# Assessment of Risk Factors, Management, and Outcomes for Suspected Crush Injuries in Pediatric Polytrauma Patients before and after Guidelines Applications

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## ABSTRACT

**Background:** Trauma can cause rhabdomyolysis through direct muscular injury due to crush or blunt injuries (e.g., road traffic accidents, falls, natural disasters, child abuse) as well as by electrical or thermal burns**, Aim:** Aims of the study was to assess the outcomes of severe polytrauma children suspected of having crush injuries attending to the emergency department of Suez Canal University Hospital; To assess the relevant risk factors; To assess our current management and effects on outcomes; and To assess the knowledge, practice and competence of the emergency doctors after application of a proposed guidelines. **Patients and Methods:** The study was an interventional prospective study. The study was conducted at Emergency department in Suez Canal University Hospital. **Results:** Hb <10 g/dl was the only risk factor that was statistically significantly related to MT. The AUROCs of Hb <10 g/dl and BIG score were fair while the AUROC of Hct <35% was good in predicting MT. **Conclusion:** Our results indicate that our management through application of proposed treatment guidelines can modify outcomes of polytraumatized children with musculoskeletal injuries and suspected of having crush injuries. Our statistical model includes several outcome predictors that can help to create criteria for assessment and management of suspected crush injuries in pediatric polytrauma patients. **Key Words: Trauma, Pediatrics, Crush Injuries; Rhabdomyolysis.**

## Introduction

Every year more than 5 million people die from non-intentional traumatic injuries, homicide and suicide, representing 9% of global deaths **[1].** Additionally, 20 to 50 million people suffer non-fatal injuries, many of them resulting in disability **[2].** Most of these injuries and deaths occur in children and adolescents below the age of 19, and virtually trauma is the leading cause of death in people less than 40 years **[3].**

Injury is the leading cause of death for children over the age of 1 year. The highest burden of injury is seen in low-and-middle income countries (LMICs), where 95% of all childhood injury deaths occur **[4].**

Trauma can cause rhabdomyolysis through direct muscular injury due to crush or blunt injuries (e.g., road traffic accidents, falls, natural disasters, child abuse) as well as by electrical or thermal burns **[5].**

The European Renal Best Practice and Renal Disaster Relief Task Force (RDRTF) addressed the prevention of AKI in crush victims following mass disasters. Recommendations indicate that patients with rhabdomyolysis should receive sodium bicarbonate, mannitol, and fluid therapy to prevent acute renal failure **[6].**

Traumatic rhabdomyolysis is diagnosed with the classic triad of muscle pain, muscle weakness and dark urine due to myoglobinuria. Elevated serum creatine phosphokinase (CPK) five times above the upper limit of normal within 48 hrs of trauma is used to confirm the diagnosis **[7].**

So, we conducted a prospective interventional study after applying a proposed management algorithm to evaluate the risk factors, management and outcomes of children with severe trauma suspected of having crush injuries presenting to the emergency department, Suez Canal University Hospital.

Aims of the study was to assess the outcomes of severe polytrauma children suspected of having crush injuries attending to the emergency department of Suez Canal University Hospital; To assess the relevant risk factors; To assess our current management and effects on outcomes; and To assess the knowledge, practice and competence of the emergency doctors after application of a proposed guidelines.

## Patients & Methods

The study was an interventional prospective study. The study was conducted at Emergency department in Suez Canal University Hospital

Study population: All emergency physicians in Suez Canal University Teaching Hospital. Severely injured polytrauma children suspected of having crush injuries presented to emergency department in Suez Canal University Teaching Hospital.

**Inclusion criteria [198]:** Severely injured polytrauma children patients presented to emergency department in Suez Canal University Teaching Hospital with any of the following combination injuries**:** Two major system injury + one significant limb injury, one major system injury + two major limb injury, one major system injury + one open grade 3 or more skeletal injury and unstable pelvic fracture with associated visceral injury(ies)**.**

**ALSO major injury** with either: Death within 24 h, injury severity score (ISS) 16 or more, intensive care unit (ICU) length of stay for 1 day or more and blood transfusion of more than 50% of total blood volume in the first hour or more than 100% in 24 hours after admission. All emergency residents and assistant lecturers in duty in the Emergency Department of Suez Canal University Hospital.

