Is Early Appropriate Care of axial and femoral fractures appropriate in multiply-injured elderly trauma patients?

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Abstract

Background: Previous work established resuscitation parameters that minimize complications with early fracture management. This Early Appropriate Care (EAC) protocol was applied to patients with advanced age to determine if they require unique parameters to mitigate complications.

Methods: Between October 2010 and March 2013, 376 consecutive skeletally mature patients with unstable fractures of the pelvis, acetabulum, thoracolumbar spine, and/or proximal or diaphyseal femur fractures were treated at a level I trauma center and were prospectively studied. Patients aged \( \leq 30 \) years \((n = 114)\), 30 to 60 years \((n = 184)\), and \( \geq 60 \) years \((n = 37)\) with Injury Severity Scores (ISS) \( \geq 16 \) and unstable fractures of the pelvis, acetabulum, spine, and/or diaphyseal femur were treated within 36 h, provided they showed evidence of adequate resuscitation. ISS, Glasgow Coma Scale (GCS), and American Society of Anesthesiologists (ASA) classification were determined. Lactate, pH, and base excess (BE) were measured at 8-h intervals. Complications included pneumonia, pulmonary embolism (PE), acute renal failure, acute respiratory distress syndrome (ARDS), multiple organ failure (MOF), deep vein thrombosis, infection, sepsis, and death.

Results: Patients \( \leq 30 \) years old (y/o) were more likely to sustain gunshot wounds \((p = 0.039)\), while those \( \geq 60 \) y/o were more likely to fall from a height \((p = 0.002)\). Complications occurred at similar rates for patients \( \leq 30 \) y/o, 30 to 60 y/o, and \( \geq 60 \) y/o. There were no differences in lactate, pH, or BE at the time of surgery. For patients \( \leq 30 \) y/o, there were increased overall complications if pH was <7.30 \((p = 0.042)\) or BE <−6.0 \((p = 0.049)\); patients \( \geq 60 \) y/o demonstrated more sepsis if BE was <−6.0 \((p = 0.046)\).

Conclusions: EAC aims to definitively manage axial and femoral shaft fractures once patients have been adequately resuscitated to minimize complications. EAC is associated with comparable complication rates in young and elderly patients. Further study is warranted with a larger sample to further validate EAC in elderly patients. Level of evidence: level II prospective, comparative study.

Keywords: Early Appropriate Care, Acidosis, Base excess, Fixation timing, Resuscitation, Elderly polytrauma,
for the body to recover [22–24]. This necessarily results in additional operations and implants and longer hospital stays. Some fracture patterns, such as those of the acetabulum, pelvis, and cervical or thoracolumbar spine may preclude DCO and, even if provisional stabilization is possible, may not permit early mobilization.

There are likely optimal conditions along the spectrum from ETC to DCO when early care is appropriate and may be undertaken. Major trauma often requires profound resuscitative efforts to correct blood and volume losses and the ensuing metabolic acidosis, reflected by changes in pH and base excess [25]. This necessitates transfusions of crystalloid, colloid, packed red blood cells (PRBC), fresh frozen plasma (FFP), and platelets (Plt). Metabolic acidosis on presentation is a prognostic indicator for the development of pulmonary complications [18, 26, 27], organ dysfunction [27, 28], and death [27–30].

Prior work from our institution led to the development of parameters designed to minimize complications. Definitive management of mechanically unstable fractures of the femur, pelvis, acetabulum, and thoracolumbar spine was performed within 36 h in patients who demonstrated a positive response to resuscitative efforts, defined as having either a lactate <4.0 mmol/L, pH ≥7.25, or base excess (BE) ≥−5.5 mmol/L [18, 31]. In the current study, we have applied this protocol prospectively, with the purpose of assessing its safety in older patients. We sought to determine if patients with advanced age require unique parameters to mitigate the risk of complications and mortality. Thus, we hypothesized that with adequate resuscitation, there would be no differences in complication rates between younger and older multiply-injured trauma patients.

