Available online at www.sciencedirect.com

ScienceDirect

Journal of Acute Medicine 6 (2016) 29–34

www.e-jacme.com

Original Research

Analysis of fluid resuscitation in critically injured patients—A central role of saline solutions

Kai Sprengel [a], Hanspeter Simmen [a], Clément M.L. Werner [a], Kai Oliver Jensen [a], Catharina Keller [b], Stefan H. Wirth [c], Martin Berli [c], Ladislav Mica [a,*]

[a] *Division of Trauma Surgery, University Hospital of Zürich, Zürich, Switzerland*
[b] *LVR-Clinic, Cologne, Germany*
[c] *Orthopädische Universitätsklink Balgrist, Zürich, Switzerland*

Received 9 March 2016; revised 27 April 2016; accepted 17 May 2016
Available online 14 June 2016

Abstract

Objective: Multiple injury patients are mostly in the productive age group and are at high risk of dying by exsanguination. In this study, the focus was set on fluid resuscitation, death, and outcome of critically injured patients.
Methods: In total, 2956 patients were included in this sample. The inclusion criteria were age $\geq$ 16 years and injury severity score $\geq$ 16. The sample was divided into groups of patients who died within 72 hours of injury and those who survived. Differences between the groups were measured by analysis of variance and Kruskal–Wallis test for parametric data. Independent predictors were analyzed by logistic regression, and the predictive quality was analyzed by receiver operating curves. The given volumina were normalized according the Trauma Score—Injury Severity Score of each patient. All analyses were performed using SPSS.
Results: The binary logistic regression revealed the given amount of saline solutions and colloids within the first 48 hours as independent predictors of survival ($p < 0.001$, $p = 0.003$). The receiver operating curves revealed that the area under the curve increased as a function of time, and after 48 hours it was 0.825 for saline solutions and 0.702 for colloids for survival.
Conclusion: Fluid resuscitation does not negatively influence survival; however, the amount of fluids given within the first 24 hours after trauma is an independent predictor of survival with very good predictive quality.

Keywords: mortality; multiple trauma; resuscitation; saline solutions

1. Introduction

Critically injured patients are at high risk of dying by exsanguination and of developing systemic inflammatory response syndrome. Trauma-induced coagulopathy is a multifactorial failure of the coagulation system to prevent ongoing bleeding. In critically injured patients, derangement of the coagulatory cascade is common, and is associated with a poor outcome by exsanguination and later inadequate resuscitation-induced complications.[1–3] Each attempt at correction may lead to further derangement of the coagulatory cascade, and to inadequate resuscitation-related organ dysfunction and immunological overactivation of the systemic inflammatory response syndrome. Inadequate resuscitation-related bleeding leads not only to a loss of oxygen carriers, but also to a loss of coagulatory factors and the complementary system, shutting down the humoral immunity and opening the door for environmental pathogens. Inadequate additional resuscitation attempts further dilute the residual concentration of coagulatory and complement factors, handicapping blood coagulation and humoral immunity. Clear resuscitation protocols for the use of crystalloids are lacking, and blood

* Corresponding author. Division of Trauma Surgery, University Hospital of Zürich, Rämistrasse 100, Zürich 8091, Switzerland.
E-mail address: ladmic@gmail.com (L. Mica).

http://dx.doi.org/10.1016/j.jacme.2016.05.001

parameters are measured continuously during resuscitation, mirroring the patient's reality in the past. Therefore, a descriptive cohort study in a retrospective manner, to provide some information on the validity of the different resuscitation fluids used in critically injured patients, and to provide orientation points for the future improvement of damage control resuscitation, was ruled out.

2. Methods

2.1. Patient sample

A total of 2956 critically injured patients admitted to the resuscitation room of the University Hospital of Zürich (Switzerland) during the period 1996−2013 were included in this retrospective cohort study. The inclusion criteria were an injury severity score (ISS) of ≥16 points, age ≥16 years, and admission within at least 24 hours of incurring multiple injuries. The patient sample was divided into two groups (Table 1) comprising patients who died within the first 72 hours and those who survived longer than the first 72 hours. All patient data were collected retrospectively. The patient data were retrieved from patient records with the approval of the local institutional review board, according to the University of Zürich institutional review board guidelines and the World Medical Association Declaration of Helsinki; the study was conducted according to our institutional guidelines for good clinical practice (Ethics Committee of the University Hospital of Zürich Permission: *"Retrospektive Analysen in der Chirurgischen Intensivmedizin"*; permission number: St.V. 01-2008).

Table 1
Patient sample.

