma PAF patients requiring ICU, from 1 to 8 days (n = 40, $\beta = 0.1909$, $p = 0.013$). The median length of stay for this group was 2.5 (2–5.5) days. There was no significant change in length of ICU stay as a whole or within any other subgroups.

Median number of operations for pelvic fixation for all patients was 1 (1–1), with 84% of the overall cohort receiving single-stage fixation. There was a statistically significant, but likely clinically insignificant, decrease in the number of operations for the hemodynamically unstable cohort ($\beta = -0.00620$, $p = 0.020$), decreasing from 1.70 to 1.13 operations per patient. This cohort received a median of 1 (1–2) operations for pelvic fixation, with 68% receiving single-stage fixation. There was no significant change in the number of operations in the overall cohort or any other subgroups.

DISCUSSION

Our data demonstrate that over the last decade, time to definitive fixation of pelvic fractures has decreased, without any significant increase in mortality, hospital stay, and ICU stay at our institution. It is known that, for hemodynamically stable patients, early definitive fixation is a safe and viable option.[2–5,13] For hemodynamically unstable patients, traditional consensus opposed early definitive fixation because of concerns regarding hemorrhage and tissue injury–associated organ failure, physiological exhaustion, and potential preventable mortality. A "damage control" approach was recommended with initial external fixation followed by delayed internal fixation performed after successful resuscitation and a return of physiological parameters closer to baseline.[1,6,10,15–18]

There have been multiple studies looking into the optimal timing of definitive fixation of unstable and borderline patients with pelvic fractures, with differing conclusions. Probst et al.[9] conducted a retrospective study of the German Trauma registry and found that short initial procedures, lasting less than 1 hour and late definitive fixation resulted in lower rates of mortality and multiple organ failure. Other studies supporting late definitive fixation include Pape et al.[10,11] and Gansslen et al.,[19] who both determined a benefit of emergency stabilization followed by late definitive fixation, for unstable patients. The first published claim for early definitive internal fixation was by Leenen et al.[20] in 1993 who described the viability of early internal fixation among a small cohort of patients with open pelvic fractures. There have since been multiple articles supporting early definitive fixation; Plaisier et al.[12] found that patients who underwent early acetabular ORIF (<24 hours) had significantly less organ dysfunction and improved functional outcomes. A review by Katsoulis and Giannoudis[1] compared the timing of reconstruction of pelvic fractures with functional outcome; five studies met the inclusion criteria with analysis suggesting early fixation provided improved outcomes, but "early" was variably defined. Significant research in this field has also been performed by Vallier et al.;[2,3,13] across multiple observational studies, they have demonstrated that early definitive pelvic fixation (<24 hours) in stable or borderline patients reduces complications and improves functional outcomes.

The Department of Traumatology at John Hunter Hospital has maintained a prospective pelvic fracture database since

TABLE 2. Blood Product Requirements by Cohort

	Nonisolated Acetabular	Hemodynamically Unstable	Polytrauma
Total PRBC	2 (0–6)	7 (4–13)	5 (2–10)
Total FFP	0 (0–2.5)	4 (2–8)	2 (0–6.25)
Total cryo	0 (0–0)	5 (0–10)	0 (0–10)
Total platelets	0 (0–0)	0 (0–1)	0 (0–1)
PRBC first 24 h	0 (0–2)	3.5 (2–8)	2 (0–6)
FFP first 24 h	0 (0–2)	2 (0–6)	1.5 (0–4)
Cryo first 24 h	0 (0–0)	4.5 (0–10)	0 (0–10)
Platelets first 24 h	0 (0–0)	0 (0–1)	0 (0–0)
PRBC intraop	0 (0–1)	0 (0–0.5)	0 (0–0)
FFP intraop	0 (0–0)	0 (0–0)	0 (0–0)
Cryo intraop	0 (0–0)	0 (0–0)	0 (0–0)
Platelets intraop	0 (0–0)	0 (0–0)	0 (0–0)

Data are presented as median (IQR).