Methods
This study was approved by the MetroHealth System Institutional Review Board (study number IRB07-01157). Between October 2010 and March 2013, a total of 376 consecutive patients were treated at a level I trauma center. Early Appropriate Care (EAC) was implemented in 2010, and relevant data were prospectively collected. All patients had an Injury Severity Score (ISS) ≥16 and were either skeletally mature or were approaching skeletal maturity and presented with fracture patterns requiring the standard fixation methods used in adults. There were 139 patients ≤30 years old (y/o), 184 patients 30 to 60 y/o, and 52 patients ≥60 y/o. All had achieved the desired level of resuscitation as measured by the correction of acidosis within 36 h after injury. Mechanisms of injury were categorized as falls from greater than 6 ft of height, motor vehicle collisions, motorcycle collisions, gunshot wounds (GSW), pedestrian versus automotive injuries, combination injuries, and other. Low-energy fractures were excluded. The time from injury until definitive fixation was determined. When patients had multiple unstable fractures, the timing of the final treated fracture was used for data analysis. Fractures that could be readily temporized with splinting (e.g., ankle and forearm fractures) were not included. The timing and techniques of fracture fixation were recorded.

As previously described [18], associated injuries were documented and their severity was assessed using the ISS [32], Abbreviated Injury Scale (AIS), and Glasgow Coma Scale (GCS) [33]. The American Society of Anesthesiologists (ASA) score was recorded. Laboratory studies including pH, BE, and lactate were documented every 8 h upon presentation to the emergency department and perioperatively. If a patient demonstrated sufficient resuscitation, the assessment of pH, BE, and lactate was discontinued, unless otherwise indicated by the trauma service. Patients were determined to be adequately resuscitated if they demonstrated one of the following: either lactate <4.0 mmol/L, pH ≥7.25, or BE ≥−5.5 mmol/L [18, 31].

Complications were recorded, including wound infection, pulmonary complications (acute respiratory distress syndrome (ARDS), pneumonia, pulmonary embolism (PE)), acute renal failure (ARF), multiple organ failure (MOF), and deep venous thrombosis (DVT). All patients were followed for a minimum of 6 months after injury to assess for complications and readmissions.

Statistical analysis was performed using Microsoft Excel (Microsoft, Redmond, WA) and GraphPad (GraphPad Software, La Jolla, CA). T tests, Fisher exact tests, ANOVA, and Mann-Whitney U tests were performed with parametric tests used if the data was normally distributed and non-parametric tests if the data was not normally distributed. Statistical significance was set at p < 0.05.

Results
One hundred fourteen patients ≤30 y/o, 184 patients 30 to 60 y/o, and 37 patients ≥60 y/o were studied. Younger patients (mean ± standard deviation (SD) 23.2 ± 4.1 y/o, range 16–30 y/o) were significantly younger than the older patients (mean ± SD 68.7 ± 9.0 y/o, range 60–91 y/o, p < 0.001). Younger patients had lower GCS (mean ± SD 12.3 ± 4.3 versus 14.2 ± 2.8, p = 0.003) and ASA (mean ± SD 2.58 ± 0.86 versus 3.03 ± 0.76, p = 0.002) with no difference in ISS (25.0 ± 9.6 versus 24.6 ± 9.0) when compared with the oldest patients. No differences in
admitted a median of 6 days (IQR 4–14 days, min 2 days, max 38 days, \( p = 0.05 \)). No differences were noted when patients in the middle age group were compared with other age groups in terms of length of stay or ventilator days.

The incidence of complications was similar for all age cohorts (\( \leq 30 \) y/o 15.8 %, 30 to 60 y/o 19.5 %, versus \( \geq 60 \) y/o 16.2 %). All complications are included in Table 6. Younger patients were more likely to develop a PE or ARDS (both \( p = 0.045 \)), when compared with the oldest patients. There were no differences in the occurrence of the other complications assessed. In general, higher ASA was associated with a greater incidence of any complication, pulmonary complication, pneumonia, ARDS, MOF, sepsis, and death, irrespective of patient age.

At the time of fixation, for patients \( \leq 30 \) y/o, 30 to 60 y/o, and \( \geq 60 \) y/o, there were no differences in lactate (2.09 \( \pm \) 0.95 mmol/L vs. 2.03 \( \pm \) 0.82 mmol/L vs. 1.86 \( \pm \) 0.81 mmol/L, respectively), pH (7.32 \( \pm \) 0.071 vs. 7.31 \( \pm \) 0.069 vs. 7.32 \( \pm \) 0.088, respectively), or BE (7.39 \( \pm \) 3.77 mmol/L vs. 3.64 \( \pm \) 3.8 mmol/L vs. 3.42 \( \pm \) 4.3 mmol/L, respectively). Subgroup analysis evaluating the severity of acidosis incrementally within patients \( \leq 30 \) y/o showed increased overall complications if pH was <7.30 (\( p = 0.042 \)) or BE <−6.0 mmol/L (\( p = 0.049 \)). There were trends toward more overall complications with BE <−5.5 mmol/L (\( p = 0.058 \)), pulmonary complications with BE <−6.0 mmol/L (\( p = 0.059 \)), and more pneumonia with pH <7.2 (\( p = 0.061 \)) or <7.25 (\( p = 0.080 \)). Patients \( \geq 60 \) y/o demonstrated more sepsis if BE was <−6.0 mmol/L (\( p = 0.046 \)) and trended toward more sepsis with BE <−5.5 mmol/L or <−5.0 mmol/L.

