Using the Red Cross wound classification to predict treatment needs in children with conflict-related limb injuries: a retrospective database study

Lisanne van Gennip1, Frederike J. C. Haverkamp1*, Måns Muhrbeck2, Andreas Wladis2,3 and Edward C. T. H. Tan1,4

Abstract

Background: The International Committee of the Red Cross (ICRC) implemented the Red Cross wound classification (RCWC) to quickly assess the severity of a wound in conflict settings. A subdivision into wound grades derived from the RCWC consists of grades 1, 2, and 3, and represents low, major, and massive energy transfer, respectively, to the injured tissue. The aim of this observational study is to assess whether the Red Cross wound grade of a pediatric patient’s wound correlates with patient outcomes.

Methods: All pediatric patients (age < 15 years) treated in an ICRC hospital between 1988 and 2014 for conflict-related penetrating extremity injuries were retroactively included. Correlations were assessed between wound grades and number of surgeries, blood transfusions, days hospitalized, and mortality. Stratification analyses were performed to evaluate potential effect modifiers.

Results: The study included 2463 pediatric patients. Pediatric patients with a higher wound grade received significantly more surgeries (grade 1 median 2; grade 3 median 3), more blood transfusions (grades 1 and 3 received 33.9 and 72.2 units per 100 patients, respectively), and were hospitalized longer (grade 1 median 15; grade 3 median 40 days). Mortality rates did not significantly differ. Stratification analyses did not reveal effect modifiers for the association between wound grades and patient outcomes.

Conclusion: The Red Cross wound grade of a pediatric patient’s extremity wound correlates independently with treatment needs. This simple wound grading system could support clinical decision-making and should be integrated into the clinical assessment of weapon-wounded pediatric patients in conflict settings.

Keywords: Global health, Pediatric surgery, Wound classification, Extremity injury

© The Author(s). 2020. Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article’s Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article’s Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by/4.0/. The Creative Commons Public Domain Dedication waiver (http://creativecommons.org/publicdomain/zero/1.0/) applies to the data made available in this article, unless otherwise stated in a credit line to the data.

* Correspondence: frederike.haverkamp@radboudumc.nl
† Lisanne van Gennip and Frederike J.C. Haverkamp contributed equally to this work.
† Lisanne van Gennip and Frederike J.C. Haverkamp shared first authorship.
1Department of Surgery, Radboudumc, P.O. Box 9101, 6500 HB Nijmegen, the Netherlands
Full list of author information is available at the end of the article
Introduction
Managing conflict-related penetrating injuries can be challenging. These injuries differ from non-conflict-related injuries in mechanism, degree of contamination, variability in tissue damage, patient’s pre-hospital transfer time, and availability of resources in these environments [1, 2]. Performing an adequate wound assessment is therefore crucial. Several classification systems exist to describe wounds and guide its management, such as the Gustilo-Anderson (GA) classification [3], Tscherne classification [4], and the Arbeitsgemeinschaft Osteosynthesefragen (AO) soft tissue grading system [5]. These classifications correlate with patient outcomes including healing and infection rates, need for secondary surgeries and amputation, length of hospitalization, and lifestyle changes [6–10]. However, the Gustilo-Anderson, Tscherne, and AO soft tissue classifications might not suffice for appropriate description of conflict-related weapon wounds. First of all, they might not be sufficiently distinctive, as conflict-related injuries are most often high-velocity injuries and will frequently be considered a grade 3 in the Gustilo-Anderson classification. Additionally, the classifications apply only to injuries related to a fracture.

Therefore, the International Committee of the Red Cross (ICRC) implemented the Red Cross wound classification (RCWC) to navigate wound assessment in conflict areas. The ICRC is a neutral, independent organization that carries out humanitarian initiatives in many ways. It is one of the world’s main organizations providing medical care in conflict areas for weapon-wounded patients. In the 1990s, the RCWC was developed by Dr. R.M. Coupland, a former ICRC surgeon and a current ICRC medical advisor.