PRBC, packed red blood cells; FFP, fresh frozen plasma; cryo, cryoprecipitate; intraop, intraoperative.
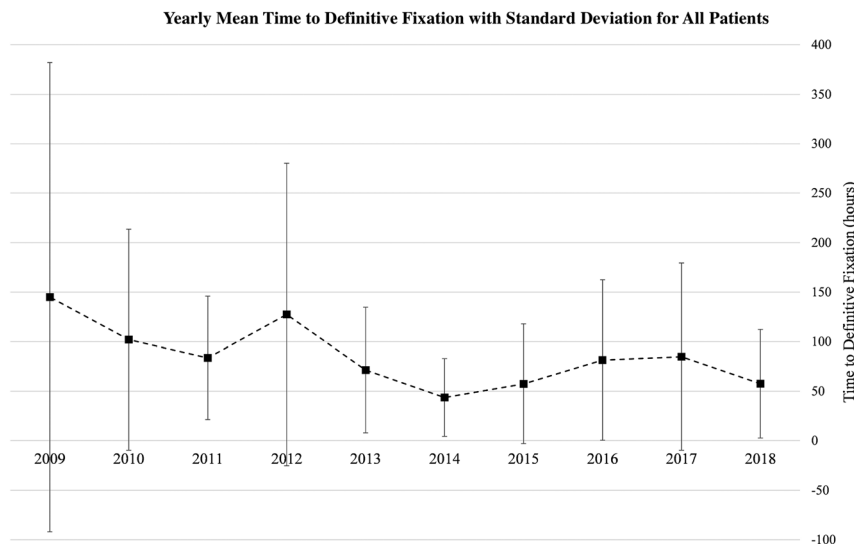
Figure 1. Mean time to definitive fixation by year.

2005, providing the ability to view trends in the management of pelvic fractures over time. We analyzed the time to definitive fixation over a consecutive sequence of patients in a 10-year period. We also compared selected patients with multiple injuries or those with similar physiological status on presentation. There was no significant difference in demographics, with all patients having comparable age, sex, and injury severity throughout the study period. Throughout the study period, we identified a statistically significant decrease in time to fixation for all groups and subgroups aside from the isolated acetabular fracture and polytrauma subgroups as illustrated in Figures 2–4.

The interpretation of these results is such that the isolated acetabular fracture group represents the baseline efficiency (or inefficiency) and access (or the lack of access) to operating rooms at our institution, with the time between presentation and fixation in this group acting as a marker of the access to shared institutional

resources. The significant changes in other subgroups compared with this baseline highlight our institutions' concentrated efforts toward early fixation of pelvic ring injuries. The nonsignificant decrease in time to definitive fixation of the polytrauma subgroup is, we believe, due to the large variability in the presentation of polytrauma patients and some of their fracture patterns and critical physiology occasionally requiring staged care.

In most measured outcomes, there was no statistically significant difference over the study period. There was a statistically significant, but likely clinically insignificant, increase in LOS for nonpolytrauma patients requiring ICU. This cohort had a median length of stay of 2.5 (2–5.5) days. This trend can be attributed to slow and gradual improvement in access to ICU beds at our hospital over the last 10 years. It is also worth noting that this cohort had a median ISS of 20 (17–25); however, these patients do not fit this study's criteria for polytrauma.
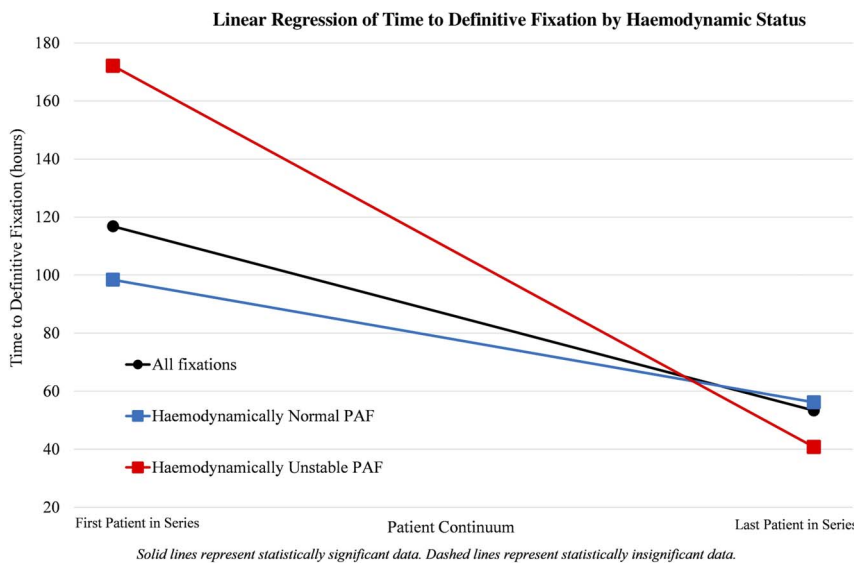