### Table 1: Mechanisms of injuries. Patients in the younger and older age groups are compared

| Classification | \( \leq 30 \) y/o (n = 114) | \( \geq 60 \) y/o (n = 37) | \( p \) |
|----------------|----------------------------|--------------------------|------|
| Falls         | 17 (14.9 %)                | 15 (40.5 %)              | 0.002|
| MVC           | 60 (52.6 %)                | 18 (48.6 %)              | 0.708|
| MCC           | 14 (12.3 %)                | 4 (10.8 %)               | 1.000|
| GSW           | 12 (10.5 %)                | 0 (0.0 %)                | 0.039|
| Pedestrian    | 7 (6.1 %)                  | 0 (0.0 %)                | 0.195|
| Combo         | 3 (2.6 %)                  | 0 (0.0 %)                | 1.000|
| Other         | 1 (0.9 %)                  | 0 (0.0 %)                | 1.000|

MVC motor vehicle collision, MCC motorcycle collision, GSW gunshot wound

### Table 2: AO/OTA classification for femur fractures

| Classification | \( \leq 30 \) y/o (N*) | \( \geq 60 \) y/o (N*) |
|----------------|------------------------|------------------------|
| 31A            | 5                      | 8                      |
| 31B            | 5                      | 2                      |
| 31C            | 0                      | 0                      |
| 32A            | 22                     | 3                      |
| 32B            | 26                     | 3                      |
| 32C            | 12                     | 3                      |

*4 patients \( \leq 30 \) y/o had ipsilateral femur fractures

### Table 3: AO/OTA classification for pelvis and acetabulum fractures

| Classification | \( \leq 30 \) y/o (N) | \( \geq 60 \) y/o (N) |
|----------------|-----------------------|-----------------------|
| 61A            | 0                     | 0                     |
| 61B            | 5                     | 2                     |
| 61C            | 10                    | 3                     |
| 62A            | 5                     | 2                     |
| 62B            | 4                     | 3                     |
| 62C            | 1                     | 2                     |
(both \( p = 0.086 \)). There were trends toward more overall complications with \( BE < -6.0 \) mmol/L \( ( p = 0.062) \) and increased MOF with \( pH < 7.2 \) \( ( p = 0.077) \) and death with \( pH < 7.2 \) \( ( p = 0.077) \).

### Discussion

The goal of EAC is to definitively stabilize fractures of the femur, pelvis, acetabulum, and spine after adequate resuscitation, such that the risks of complications are minimized. Patients who are hemodynamically stable and are demonstrating objective evidence of adequate resuscitation may benefit from early fixation. The advantages of early fixation of unstable axial and femoral fractures appear to outweigh the risks of complications in patients with a lactate <4.0 mmol/L, \( pH \geq 7.25 \), or \( BE \geq -5.5 \) mmol/L [18, 31, 34, 35]. These parameters were initially developed and tested in skeletally mature patients of all ages. In this study, we used these parameters to compare the results of treating an elderly patient population with high-energy injuries and multiple system involvement.

Elderly patients represent a unique population of great importance as this cohort of patients continues to grow. The rate of mortality is substantially higher in the elderly population compared to younger patients [36]. Mortality was found to increase 6.8 % per year in elderly trauma patients over 65 y/o [37], and pre-existing medical conditions place patients in this age group at greater risk [37, 38]. ISS, GCS, emergent intubation, coagulopathy, anemia, fluid requirements, and pre-existing chronic renal failure have been shown to be predictors of mortality [39-41].

Resuscitation is paramount to treating the elderly population, a population that may require more intensive resuscitation and monitoring [42-44]. However, it must be undertaken carefully, as high-volume resuscitation was shown to be an independent predictor of mortality in patients \( \geq 70 \) y/o [45]. In the elderly population, measures of metabolic acidosis including abnormal lactate and base deficit have been linked to increased mortality [29, 46]. Davis and Kaups compared patients \( \geq 55 \) y/o against younger patients and found greater mortality for older patients with base deficits on presentation [47].

