Do Parameters Used to Clear Noncritically Injured Polytrauma Patients for Extremity Surgery Predict Complications?

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Abstract

Background In multiply injured patients, definitive stabilization of major fractures is performed whenever feasible, depending on the clinical condition.

Questions/purposes We therefore asked whether (1) any preoperative indicators predict major complications after major extremity surgery; (2) perioperative routine parameters other than those indicative of hemorrhagic shock predict postoperative complications; and (3) any postoperative clinical findings can predict major complications in the further course of the patient.

Methods We prospectively followed patients with femoral midshaft fracture, Injury Severity Score (ISS) > 16 points, or three fractures and Abbreviated Injury Scale

(AIS) ≥ 2 points and another injury (AIS ≥ 2 points), and age 18 to 65 years. We recorded multiple clinical parameters. End points were pneumonia, sepsis, acute respiratory distress syndrome, acute lung injury, and multiple organ failure.

Results Forty-three of 165 patients developed complications. (1) Patients with complications had a decreased initial Glasgow Coma Scale and tended to have a lower ISS. (2) None of the assessed perioperative parameters was able to sufficiently predict postoperative complications. (3) The presence of a lung contusion and ventilation > 48 hours were associated with complications in the further course.

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Conclusions In stable multiply injured patients, none of the individual routine clinical parameters was able to predict complications. Severe head and thoracic injuries seem to be important drivers for the development postoperative complications.

Level of Evidence Level II, prognostic study. See Guidelines for Authors for a complete description of levels of evidence.

Introduction

The operative management of patients plays a major role in the resuscitation process. The clearing process is crucial to ensure timely major operations and appropriate fracture fixation [20]. Most general surgeons use parameters indicative of hemorrhagic shock (lactate, base excess) to determine whether a patient is cleared for major extremity surgery [7, 22]. For patients with acute severe bleeding such as might be induced by gunshot injuries or blunt trauma with severe vascular injuries, lactate and base deficits are valuable in predicting complications [1]. A systolic blood pressure < 90 mmHg appears to be appropriate to diagnose hemorrhagic shock. The changes associated with severe trauma have been named the triad of death by general surgeons (hemorrhagic shock, acidosis, coagulopathy) [19, 33, 37].

However, complications in patients with blunt trauma usually are associated with severe tissue injuries and inflammatory changes, unreflected by lactate and base deficit data. The main concern in these patients is the development of secondary complications such as multiple organ dysfunction syndrome and multiple organ failure (MOF) related to the inflammation [9]. Major operations induce inflammatory reactions [12, 15]. Thus, if a major operation is performed during the phase of pathologically increased systemic inflammatory response, adverse effects may occur [6]. Because major operations are usually required in the early stages after trauma, they can affect the inflammatory state. Therefore, it is crucial to assess whether patients can withstand the surgery-induced inflammatory changes and these assessments should be reflected in the clearing process for major operations [20]. The decision to operatively fix major fractures must consider the risk of patients developing late complications such as MOF. From the orthopaedic point of view, the relevance of inflammatory changes associated with fracture care is especially important in pelvic, acetabular, and in major extremity fractures [8, 16].

Multiple trauma scores have been developed within the last decades. Several were designed to assess mortality [7, 21, 26]. The New Injury Severity Score [4] reportedly correlates with survival. Veysi et al. found the presence of

severe chest injuries predicted mortality [38]. Our group looked at the thoracic Abbreviated Injury Score (AIS) and found it predicted the development of acute respiratory distress syndrome (ARDS). This prediction was stronger when radiographic evidence of a lung contusion and additional physiologic changes occurred, namely a drop in the PaO₂/FiO₂ ratio [24]. Esme et al. found the Lung Injury Scale correlated with the Injury Severity Score, length of mechanical ventilation, and duration of the hospital stay [10].