**Exclusion criteria:** Patients with a preexisting coagulation profile or bleeding disorders, patients with medical disorder causing acidosis and polytrauma patients with mild or moderate injuries.

**Methods of the study:** An informed written consent was obtained from all patients' guardians participating in the study. All of the studied patients were subjected to careful history, examination and investigations.

Complete personal, medical history including: Serial number, age, educational level, occupation, address and past history of any chronic illnesses, operations, hospitalizations, trauma, accidents, allergies; medications; illicit drugs or drug abuse.

Prehospital factors such as; type of trauma, time before admission, transportation, any interventions by ambulance personnels, laypersons, or other caregivers such as, type and amount of fluid infusion or blood transfusion, splinting, tourniquets, compressive dressings, bandages or slabs; or any life-saving advanced procedures such as intubation, cricothyroidotomy, or chest drains.

Complete physical examinations including anthropometric measures (height/length, weight, BMI), primary survey with the ABCDE approach, vital signs, GCS, random blood sugar, neuromuscular examination, peripheral pulsations, muscle power, grade of skeletal injuries.

Laboratory investigations including complete blood count, liver functions, prothrombin time (PT), partial thromboplastin time (PTT), international normalized ratio (INR), arterial/venous blood gases (A/VBG), electrolytes (Na, K, Ca, $PO_4$, & lactates), creatinine and urea, and serial serum creatine phosphokinase (CPK).

Imagings including plain X rays, Focused Assessment with Sonography for Trauma (FAST), and CT scan, Doppler Ultrasound for extremities, if indicated.
ECG was a routine and was repeated in cases of electrolyte disturbances, dysrhythmias, development of AKI, or with suspected precordial trauma.
Relevant scores like ISS, revised injury score (RTS), BIG score, pediatric trauma score, in addition to pRIFLE and estimated creatinine clearance (eCCl).
Length of Stay in the ED, ICU length of stay, need and time course of ventilation and hospitalization were also be recorded.
Assessment of patients' management and outcomes were done for participating polytrauma children included in the study before and after the intervention program.
All emergency physicians were subjected to a questionnaire to assess their knowledge before and after health education session about crush of polytrauma children to assess their knowledge and skills.