The timing of definitive fixation must also be given consideration. In elderly patients with hip fractures, mortality increased if surgery was delayed more than 3 days [48, 49] or 4 days [50]. Kenzora et al. found that patients operated on within 24 h had a higher mortality than those delayed 2 to 5 days and that patients with more comorbidities had a higher mortality. The authors recommended resuscitating the patients and treating

### Table 4 Associated injuries

| Table 4 | Associated injuries | \( \leq 30 \) y/o (\( n = 114 \)) | \( \geq 60 \) y/o (\( n = 37 \)) | \( p \) |
|---------|---------------------|-------------------------------|-------------------------------|-------|
| Abdominal injury | Any | 31 (27.2 %) | 7 (18.9 %) | 0.387 |
| Minor | 19 (16.7 %) | 3 (8.1 %) | 0.285 |
| Severe | 12 (10.5 %) | 4 (10.8 %) | 1.000 |
| Chest injury | Any | 62 (54.4 %) | 19 (51.4 %) | 0.850 |
| Minor | 28 (24.6 %) | 9 (24.3 %) | 1.000 |
| Severe | 34 (29.8 %) | 10 (27.0 %) | 0.837 |
| Head injury | Any | 78 (68.4 %) | 18 (48.6 %) | 0.048 |
| Minor | 54 (47.4 %) | 12 (32.4 %) | 0.130 |
| Severe | 24 (21.1 %) | 6 (16.2 %) | 0.639 |

Minor injuries to the chest and abdomen had AIS of 1 or 2, while severe injuries had AIS of 3 or higher. Minor head injuries had presenting GCS >8, while severe injuries had lower GCS values for the middle age group versus the other groups were nonsignificant \( ( p > 0.05) \).

### Table 5 The number of patients having transfusion of one or more blood products is listed

| Table 5 | The number of patients having transfusion of one or more blood products is listed | \( \leq 30 \) y/o (\( n = 114 \)) | \( 30 \) to \( 60 \) y/o (\( n = 184 \)) | \( \geq 60 \) y/o (\( n = 37 \)) | \( p \) |
|---------|-------------------------------------|-------------------------------|-------------------------------|-------------------------------|-------|
| PRBC | 66 (57.9 %) | 110 (60 %) | 26 (70.3 %) | 0.245 |
| FFP | 16 (14.0 %) | 32 (17.4 %) | 10 (27.0 %) | 0.082 |
| Plt | 8 (7.0 %) | 15 (8.2 %) | 9 (24.3 %) | 0.007 |
| Cryo | 2 (1.8 %) | 2 (1.1 %) | 1 (2.7 %) | 0.573 |
| Any | 68 (59.6 %) | 112 (61 %) | 28 (75.7 %) | 0.115 |

\( p \) values are shown for the youngest versus the oldest patients. All \( p \) values for the middle age group versus the other groups were nonsignificant \( ( p > 0.05) \).

**Table 6 Complications for patients \( \leq 30 \) y/o, 30 to \( 60 \) y/o, and \( \geq 60 \) y/o**

| Table 6 | Complications for patients \( \leq 30 \) y/o, 30 to \( 60 \) y/o, and \( \geq 60 \) y/o | \( \leq 30 \) y/o (\( n = 114 \)) | 30 to \( 60 \) y/o (\( n = 184 \)) | \( \geq 60 \) y/o (\( n = 37 \)) | \( p \) |
|---------|---------------------------------------------|-------------------------------|-------------------------------|-------------------------------|-------|
| Any | 18 (15.8 %) | 36 (19.5 %) | 6 (16.2 %) | 0.84 |
| Pulmonary | 14 (12.3 %) | 22 (12.0 %) | 3 (8.1 %) | 0.46 |
| Pneumonia | 8 (7.0 %) | 20 (10.9 %) | 3 (8.1 %) | 0.86 |
| PE | 4 (3.5 %) | 4 (2.2 %) | 0 (0.0 %) | 0.045 |
| ARF | 0 (0.0 %) | 2 (1.1 %) | 1 (2.7 %) | 0.32 |
| ARDS | 4 (3.5 %) | 1 (0.5 %) | 0 (0.0 %) | 0.045 |
| MOF | 0 (0.0 %) | 1 (0.5 %) | 1 (2.7 %) | 0.32 |
| DVT | 2 (1.8 %) | 4 (2.2 %) | 0 (0.0 %) | 0.16 |
| Infection | 3 (2.6 %) | 6 (3.3 %) | 0 (0.0 %) | 0.083 |
| Sepsis | 1 (0.9 %) | 5 (2.7 %) | 2 (5.4 %) | 0.25 |
| Death | 2 (1.8 %) | 2 (1.1 %) | 1 (2.7 %) | 0.75 |

**Table 6** Complications for patients \( \leq 30 \) y/o, 30 to \( 60 \) y/o, and \( \geq 60 \) y/o

\( p \) values are shown for the youngest versus the oldest patients. All \( p \) values for the middle age group versus the other groups were nonsignificant \( ( p > 0.05) \).