However, none of these assess the clinical parameters used to clear patients for surgery or combine physiologic and anatomical variables such as lactic acid, base deficits, oxygenation ratios, or hemostatic changes reflecting hemorrhagic shock. Likewise, none of them addresses patients in borderline conditions or those who may be particularly susceptible to adverse effects.

We therefore asked whether (1) any preoperative indicators predict major complications after major extremity surgery; (2) perioperative routine parameters other than those for hemorrhagic shock predict postoperative complications; and (3) any postoperative clinical findings can predict major complications in the further course of the patient.

Patients and Methods

This investigation was designed as a prospective cohort study from eight Level I trauma centers. The current study is part of a clinical series undertaken by the EPOFF study group [25]. We prospectively enrolled 165 patients using criteria in previous publications [23, 24]. Briefly, the inclusion criteria were as follows: (1) multiple injuries including a midshaft femur fracture, treated by intramedullary nailing or external fixator; (2) Injury Severity Score (ISS) > 16 points or three extremity injuries with an AIS [3, 25] of 2 or more points in association with an injury of another body region with an AIS of 2 or more points; and (3) age between 18 and 65 years. We excluded patients with (1) previous severe injuries or femur fractures; (2) body weight > 250 pounds; (3) open epiphyseal plates; and (4) multiple premorbid conditions. Among these latter conditions was cardiac insufficiency, coronary insufficiency, cardiac transplantation, pulmonary hypertension, emphysema, or another medical treatment that would prevent a patient from being cleared for fracture stabilization. We also excluded patients if they were admitted in extremis condition and when their cardiovascular status could not be stabilized. All patients had sustained moderate to severe injuries; all were the result of blunt trauma. All participating centers took part in biannual meetings to assure quality of documentation and data collection and the

Table 1. Demographic data, injury characteristics, and injury severity and distribution

Age (years)*	32.6 ± 11.7
Sex (male/female)	132/33
Type of accident	
Motor vehicle accident	115 (70%)
Motorcycle accident	31 (19%)
Pedestrian accident	11 (7%)
Fall from great heights	4 (2%)
Suicide attempt	4 (2%)
Injury scores*	
ISS	25.8 ± 9.6
NISS	29.0 ± 9.7
RTS	0.88 ± 0.43
Femur fracture characteristics	
Open/closed	42/123
Bilateral/unilateral	19/146

* All values are depicted as the mean ± SD; ISS = Injury Severity Score; NISS = New Injury Severity Score; RTS = Revised Trauma Score.

accuracy of the data. Institutional review board approval (No. 2019) was obtained by the coordinating center and each local facility.

Demographic data demonstrate that patients were young and predominantly male (Table 1). The typical type of injury was a motor vehicle accident. The majority of femoral fractures was closed.

Patients were graded according to their clinical condition on admission by the attending physician into four different categories (stable, borderline, unstable, in extremis), as previously proposed [22, 25]. The parameters used to differentiate these conditions were those reflecting hemorrhagic shock, lung contusion, hypothermia, and coagulopathy [1, 2, 22, 23, 25]. Only patients in stable or borderline conditions were enrolled in the study. To facilitate comparison with other studies, the degree of total severity of injury was also categorized by the ISS [3] calculated from the data collected for the AIS. The Revised Trauma Score [7] was calculated based on the data obtained on arrival of the patient based on an initial head CT scan. The initial neurological state was evaluated according to the Glasgow Coma Scale (GCS) [31]. Acute lung injury (ALI) was diagnosed according to a scoring system reported by Bernard et al. [5]. The severity of thoracic injuries was graded according to the Thoracic Trauma Score [24]. The number of rib fractures was documented as were the incidences of pneumothorax, hemothorax, pressure pneumothorax, and lung contusion [24, 34].