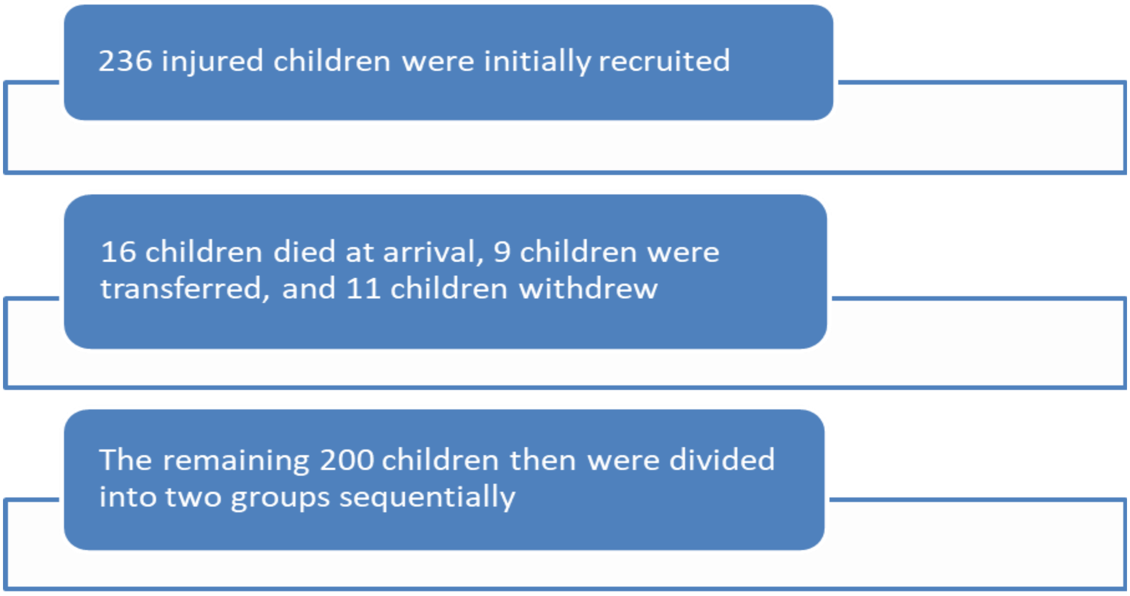


**Fig. 1: Flow Chart of the Study Population**

**Statistical Analysis:** The collected data were coded, processed and analyzed using the SPSS (Statistical Package for Social Sciences) version 26 for Windows® (IBM, SPSS Inc, Chicago, IL, USA). Data were tested for normal distribution using the Shapiro Walk test. Qualitative data were represented as frequencies and relative percentages. Chi square test ($\chi 2$) and Fisher exact was used to calculate difference between qualitative variables as indicated. Quantitative data were expressed as mean ± SD (Standard deviation). Independent samples t-test was used to compare between two independent groups of normally distributed variables (parametric data) while Mann Whitney U test was used for non-normally distributed Data (non-parametric data).

## Results

Table (1) demonstrates the demographic data of the two groups.

| | | Pre-implementation (n= 100) | Post-implementation (n= 100) | 95% CI | P |
|---|---|---|---|---|---|
| **Age (years)** | | 10.74 ± 3.768 | 10.97 ± 3.540 | -1.2, 0.8 | **0.657** |
| **Gender** | **Male** | 72 (72.0%) | 69 (69.0%) | - | **0.642** |
| | **Female** | 28 (28.0%) | 31 (31.0%) | | |
| **Height/Length (cm)** | | 119.81 ± 23.469 | 121.37 ± 22.371 | -4.9, 6.2 | **0.809** |

| | | | | | |
|---|---|---|---|---|---|
| **Weight** | | 29.18 ± 7.149 | 31.18 ± 6.956 | -3.8, 4.7 | **0.733** |
| **Residency** | **Rural** | 40 | 42 | - | **0.879** |
| | **Urban** | 60 | 58 | | |

The mean age was around 11 years, 70% being males and 41% were from rural areas. Demographics didn't significantly differ between the two groups before and after intervention.

**Table 2: FAST results & Need for Laparotomy**

| | | Pre-implementation (n= 100) | Post-implementation (n= 100) | P |
|---|---|---|---|---|
| **FAST** | **Free** | 74 (74.0%) | 73 (73.0%) | **0.864** |
| | **Mild Collection** | 18 (18.0%) | 21 (21.0%) | |
| | **Moderate to Severe Collection** | 8 (8.0%) | 6 (6.0%) | |
| **Need for Laparotomy** | | 2/8 (25%) | 1/6 (17%) | **0.314** |

Most of the injured children in both arms had a free FAST examination at presentation to the trauma bay. Only 14 children (8 before and 6 after intervention) had moderate to severe or progressive intraperitoneal collection. No patient was seen to have a solid organ injury (SOI). Among these 14 patients, only three children required surgical exploration.

**Table 3: Fluid and Blood Management among the Two Groups**

| | Pre-implementation (n= 100) | Post-implementation (n= 100) | P |
|---|---|---|---|
| **Amount of Crystalloid (ml/Kg)** | 14.98 ± 6.008 | 11.61 ± 3.327 | **0.041** |
| **Amount of Transfused Blood (ml/Kg)** | 19.917 ± 4.680 | 19.220 ± 5.559 | **0.324** |
| **Amount of Transfused FFP (ml/Kg)** | 14.292 ± 5.377 | 15.250 ± 4.390 | **0.417** |
| **Total blood products transfusion (ml/Kg)** | 23.171 ± 9.760 | 27.047 ± 10.710 | **0.046** |
| **Total crystalloids & blood products (ml/Kg)** | 23.17 ± 14.574 | 28.56 ± 15.943 | **0.039** |

The mean amount of ***crystalloid*** was statistically significantly ***higher*** in the pre-implementation group. Children were more likely to receive less crystalloids and more likely to receive blood/blood products after the intervention program. Other resuscitative/hemostatic measures such as platelets transfusion, fibrinogen, cryoprecipitates, tranexamic acid, calcium, mannitol or bicarbonate infusion, as well as inotropic amines were not used in our management.

