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Original Research

10-Year trend in crystalloid resuscitation: Reduced volume and lower mortality☆

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HIGHLIGHTS

- Recent guidelines emphasize limited crystalloid resuscitation in trauma settings.
- There are poor outcomes associated with a fluid overload state.
- There is a lower adjusted mortality among patients who receive less crystalloids.

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ABSTRACT

Background: Liberal emergency department (ED) resuscitation after trauma may lead to uncontrolled hemorrhage, reduced organ perfusion, and compartment syndrome. Recent guidelines reduced the standard starting point for crystalloid resuscitation from 2 L to 1 L and emphasized "balanced" resuscitation. The purpose of this study was to characterize how an urban, Level 1 trauma center has responded to changes in crystalloid resuscitation practices over time and to describe associated patient outcomes.

Methods: This is a retrospective review of trauma patients who sustained moderate to severe injury (ISS > 9) and received crystalloid resuscitation in the ED during 1/2004–12/2013 at an urban, Level 1 trauma center. Patient data collected included age, gender, Glasgow Coma Scale (GCS) score, initial systolic blood pressure (SBP), mechanism of injury, regional Abbreviated Injury Scale (AIS) score, Injury Severity Score (ISS), volume of blood products and crystalloids administered in the ED. Patients who received <2 L of crystalloid were considered low-volume while those who received ≥2 L were high-volume patients. Clinical characteristics and outcomes were compared between high- and low-volume cohorts, and multivariate regression was used to adjust for confounders. Trend analysis examined changes in variables over time.

Results: 1571 moderate to severely injured patients received crystalloid resuscitation; 1282 (82%) were low-volume and 289 (18%) were high-volume. Compared to high-volume patients, low-volume patients presented with a higher median SBP (134 vs. 122 mmHg, $p < 0.001$) and GCS (15 vs. 14, $p < 0.001$). Low-volume patients also had lower median ISS (15 vs. 19, $p < 0.001$). Unadjusted mortality was lower in the low-volume cohort (7% vs. 19%, $p < 0.001$). Multivariate analysis demonstrated that high-volume patients had increased odds of mortality compared to low-volume patients (AOR 1.88, $p = 0.008$). Decreased rates of high-volume resuscitation and overall mortality were demonstrated over the 10-year study period.

Conclusions: The observed decrease in high-volume crystalloid resuscitations in the ED paralleled a reduction in mortality over the ten-year period. In addition, adjusted mortality was higher in those receiving high-volume resuscitation.

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1. Background

Intravenous fluid resuscitation plays an integral role in the early management of trauma, restoring perfusion and preventing shock in the hemorrhaging trauma patient. Administration of crystalloid fluids can be crucial for managing a hemodynamically unstable patient until definitive surgical control is established. However, a growing body of research has identified numerous risks associated with fluid overload during damage-control treatment. Over-resuscitation may lead to increased bleeding [1,2], coagulopathy [3,4], acidosis [5,6], and an exaggerated inflammatory response [7], increasing the risk for morbidity and mortality.

Mounting evidence against liberal fluid replacement over the past two decades, particularly with penetrating injury [8], has resulted in a shift toward recommendations to limit crystalloid resuscitation. Best practices are less clear in elderly patients and in those sustaining blunt injury. The American College of Surgeons amended the standard starting point for crystalloid resuscitation from 2 L to 1 L for adults and eliminated the term "aggressive resuscitation" in the most recent Advanced Trauma Life Support (ATLS) manual [9]. Emphasis was placed instead on "balanced resuscitation," with the goal of achieving adequate organ perfusion while avoiding circulatory overload and tempering the risk of re-bleeding. While these guidelines are applied to all adults, the elderly are a vulnerable population who may warrant even more cautious management due to cardiovascular risk, higher incidence of hypertension, and the likelihood of anti-coagulation use [4,10]. In the setting of these changes and considerations, how trauma centers altered crystalloid resuscitation practices over the previous ten years has not been well characterized.

This study was conducted to characterize temporal trends in crystalloid resuscitation volumes administered in the Emergency Department (ED) at an urban, Level I trauma center. The objectives of this study were to 1) compare clinical outcomes between adult trauma patients receiving ≥2 L of crystalloids to those receiving <2 L in the ED, 2) determine whether these findings are consistent in elderly patients and in those injured via blunt mechanism, and 3) evaluate trends in resuscitation volume and mortality rate over a 10-year period.