Systemic inflammatory response syndrome (SIRS) was defined as the presence of the following criteria: body temperature > 38° C, heart rate greater than 90 beats/min,

respiratory rate greater than 20 breaths/min or PaCO₂ < 32 mmHg, and neutrophil count greater than 12,000/mL or less than 4000/mL. Sepsis was diagnosed by a scoring system [30]. Pneumonia was diagnosed if the body temperature was at least 38.5° C and if, in addition, one of the following criteria was met: infiltrate on chest radiograph in the absence of ARDS or positive culture in bronchoalveolar lavage fluid. MOF was diagnosed according to a scoring system [18] when at least three organs demonstrated a Grade II dysfunction. The diagnosis of a fat embolism syndrome was made according to a scoring system [13].

End points of the study included the pulmonary (ARDS, ALI) and systemic complications (sepsis, MOF) that developed postoperatively; an adverse outcome was defined by the development of any of these four complications.

Overall, 43 patients (26%) experienced a complication during their hospital course. In 35 patients (21%), ALI was diagnosed and sepsis occurred in 18 patients (11%). No patient developed ARDS and none developed MOF. Besides the defined adverse effects, the criteria for SIRS were fulfilled in 53 patients (32%). No patient died from any of the ensuing clinical complications.

We used independent sample t-tests to determine the differences in age and ISS and for AIS values and GCS, the Mann-Whitney U test was used to seek a discrepancy in patients without and with major complications. Pearson chi-square tests were performed to determine differences in sex patients without and with major complications. Pearson chi-square tests were performed to determine differences in sex between the two groups. For binary outcomes assessing events during the clinical course (ie, ISS > 30, GCS < 9, partial thromboplastin time, volume requirement > 1.5 L/1 hour, platelet count < 150,000/mm³, base deficit < -6 mmol/L, temperature < 35° C, AIS chest > 2, presence of lung contusion, ventilation duration > 48 hours), logistic regressions were used. For all regression models, robust SEs were used and p values < 0.05 were considered significant. Odds ratios (ORs) were calculated for all variables. We performed a sensitivity, specificity, and positive predictive value analysis on all of the described events to predict the occurrence of one or more of the four complications. Variables were then grouped into clusters of three and sensitivity, specificity, and positive predictive value for the development of complications again computed. All data were analyzed using SPSS software (Version 20; SPSS Inc, Chicago, IL, USA).

Results

We found a lower GCS (p = 0.032) in patients with complications compared with those with an uneventful clinical course (Table 2).

Table 2. Demographic data for patients with and without adverse outcomes

Preoperative indicators	Patients with complications (n = 43)	Patients without complications (n = 122)	p value
Sex (male/female)	34/9	98/24	0.503 [‡]
Age (years)	30 ± 10	36 ± 14	0.022*
ISS (points)	22 ± 8	25 ± 6	0.055*
GCS (points)	11.7 ± 4.3	13.7 ± 3.1	0.032 [†]
AIS (points)			
Head	0.9 ± 1.2	1.1 ± 1.4	0.645 [†]
Face	0.3 ± 0.8	0.5 ± 1.1	0.500 [†]
Thorax	2.0 ± 1.7	2.2 ± 1.5	0.619 [†]
Abdomen	0.9 ± 1.4	1.2 ± 1.5	0.262 [†]
Extremities	3.0 ± 0.9	3.0 ± 0.8	0.845 [†]

* Independent samples t-test; [†]Mann-Whitney U test; [‡]Pearson's chi-square test; ISS = Injury Severity Score; GCS = Glasgow Coma Scale; AIS = Abbreviated Injury Score.

None of the assessed perioperative clinical parameter reached statistical relevance in predicting postoperative complications. Only patients matching the preoperative indicators (ISS > 30 [OR 3.61, $p = 0.02$] and GCS < 9 [OR 3.61, $p = 0.02$]) showed higher risks to sustain adverse effects. None of the laboratory parameters was indicative of later complications (Table 3).