**Table 4:** Predictors of Massive Transfusion (MT)

| **Test Result Variable(s)** | | **P- Value** | **AUROC** | **Std. Error** | **95% Confidence Interval Lower Bound** | **95% Confidence Interval Upper Bound** |
|---|---|---|---|---|---|---|
| **Vital Signs** | **Tachycardia** | 0.72 | 0.391 | 0.068 | 0.258 | 0.523 |
| | **Hypotension** | 0.107 | 0.584 | 0.084 | 0.419 | 0.750 |
| **CBC** | **Hb < 10 g/dl** | 0.015 | 0.738 | 0.066 | 0.654 | 0.912 |
| | **Hct < 35** | 0.089 | 0.808 | 0.049 | 0.713 | 0.903 |
| **Traum** | **GCS** | 0.603 | 0.343 | 0.080 | 0.187 | 0.499 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | **ISS** | 0.118 | 0.676 | 0.061 | 0.556 | 0.795 |
| | **NISS** | 0.341 | 0.628 | 0.075 | 0.481 | 0.776 |
| | **RTS** | 0.278 | 0.546 | 0.078 | 0.394 | 0.698 |
| | **PTS** | 0.918 | 0.468 | 0.084 | 0.303 | 0.633 |
| | **BIG Score** | 0.322 | 0.714 | 0.071 | 0.574 | 0.853 |
| | **Shock Index** | 0.970 | 0.519 | 0.081 | 0.361 | 0.677 |
| **FAST** | | 0.426 | 0.504 | 0.080 | 0.347 | 0.861 |
| **Lactate** | | 0.399 | 0.560 | 0.073 | 0.417 | 0.704 |
| **BD** | | 0.119 | 0.595 | 0.069 | 0.459 | 0.731 |
| **ABG** | **Ph** | 0.414 | 0.372 | 0.096 | 0.184 | 0.559 |
| | **$HCO_3$** | 0.724 | 0.390 | 0.094 | 0.206 | 0.574 |
| **Coagulopathy** | | 0.929 | 0.611 | 0.066 | 0.480 | 0.741 |
| **Lethal Triad of Trauma** | | 0.216 | 0.626 | 0.082 | 0.466 | 0.787 |

Hb <10 g/dl was the only risk factor that was statistically significantly related to MT. The AUROCs of Hb <10 g/dl and BIG score were fair while the AUROC of Hct <35% was good in predicting MT.

**Table 5: ISS and Predicting Mortality at Cut Points 16 & 25.**

| | Survivors (%) | Non-Survivors (%) | P |
|---|---|---|---|
| **ISS ≥16** | 185/200 (92.5%) | 15/200 (7.5%) | **0.715** |
| **ISS ≥25** | 50/58 (86.2%) | 8/58 (13.8%) | **0.038** |

The area under the curve was estimated after plotting the trauma scores against the major outcomes. Trauma scores performed poorly in predicting mortality except the BIG score that was fair with an AUROC of 0.704. The best cut-off for the BIG score was 8.5 with a sensitivity of 60% and a specificity of 73.5%.

**Table 6: Coagulopathy & The Lethal Triad as Outcome Predictors.**

| Outcome (p value) / Predictor | Death | MODS | RRT | Elevated CK | AKI | Hospital LOS | ICU LOS | Vent. Days |
|---|---|---|---|---|---|---|---|---|
| **INR** | 0.033 | 0.002 | 0.066 | 0.000 | 0.127 | 0.043 | 0.087 | 0.009 |
| **Coagulopathy** | 0.513 | 0.431 | 0.367 | 0.029 | 0.866 | 0.920 | 0.989 | 0.986 |
| **Lethal Triad** | 0.535 | 0.205 | 0.001 | 0.000 | 0.257 | 0.202 | 0.019 | 0.194 |

INR was a predictor of mortality and MODS. Surprisingly, coagulopathy was not a predictor of any outcome. The lethal triad was a predictor of renal replacement therapy, elevated CK levels, and ICU stay

**Table 7: FAST as an Outcome Predictor.**

| Outcome (p value) / Predictor | Death | MODS | RRT | Elevated CK | AKI | Hospital LOS | ICU LOS | Vent. Days |
|---|---|---|---|---|---|---|---|---|
| **FAST** | 0.473 | 0.570 | 0.697 | 0.000 | 0.051 | 0.017 | 0.121 | 0.121 |