2. Methods

This was a retrospective review of all trauma patients who sustained moderate to severe injury (Injury Severity Score > 9) and received crystalloid resuscitation upon admission to the Emergency Department (ED) at a Level I trauma center between January 2004 and December 2013. Demographics and clinical data at the time of ED presentation were obtained from a trauma registry including age, gender, Glasgow Coma Scale (GCS) score, initial systolic blood pressure (SBP), mechanism of injury (blunt vs. penetrating), regional Abbreviated Injury Scale (AIS) score, Injury Severity Score (ISS), volume of blood products (packed red blood cells, plasma, and platelets) and total crystalloid resuscitation volume received in the pre-hospital phase and in the ED. Outcomes included in-hospital mortality, hospital length of stay (LOS) and intensive care unit (ICU) LOS. Patients who were less than 18 years of age, dead on arrival, or missing GCS, ISS, or SBP data were excluded.

Patients were categorized according to the volume of crystalloids (normal saline, lactated Ringer's) they received in the ED and pre-hospital phase; those who received < 2 L of crystalloids were considered low-volume patients (LOW) and those who received ≥2 L of crystalloids were considered high-volume patients (HIGH). Clinical variables and outcomes were then compared between low and high-volume cohorts, and multivariate regression analysis was used to evaluate mortality and outcomes while controlling for confounders. Trend analysis was conducted to examine changes in the proportion of high-volume patients, volume of ED blood transfusions, and mortality rate over the 10-year period.

As all continuous data were non-parametric, continuous variables were analyzed using the Mann-Whitney *U* test and are reported as median (interquartile range). Categorical variables were analyzed using chi-squared or Fisher's Exact test and are reported as percentages. Multivariate logistic regression was used for an adjusted comparison of mortality between patients receiving low and high-volume resuscitation, controlling for the following confounders: Elderly (age ≥ 65 years), SBP < 90 mmHg, GCS ≤ 8, ISS ≥ 16, and blunt mechanism of injury. The factors entered into the regression model had p-values < 0.2 on univariate analysis or were determined to be potential confounders based on clinical judgment. Adjusted odds ratios of mortality were also calculated for elderly patients (age ≥ 65 years) and patients who sustained blunt injury. Trend analysis was performed using the Cochran-Armitage trend test for categorical variables and the Jonckheere-Terpstra trend test for continuous variables. P-values < 0.05 were considered statistically significant. All statistical analyses were performed using SPSS (Version 22, SPSS Inc., Chicago, IL). This study was approved by the Cedars-Sinai Medical Center Institutional Review Board.

3. Results

Of the 1571 trauma patients who received crystalloid fluid

Table 1
Clinical characteristics.

Variables	LOW < 2 L Crystalloid N = 1282	HIGH ≥ 2 L Crystalloid N = 289	Unadjusted p-value
Age (years)[a]	39 (26–56)	39 (27–51.5)	0.243
Elderly (age ≥ 65 years), % (n)	17.6 (226)	12.5 (36)	0.033
Male, % (n)	73.2 (939)	76.8 (76.8)	0.212
GCS[a]	15 (14–15)	14 (9–15)	<0.001
GCS ≤ 8, % (n)	10.3 (132)	24.6 (71)	<0.001
ISS[a]	15 (10–21)	19 (13–29)	<0.001
ISS ≥ 16, % (n)	50.0 (641)	65.4 (189)	<0.001
Head AIS[a]	0 (0–3)	0 (0–4)	0.757
Head AIS ≥ 3, % (n)	43.9 (563)	39.1 (113)	0.135
SBP (mmHg)[a]	134 (118–149)	122 (101–144)	<0.001
SBP < 90 mmHg, % (n)	3.7 (48)	12.1 (35)	<0.001
Blunt (vs. penetrating) Injury, % (n)	89.1 (1142)	80.6 (233)	<0.001
Blood Products Transfused, % (n)	10.9 (125)	43.2 (115)	<0.001
Volume of Blood Products (mL)[a]	700 (480–1233)	1111 (700–1997)	<0.001
Crystalloid Fluids (L)[a]	1 (0.5–1)	2.1 (2–3)	<0.001

GCS, Glasgow coma scale; ISS, injury severity score; AIS, abbreviated injury scale; SBP, systolic blood pressure.
[a] Reported as median (interquartile range).