From postoperative findings, patients with lung contusion (OR 2.29, $p = 0.04$) and with ventilation hours exceeding 48 hours (OR 3.02, $p = 0.01$) showed a higher risk to develop complications. When grouping factors to clusters of three, with the combination of AIS chest > 2, ventilation hours exceeding 48 hours, and GCS at arrival < 9, a 0.95 sensitivity (with a 0.41 specificity) was reached (Table 3).

Discussion

In patients with multiple injuries, a variety of general parameters has been used to predict outcomes or to describe the general risk of complications. In the first report about this topic, the value of systolic blood pressure, heart rate, central venous pressure, and hematocrit was discussed [32]. The criteria proposed by the Advanced Trauma Life Support program also include different stages of acute hemorrhage [28]. To estimate the degree of blood loss, the requirement of mass transfusion (10 units/12 hours) has been advocated [27, 40]. Among the metabolic parameters predicting survival, Asensio et al. [1] recommended the use of increased lactate or base excess values. Acute coagulopathy reportedly independently predicts

adverse outcome in trauma patients [11]. We have previously described that subclinical parameters can indicate an increased risk of complications [23, 24]. We looked at scoring systems and routine parameters known to determine the clinical status. We therefore asked whether (1) any preoperative indicators predict major complications after major extremity surgery; (2) perioperative routine parameters other than those for hemorrhagic shock predict postoperative complications; and (3) any postoperative clinical findings can predict major complications in the further course of the patient.

Our study has certain limitations. First, excluding patients not cleared for major extremity surgery may represent a selection bias. Similar questions have been addressed by the Canadian Orthopaedic Trauma Society [29] and with any study design, there will always be the decision between including all subgroups versus showing only the best cases, ie, including only very stable patients. We chose a compromise with including patients in borderline condition. Patients in unstable or in extremis condition, which we excluded, are routinely judged by their hemodynamic parameters. Therefore, our findings confirm these particular parameters are of limited value in this particular patient subset. Second, both external fixators and intramedullary nails were used for initial stabilization of the femoral shaft fracture. All patients were by study protocol amenable to an intramedullary nail, but not all were initially treated with the intramedullary device. One may argue that this is a selection bias. Instead, all parameters were applied in a fairly well-defined subgroup and most parameters were assessed either pre- or perioperatively. Only in borderline patients treated with primary nailing ($n=23$) an increased ventilation time might be viewed as a potential influence, as described previously [25]. In the current study, however, the focus was on other factors, especially those regarding the perioperative condition. Third, the number of patients is limited in the group with complications (43 versus 122 without). This can be explained by the strict inclusion criteria that focused on the patients in stable and borderline condition. Again, we examined a patient cohort with very strict inclusion criteria, which may be a confounding factor. On the other hand, had we included numerous other centers, just to increase patient numbers, the variability in the local management strategies could have interfered with the data obtained. The group of authors involved in the initial study (25) believed this might weaken the quality of data collection.

Patients with complications in the course showed a relevant decrease in GCS values on admission. Thus, our findings confirm previous studies [22] suggesting that established early accessible indicators are useful adjuncts in predicting postoperative complications. Among these, the GCS appears to be important. We are, however, unable