**Table 8:** AUROC of SCr and developing AKI

| Test Result Variable(s) | Area | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|
| | | | | Lower Bound | Upper Bound |

| | | | | | |
|---|---|---|---|---|---|
| **Estimated Creatinine Clearance (eCCl)** | .047 | .016 | .000 | .015 | .079 |
| **Initial Serum Creatinine** | 0.713 | .041 | .000 | .632 | .794 |
| **48 hrs Serum Creatinine** | .464 | .045 | .416 | .376 | .551 |
| **Serum Creatinine on Discharge** | .528 | .045 | .529 | .439 | .617 |
| A chosen best cut-off initial serum creatinine 0.91 mg/dl has a sensitivity of 65% and a specificity of 75%. | | | | | |

Predictors of AKI on multivariate and regression analyses were; RR (P= 0.029), eCCl (0.000), 48 hrs S. Cr. (P= 0.013), and mechanical ventilation (P= 0.006). Initial creatinine was predictive of AKI on univariate analysis and had a fair AUROC of 0.713 for detecting AKI (Best cut-off 0.91 mg/dl with 65% sensitivity and 75% specificity.

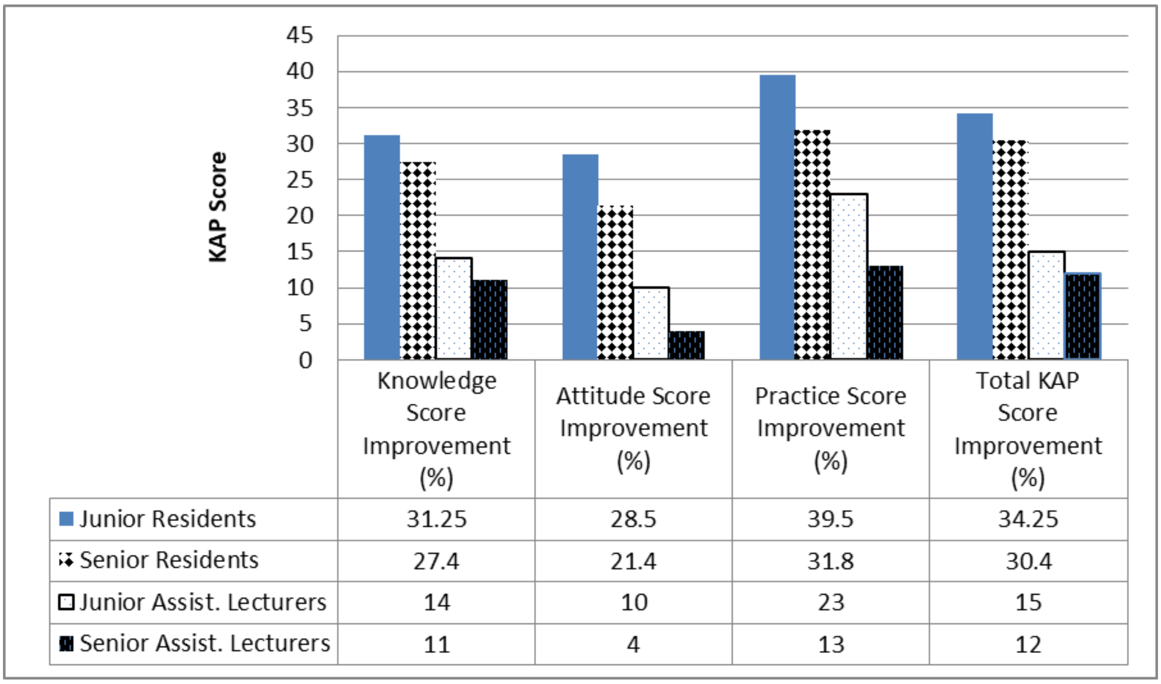


**Fig. 2:** Effect of ED Staff Experience on Improvement of KAP Scores. KAP domains and total KAP Scores Changes (X- Axis) plotted against the Corresponding Percentage (Y- Axis); P < 0.01.