Figure 2. Time to definitive fixation by hemodynamic status. Solid lines represent statistically significant data. Dashed lines represent statistically insignificant data.
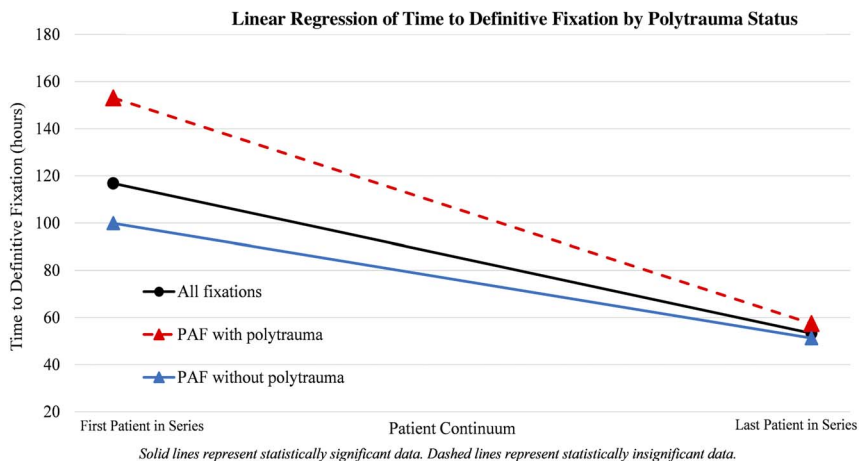
Linear Regression of Time to Definitive Fixation by Polytrauma Status

Solid lines represent statistically significant data. Dashed lines represent statistically insignificant data.

Figure 3. Time to definitive fixation by polytrauma status. Solid lines represent statistically significant data. Dashed lines represent statistically insignificant data.

Our institution's trend toward single-stage fixation for PAFs is highlighted by the low number of separate operations for pelvic fixation received by our patients. Analysis revealed that 84% of all patients and 68% of hemodynamically unstable patients received only one operation for their pelvic fracture. This provides a significant benefit to both the patient and health care system in comparison with staged fixation. Anesthetic risks and other surgery-related complications are reduced with a single operation. From a health economics perspective, single-stage fixation also provides significant economic benefits to the hospital with decreased total operative costs, improved theater availability for other patients, and increased operative availability for surgeons.

This study reports an extremely low mortality rate among pelvic fracture patients requiring fixation. Mortality rates among patients with pelvic fractures are reported between 5% and 20%.[9,21,22] Our institution reports an overall mortality rate of 2.3% of patients with unstable pelvic fractures receiving fixation, significantly lower than the rates reported in the literature. Patients presenting with hemodynamic instability accounted for seven of the eight deaths, resulting in a mortality rate of 7.6% within this cohort. Mortality rates for patients presenting with pelvic fractures and hemodynamic instability range from 21% to 50% in contemporary studies.[23–25] In this study, there were no deaths directly attributed to hemorrhage from pelvic or other sources, a major reported cause of mortality among patients with significant pelvic fractures.[23–25]