Table 3. Clinical parameters and prognostic values

Single factor analysis	Sensitivity	Specificity	Positive predictive value	Regression analyses		
				Odds ratio	p value	Z
GCS (< 9)	0.26	0.91	0.65	3.61 (1.22–10.65)	0.02	2.33
ISS (> 30)	0.19	0.91	0.65	3.61 (1.22–10.65)	0.02	2.33
PTT (> 45 seconds)	0.16	0.91	0.54	2.04 (0.64–6.54)	0.23	1.20
Volume requirement (> 1.5 L/1 hour)	0.49	0.59	0.43	1.40 (0.65–3.01)	0.39	0.86
Platelet count (< 150,000/mm ³)	0.16	0.81	0.35	0.84 (0.3–2.30)	0.73	0.34
Temperature (< 35° C)	0.09	0.96	0.57	2.26 (0.48–10.61)	0.30	1.03
Base deficit (< –6 mmol/L)	0.09	0.99	0.80	6.97 (0.75–64.63)	0.09	1.71
Lung contusion (yes)	0.47	0.57	0.40	2.29 (1.03–5.09)	0.04	2.03
Ventilation (> 48 hours)	0.77	0.72	0.63	3.02 (1.29–7.08)	0.01	2.55
AIS chest (> 2)	0.56	0.48	0.40	1.16 (0.54–2.49)	0.71	0.38
Triple factor analysis			Sensitivity	Specificity	Positive predictive value	
AIS chest (> 2)/ventilation (> 48 hours)/GCS (< 9)			0.95	0.41	0.68	
AIS chest (> 2)/ventilation (> 48 hours)/temperature (< 35° C)			0.95	0.38	0.68	
AIS chest (> 2)/ventilation (> 48 hours)/PTT (> 45 seconds)			0.93	0.39	0.67	
AIS chest (> 2)/ventilation (> 48 hours)/base deficit (< –6 mmol/L)			0.95	0.41	0.68	
AIS chest (> 2)/volume requirement (> 1.5 L/1 hour)/PTT (> 45 seconds)			0.77	0.29	0.55	

AIS = Abbreviated Injury Score; PTT = partial thromboplastin time; ISS = Injury Severity Score; GCS = Glasgow Coma Scale.

to assess whether these parameters played a particular role in our patient subset. A further study appears to be required that includes patients with higher ISSs.

We observed a lack of predictive power for routinely used parameters assessing the clinical status. We found this surprising because other authors have reported a number of parameters (eg, number of blood units given, presence of more than three rib fractures, high ISS scores) relevant in predicting adverse outcome and increased mortality [11, 12, 21, 24]. Our apparently contradictory findings may be related to patient selection in addition to limited power. All patients were in a reasonable clinical condition based on the inclusion criteria. Those factors that are commonly used in critically injured patients, namely hypothermia, acidosis, and coagulopathy (indicating the “triad of death”) [17], were irrelevant in this particular patient subset. The fact that routine scores such as the ISS and GCS were associated with adverse outcomes is interesting because all these patients were expected to have an uneventful hospital course. This underlines the importance of these established grading systems. One may argue that the ISS should not be used alone, because it was assessed at the time of discharge for this particular study. The strength of the ISS in this particular study may be overrated. Had the ISS scores not been used, the undiagnosed injuries might have led to a lower association with outcome.

The predictive postoperative parameters demonstrate the importance of thoracic trauma in predicting adverse

effects. To understand this, certain aspects in terms of the posttraumatic pathophysiology have to be considered. The close interaction among several cascade systems of the posttraumatic stress response has been well described [9]. A main inductor of hypoxemia and inflammation is the presence of soft tissue injuries [2]. These can derive from the extremities or the lung [39]. The pulmonary vasculature is known for its potential to recruit polymorphonuclear leukocytes. This was in part attributed to its extraordinary perfusion [35]. It can increase in the presence of lung contusions. This might explain why lung contusions were among the best predictors of adverse outcome in this study. Interestingly, chest trauma has not been believed to represent an important factor in the decision-making process about fracture fixation, yet none of the reports dealing with chest trauma has been designed as a prospective study. The fact that our study was documented prospectively may represent an advantage [14, 36]. Likewise, the degree of chest trauma has not been quantified in many of the available studies. Given the differences in the risk of ARDS between lung contusions versus rib fractures only, the clinical relevance of some of these studies is limited [23].

We found the most sensitive individual parameters associated with postoperative complications in uncritical polytrauma patients were low GCS levels at admission and the presence of lung contusions. The data suggest routine clinical parameters are not predictors of adverse outcome

in this particular patient population presenting with a moderate ISS. Better predictions can be achieved when using a combination of factors. Whether these values might help in the decision-making process to clear more severely injured polytraumatized patients for major operations may be subject to future study.

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