The ED staff of low experience (up to one year residency) demonstrated low baseline KAP Scores. Baseline total KAP scores and the three KAP domain scores tended to increase with the staff experiences. The KAP scores improvements post-intervention were maximal among the junior residents and the improvements declined steadily so that KAP scores among junior staff became comparable to those of senior assistant lecturers.

## Discussion

Analysis of the Trauma Audit and Research Network (TARN) national database in UK demonstrated a trend of decreasing overall mortality as mortality decreased from 4.2% to 3.1% **[8].**

This is an interventional study conducted of a consecutive sample of severely injured polytrauma children suspected of having crush injuries presented to Emergency Department, Suez Canal University Hospital (SCUH).

Assessment of patients' management, outcomes and risk factors was done for 200 polytrauma children included in the study subdivided into 2 groups; pre (n= 100) and post (n= 100) implementation of a guideline based on published works.

The mean age of our cohort was 10.81±3.63 years, 70% of them were males. In a study performed by **Iz et al., [9],** the mean age was 12.3±2.9 years with 65.2% % of the injured patients were males. Males comprised 69% of 9851 children with moderate and severe injuries in a study with data drawn from TARN **[10].** In a Nigerian study, 60.9% of trauma children were males with a mean age of 12.5±6.9 years **[11].**

The majority (91.5%) of injuries in our cohort were due to road traffic injuries (pedestrians and vehicle occupants), followed by falls from height. The very high rate of motor road accidents in our cohort may reflect a selection bias because of including only trauma children suspected of having crush injuries. **Naqvi et al., [10]** reported that vehicle related incidents were the most common mechanism of injury in 46.0% of their cohort. **Chen et al., [12]** reported that the major fatal mechanisms in under-five unintentional injury were drowning and road injury**.**

In our study, 26.5% had a positive FAST in the whole cohort at presentation. Among 508 pediatric trauma patients, 19.3% were FAST positive **[13].** Among the 925 children with **stable** torso blunt trauma, FAST was positive in 5.4% **[14].** A positive FAST was reportedly high in a series of 1066 pediatric patients with possible abdominal injuries at a rate of 63% **[15].**

A positive FAST and a positive physical examination were predictors of intra-

In our study, among the 14 patients with moderate/marked or progressive free fluid collection, only three children (1.5%) required surgical exploration due to hemodynamic instability. The incidence of children subjected to laparotomy in our cohort is similar to 1.8% reported in a series of 925 trauma children with a mean age of 9.7±5.3 years **[14].** Only 2.1% of children with torso trauma required an acute intervention in the form of abdominal operation or angiographic embolization **[16].** In a series of 1066 pediatric patients with possible abdominal injuries, only 3.5% were treated surgically **[15].**

We reported only three children who needed laparotomy. These three unfortunate children who passed later during their ICU stay after few days of post emergency laparotomy. FAST didn't detect any solid organ injuries (SOIs), however on exploration two had splenic tears and one had a hepatic injury with associated bowel injuries. A lot of studies documented the low sensitivity of FAST for detecting SOIs **[17].**

The incidence of mortality to hospital discharge was 7.5% in our cohort with 8 children (8.0%) of the pre-implementation group, and 7 (7.0%) of the post-implementation group. All the 15 deaths occurred during the course of ICU stay due to severe TBI, respiratory failure, MODS and sepsis.

Our death rate is comparable to the death rate of 7% reported in a Korean study over 545 trauma children **[18].** In a retrospective study over 597 children < 18 years with NISS >15, the 30-day mortality was 9.8% **[19].**

None of the studied trauma scores were associated with mortality in our study. However, ISS at the cut point ≥25 became predictive of mortality. **Brown et al., [20]** found that an ISS of 25 should be the cut point for defining severe trauma in children as it predicted in children a mortality rate comparable to that associated with ISS >15 in adult trauma.

The incidence of MODS in our cohort was 10.5%, comprised of 10 children among the pre-implementation group, and 11 among the post-implementation group.

The mean length of hospital stay in our cohort was 6.675±4.402 days [range 2-32]. Among 12,508 pediatric trauma patients presented to the ED, 8.8% of all patients were hospitalized for at least one day **[21].** In the propensity matched cohort addressing PHI in children, the median LOS was 3 (IQR: 7) days **[22].**

The predictors for hospital stay in our study were; the RR, external bleeding and severe injuries. Injury severity measured by different scores except SI and NISS predicted hospital length of stay. Both RTS and PTS were excellent predictors with an AUROC of >0.9.