Pulmonary complications include pneumonia, ARDS, and PE; ARDS adult respiratory distress syndrome; PE pulmonary embolism; ARF acute renal failure; MOF multiple organ failure; DVT deep venous thrombosis.
active medical issues prior to surgical intervention [51]. In contrast, a multi-center study of trauma patients ≥60 y/o, excluding “slip-and-fall” injuries, showed that patients who required only orthopedic surgery, including early fixation of long-bone fractures and external fixation of pelvic fractures, were less likely to die than those requiring no surgery. Timing, ≤24 h or >24 h, was not found to be a risk factor for mortality [39].

In the current study, in the context of the resuscitation parameters, there were no differences between ≤30 y/o, age 30 to 60 y/o, and patients ≥60 y/o with respect to lactate, pH, or BE at the time of definitive fixation. This is consistent with all patients being similarly resuscitated according to the same guidelines. It is reassuring that when using the EAC protocol, the rate of complications was similar in patients ≤30 y/o and patients ≥60 y/o at 15.8 and 16.2 %, respectively. Moreover, all groups met the goal of fewer than 20 % overall pulmonary complications (12.3 and 8.1 %, respectively, for the younger and older cohorts) [18]. These data suggest that, independent of age, markers of resuscitation may dictate the appropriate timing of surgery. Nevertheless, in the younger cohort, patients were more likely to have complications with a lower pH or BE, and older patients demonstrated more sepsis with a lower BE. Therefore, there may still be age-specific risks associated with acidosis on presentation.

Our study is strengthened by its prospective nature. As such, we were able to employ a standardized protocol in treating all patients. This is in addition to the standardization at our institution for the administration of perioperative antibiotics and DVT prophylaxis. The regimen for obtaining laboratory values was consistent and accurately reflected the resuscitation status at the time of definitive fixation. However, our study is limited in that the frequency and timing of non-orthopedic procedures was not recorded. The protocol is meant to be generalizable to the elderly trauma population, but we recognize not all fractures behave similarly, and future study into variations in the protocol for specific fractures or other injuries and baseline morbidities is warranted. Determining which lab values, or which combinations of lab values, are most predictive of patient outcomes would also be valuable. Further, with relatively small groups and low incidences of complications in this study, larger groups of patients will be necessary for more statistically and clinically significant conclusions to be made.

Conclusions

In conclusion, the Early Appropriate Care of elderly patients with high-energy mechanism and multiple trauma appears to be a viable treatment algorithm. While historically the rates of complications in the elderly population have exceeded that of their younger counterparts, in the current study, although groups were small, there appears to be comparable complication rates and hospital course in adequately resuscitated patients, as measured by the correction of metabolic acidosis, irrespective of age. Further study is certainly indicated to expand on these results, to evaluate the impact of pre-existing medical conditions and ASA scores, and to study a larger cohort of patients.

Abbreviations

ARDS: Acute respiratory distress syndrome; ASA: American Society of Anesthesiologists; BE: Base excess; DCO: Damage-control orthopedics; EAC: Early Appropriate Care; ETC: Early total care; GCS: Glasgow Coma Scale; ISS: Injury Severity Score; MOP: Multiple organ failure; PE: Pulmonary embolism

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Authors’ contributions

MR performed the literature review and data collection and analysis and drafted the manuscript. AJ performed the majority of the data collection and critically revised the manuscript. TM developed the study, reviewed the data, and critically revised the manuscript. HV developed the study, analyzed and interpreted the data, and critically revised the manuscript. All authors read and approved the final manuscript.

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All authors are based at the MetroHealth System, affiliated with Case Western Reserve University.

Competing interests

The authors declare that they have no competing interests.

Consent for publication

Not applicable.

Ethics approval and consent to participate

This study was approved by the MetroHealth System Institutional Review Board (study number IRB07-01157) and consent was waived per the IRB.

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