The RCWC describes the wound size and the presence or absence of a cavity, fracture, injury to a vital structure, or metallic foreign body (see Table 1). A subsequent classification system derived from the RCWC is the wound grading system (see Table 2), which subdivides wounds into grades 1, 2, or 3 based on wound size, fracture type (if any), and the presence or absence of a cavity. These grades represent the amount of tissue damage and degree of kinetic energy transferred from the projectile to the body tissue [2, 12–14]. The RCWC was intended to systematically assess wound severity and the type of tissue involved in a quick and easy manner; it recognizes wounds as surgical lesions rather than as weaponry phenomena [2, 11, 13, 15]. Its application could be used to audit surgical performance, to establish a scientific approach to war surgery, and to derive information from the field on wound ballistics [13].

For many years, ICRC surgeons have routinely used the RCWC during assessment of patients treated at ICRC-supported hospitals. A significant part of this patient population comprises pediatric patients with serious conflict-related injuries [16–21]. The application of the RCWC has never been studied in pediatric patients specifically. Wounds with a similar Red Cross wound grade are expected to have a different, more severe impact on the pediatric patient in comparison to an adult patient due to differences in physiology and anatomy [22–25]. Moreover, additional guidance in the management of pediatric patients has been requested by healthcare professionals working in conflict zones [26–29].

Table 1 Red Cross wound classification [11]

| Wound feature | Definition |
|---------------|------------|
| E (entry)     | Estimate the maximum diameter of the entry wound in cm |
| X (exit)      | Estimate the maximum diameter of the exit wound in cm (X = 0 if no exit) |
| C (cavity)    | Can the “cavity” of the wound take two fingers (finger width) before surgery? |
|               | C = 0, no |
|               | C = 1, yes |
| F (fracture)  | F = 0, no fracture |
|               | F = 1, simple fracture, hole, or insignificant comminution |
|               | F = 2, clinically significant comminution |
| V (vital structure) | V = 0, no vital structure injured |
|               | V = N (neurological), penetration of the dura of the brain or spinal cord (includes penetrating injuries of the head or paraplegia due to projectiles) |
|               | V = T (thorax or trachea), penetration of the pleura or of the trachea in the neck |
|               | V = A (abdomen), penetration of the peritoneum |
|               | V = H (hemorrhage), injury of a major peripheral blood vessel, down to the brachial artery in the arm or the popliteal in the leg |
| M (metallic body) | M = 0, none |
|               | M = 1, one metallic body |
|               | M = 2, multiple metallic bodies |

V = N, T, and A are subcategories of central wounds; V = H is a subcategory of wounds of the limbs.
those who are less familiar with conflict-related penetrating injuries, clear and robust guidance on wound management is essential. This assistance might be provided by the Red Cross wound grading system. Therefore, the aim of this study is to assess whether the Red Cross wound grade of a pediatric patient’s wound correlates with patient outcomes.

Methods
A retrospective observational study was performed using an ICRC database, which contained data of 38,312 patients from various time periods between 1988 and 2014. Patients were treated in one of the ICRC-supported field hospitals at the following locations: Goma, Democratic Republic of the Congo; Kabul, Afghanistan; Khao-I-Dang, Thailand; Lokichogio, Kenya; Kandahar, Afghanistan; Novye Atagui, Russian Federation; Peshawar, Pakistan; and Quetta, Pakistan (Table 3). All patients at each hospital were included during the given time periods. The data were originally registered on handwritten patient files based on patient assessment by an attending surgeon. The patient files were manually converted into an anonymous electronic database using Microsoft Office Excel®.

This study included pediatric patients under 15 years old with conflict-related extremity wounds (Fig. 1). Pediatric patients with wounds to the head, neck, thorax, abdomen, pelvis, buttocks, back, and junctional areas (e.g., axilla or groin) were excluded, because the exact anatomical site in these injuries may define the outcome of the patient to a greater extent than the wound grade. For example, a small wound to the thorax can still be lethal when involving the heart. Furthermore, patients who lacked variables of the RCWC were excluded. Analyses were limited to patients who had the complete data required for that analysis.