Polytrauma management and traumatic shock resuscitation are a special focus of our institution where massive transfusion protocol and hemostatic resuscitation with minimization of crystalloid infusion are existing strategies since 2005. The consultant led anesthetic and surgical care with immediate availability of blood products, and pelvic surgeons contribute to our low mortality rate and are integral parts of our institution's ability to safely operate on severely injured patients presenting with hemodynamic instability, as has been previously reported by Enninghorst et al.[7]

The extremely low mortality rate and lack of significant difference in outcome measures such as hospital LOS and ICU LOS in critical subgroups, despite decreased times to fixation, are promising trends toward highlighting the viability of early definitive internal fixation among complex patients.

The limitations of our study include the retrospective analysis of prospectively collected data. We believe that the
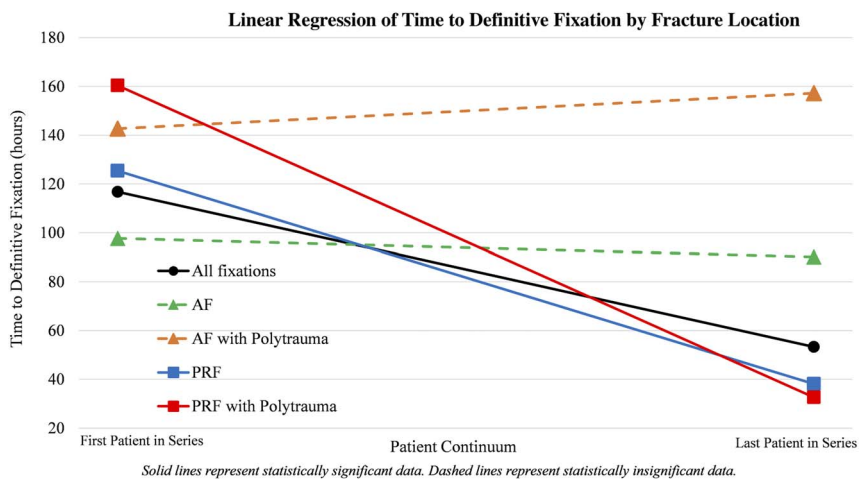
Linear Regression of Time to Definitive Fixation by Fracture Location

Solid lines represent statistically significant data. Dashed lines represent statistically insignificant data.

Figure 4. Time to definitive fixation by fracture location. Solid lines represent statistically significant data. Dashed lines represent statistically insignificant data.

availability of our trauma registry independent pelvic and acetabulum fracture database provides better quality data than most retrospective studies. Unfortunately, information on postoperative infections was not recorded on the database during this period and was therefore not included in this study. The very low mortality rate in our cohort makes our study unpowered to comment on any mortality benefit from the earlier definitive surgical stabilization. All operations were performed in a level 1 trauma center by orthopedic trauma surgeons with extensive experience in managing pelvic injuries, and therefore, our outcomes may not be reproducible in hospitals without these resources. Because our data set only includes patients with pelvic fractures who received fixation, the authors acknowledge that our mortality rate does not include patients presenting in significant shock unsuitable for fixation. Conversely, however, it does not include the almost 900 patients who presented with stable, uncomplicated pelvic fractures not requiring fixation. The authors therefore argue that the overall mortality rate for all comers at our institution may be even lower than reported in this study.

Overall, our results demonstrate that early definitive fixation of pelvic ring fractures is safely achievable even in hemodynamically unstable and polytrauma patients. This builds on previous research that timely definitive fixation of pelvic fractures is a safe and viable alternative to staged surgery in select patients.

AUTHORSHIP

G.L.D. performed the literature search, data collection, data analysis, data interpretation, writing, and critical revision. J.B. performed the literature search, data collection, data analysis, data interpretation, and writing. K.L.K. was responsible for the database integrity and contributed to data interpretation and critical revision. Z.J.B. conceived the pelvic acetabular fracture database, designed the study, data interpretation, writing, critical revision, and research mentorship.

DISCLOSURE

The authors declare no conflicts of interest.

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