Predictors of ICU LOS in our study were; age, prehospital transport time, length/height, peripheral oxygen saturation, capillary RBS, NISS, $HCO_3^-$ , and mechanical ventilation. ICU admission was associated with abnormal SIPA, increased ISS, lower GCS, TBI, cervical spine injury, skull fracture, severe solid organ injury, and anemia with Hct >30%**.** Trauma children admitted to the PICU had 2-3 times significantly higher risk of hospital readmission compared with those never admitted to the PICU **[23].**

Ninety nine children in our whole cohort (49.5%) received blood/blood products. In a Korean study over 545 trauma children, 43.5% needed transfusion **[18].** Of 356,583 pediatric trauma patients ≤ 14 years, 13,523 (4%) received any transfusion in the first 24 hours and only 173 (0.04%) had a massive transfusion **[24].**

We encountered 43 children (21.5%) with intraperitoneal free fluid collection; 29 children (14.5%) of them had mild collection and 14 (7%) had moderate/marked collection. In a meta-analysis encompassing 2135 children with blunt abdominal trauma in eight prospective studies, the weighted prevalence of intraabdominal injuries was 13.5% **[25].**

Rhabdomyolysis defined as elevated CPK > 1000 U/L occurred in 7.5% of our children. This is much lower than the 40.3% prevalence reported in a retrospective study of 372 adult trauma patients reported by **Assanangkornchai et al [26].** This might be due to the fact that children has less muscle mass than adults. A study found that body mass index was correlated with both CK levels and AKI **[27].**

Predictors of elevated CK levels (A diagnostic surrogate of RML) were mechanism of injury, SBP, pulse oximetry (SO2 saturation), SI, ALT, AST, MODS, RRT, and operative orthopedic interventions.

In our cohort, the mean estimated creatinine clearance was (94.83 ± 14.201 ml/min) in the pre-implementation group, and (95.37 ± 13.850 ml/min) in the post-implementation group. The mean SCr was 0.89 mg/dl before and 0.92 mg/dl after implementing the intervention.

In our cohort, 61 children (30.5%) had AKI according to pRIFLE SCr criteria. The reported overall incidence of post-traumatic AKI ranges from 15% to 50% with an incidence of severe AKI ranging from 9% to 26% **[28].** 35.9% of children developed AKI in a series of 64 children with a median age, 9.6 years subjected to motor vehicle crashes. Acute kidney injury patients had higher injury severity scores **[29].**

Current use of ISS in pediatric trauma may not accurately reflect injury severity**.** An ISS score of 25 was suggested to be the cut off for pediatric trauma equivalent to the usual cut off of 16 in adults for defining severe trauma **[20].**

The performance of trauma scores GCS, ISS, and RTS for predicting mortality and prolonged ICU stay more than 14 days was investigated in children less than 6 years with a mean age of 3.1 ± 1.82 years admitted with any traumatic injury. An elevated ISS 34±19.9, lower GCS 8±5, and lower RTS 5.58±1.498 were all associated with mortality. All the three scores were independent risk factors also for prolonged ICU stay and had a linear correlation with increased hospital LOS **[30].**

In our cohort, a considerable set (49.5%) of children had been transfused.

Independent predictors of MT in a series of 356,583 pediatric trauma patients ≤ 14 years were children ≥ 12 years, hypothermic patients < 35 °C, GCS <8, and ISS ≥ 25 **[24].**
In our study, FAST results were predictive only for hospital stay and elevated CPK level. In a study over 211 adult trauma patients managed nonoperatively, FAST didn't affect the outcomes**.** A positive FAST examination is a highly significant predictor of in-hospital mortality in children and adults with pelvic fractures**.**
Trauma patients with confirmed abdominal injury and a false-negative FAST have a better outcome than those with a positive FAST **[31].**

## Conclusion

Our results indicate that our management through application of proposed treatment guidelines can modify outcomes of polytraumatized children with musculoskeletal injuries and suspected of having crush injuries. Our statistical model includes several outcome predictors that can help to create criteria for assessment and management of suspected crush injuries in pediatric polytrauma patients.

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