Admission	Exitus < 72 h	Survival > 72 h	Total	p
N	615	2341	2956	<0.001[a]
Age (y)	51.2 ± 22.1	42.8 ± 18.4	44.5 ± 19.6	<0.001[b]
Sex (male/female)	436/179	1732/609	2168/788	<0.001[a]
T admission (C°)	34.5 ± 2.6	35.7 ± 1.5	35.5 ± 1.8	<0.001[b]
BMI (kg/m^2)	25.3 ± 4.6	25.0 ± 4.4	25.0 ± 4.4	0.425[b]
Shock (ATLS)	2.1 ± 1.1	1.4 ± 0.7	1.6 ± 0.9	<0.001[b]
GCS	5.9 ± 4.0	11.0 ± 4.5	9.9 ± 4.9	<0.001[b]
ISS	36.9 ± 17.0	26.4 ± 12.5	28.6 ± 14.2	<0.001[b]
NISS	50.8 ± 16.6	35.0 ± 15.4	38.2 ± 17.0	<0.001[b]
AIS head	4.1 ± 1.7	2.6 ± 1.9	2.9 ± 2.0	<0.001[b]
AIS face	0.4 ± 1.0	0.6 ± 1.0	0.6 ± 1.0	0.002[b]
AIS thorax	1.6 ± 1.8	1.7 ± 1.6	1.7 ± 1.7	0.330[b]
AIS abdomen	1.0 ± 1.8	1.0 ± 1.7	1.0 ± 1.7	0.990[b]
AIS spine	0.5 ± 1.2	0.9 ± 1.4	0.8 ± 1.4	<0.001[b]
AIS extremities	1.1 ± 1.4	1.5 ± 1.4	1.4 ± 1.5	<0.001[b]
AIS pelvis	0.6 ± 1.2	0.6 ± 1.2	0.6 ± 1.2	0.471[b]
AIS skin	0.4 ± 0.8	0.5 ± 0.8	0.54 ± 0.8	<0.001[b]
APACHE II	23.8 ± 7.4	12.6 ± 7.7	14.9 ± 8.9	<0.001[b]
TRISS	0.501 ± 0.296	0.817 ± 0.234	0.752 ± 0.279	<0.001[b]

For all nonparametric data, Kolmogorov−Smirnov was $p > 0.05$.
AIS = Abbreviated Injury Scale; APACHE = Acute Physiology and Chronic Health Evaluation; ANOVA = analysis of variance; ATLS = Advanced Trauma Life Support; BMI = body mass index; ISS = injury severity score; GCS = Glasgow Coma Scale; NISS = New Injury Severity Scale; SD = standard deviation; TRISS = Trauma Score—Injury Severity Score.
[a] χ^2, mean ± SD.
[b] ANOVA.

2.2. Diagnostic protocol

Unstable patients underwent resuscitative procedures according to the Advanced Trauma Life Support (ATLS) standards of the American College of Surgeons, and life-saving surgery was performed according to Definitive Surgical Trauma Care (by International Association for Trauma Surgery and Intensive Care).[4,5] Hemodynamically stable patients received diagnoses according to the clinical findings or a whole-body computed tomography scan in uncertain situations. Hemodynamically unstable patients received focus-oriented diagnostics with immediate problem solving, according to the ATLS and Definitive Surgical Trauma Care guidelines.

2.3. Scoring systems

The Acute Physiology and Chronic Health Evaluation II score was used to evaluate the overall physiological impairment of the patient at admission.[6] The ISS and the New Injury Severity Scale were used to define the severity of trauma.[7,8] The Abbreviated Injury Scale (AIS; 2005 version) was used to describe injuries in specific anatomical regions.

The Trauma Score—Injury Severity Score (TRISS) was used to analyze the probability of death in the patient sample.[9]

2.4. Hypothetical sources of bias

All patients were selected retrospectively. Documentation of all parameters followed the Good Clinical Practice guidelines. Several persons collected the data under the guidance of the personnel selecting the patients. The 17-year time span could have led to a bias in time-related changes in the treatment of trauma-associated coagulopathy; however, the definition of systemic inflammatory response syndrome and sepsis remained the same, as well as the measurement of quantities. The scores and values were calculated using a single Excel sheet (Office 2010; Microsoft, Redmond, WA, USA).

2.5. Statistical analysis

Data are presented as the mean ± standard deviation for continuous variables and as percentages for categorical variables. Cases with an incomplete data set were analyzed by missing completely at random test. The two-tailed Kolmogorov−Smirnov test was used for testing normality, and if $p > 0.05$, the data were considered as normally distributed. Categorical data were analyzed using the χ^2 and Kruskal−Wallis test; the one-way analysis of variance was used for continuous normally distributed data. Results were considered statistically significant at $p < 0.05$. The predictive quality of the different fluids was reported as the area under the receiver operator characteristic (ROC) curve (AUC). The independent predictivity was analyzed by binary logistic regression; the goodness of fit for the logistic regression was given by the Hosmer−Lemeshow test and considered as good if $p > 0.05$. The data were considered as independent predictive variables