Independent variables available in the database were age, gender, mechanism of injury, distribution of limb injuries (upper or lower), time to reach the hospital since sustaining injury, and the RCWC. The available dependent (outcome) variables were number of surgeries, number of blood transfusions, length of hospital stay, and mortality rate. The variable on mechanism of injury is subdivided into gunshot wounds, mine injuries, burn injuries, fragment injuries, and other injuries. Fragment injuries comprise penetration injuries from shells, bombs, or rockets [13]. The following factors were considered possible effect modifiers on the potential correlation between wound grades and patient outcomes: gender, age category (child or adult), time to reach the hospital since sustaining injury, mechanism of injury, and the presence or absence of a fracture. This latter hypothesis was based on clinical reasoning and supported by previous studies that have demonstrated a correlation between these patient factors and outcome or injury severity [8, 21, 30].

All statistical analyses were executed using SPSS statistical software (IBM SPSS Statistics for Windows, Version 25.0). Descriptive analyses were performed for all variables, and results are presented as percentages or median with interquartile range. Comparative analyses were performed between wound grades and among baseline characteristics as well as outcome variables. If patients had multiple wounds registered, the wound with the

Table 2 Wound grades derived from the Red Cross wound classification [11]

| Grade | Skin defect* | Cavity | Fracture |
|-------|-------------|--------|----------|
| 1     | < 10 cm AND | Absent AND | Absent or simple fracture |
| 2     | < 10 cm AND | Present OR | With clinically significant comminution |
| 3     | ≥ 10 cm AND | Present OR | With clinically significant comminution |

*aSkin defect: size of entry and exit wound combined

Table 3 Specifications per hospital

| Hospital location                     | Period of data collection | Hospital opening date and closing date |
|---------------------------------------|---------------------------|---------------------------------------|
| Kao-I-Dang, Thailand                  | Jan 1988–Sept 1992       | 1979–1993                             |
| Lopiding, Lokichogio, Kenya           | Mar 1988–Mar 2006        | 1987–2006                             |
| Kabul, Afghanistan                    | Mar 1990–Jun 1992        | 1989–1992                             |
| Quetta, Pakistan                      | Apr 1990–Aug 1996        | 1983–1996                             |
| Peshawar, Pakistan                    | Jun 1990–Apr 1993        | 1981–1993                             |
|                                       | Feb 2009–May 2012        | 2009–2014                             |
| Mirwais, Kandahar, Afghanistan        | May 1996–Jun 1999        | 1996–still open                       |
| Novye Atagui, Russian Federation      | Sept 1996–Nov 1996       | Sept 1996–Dec 1996                   |
| Goma, Kivu, Democratic Republic of the Congo | Nov 2012–Oct 2014    | 2012–still open                       |
highest grade was used for comparative analyses between wound grades. A Kruskal-Wallis test was used to determine significant differences for continuous variables, and a chi-square test was used for comparisons of categorical variables. A Bonferroni correction was used for multiple testing. Age, number of surgeries, and length of hospital stay were analyzed as continuous variables. Gender, mechanism of injury, distribution of upper and lower limb injuries, time to reach the hospital since sustaining injury, the RCWC, wound grades, and mortality rate were analyzed as categorical variables in the way they were registered at the initial phase of data entry. The predictive ability was evaluated using $p$ values. A two-tailed $p$ value $< 0.05$ was considered significant.

Stratification analyses were performed to evaluate the influence of potential effect modifiers on associations between the wound grades and outcome variables (number of surgeries, number of blood transfusions, and length of hospital stay). The outcome variable of mortality was not included in the latter analysis, because of the low absolute numbers of deaths.

Data collected at Peshawar (during 2009–2012) and Goma contained some additional variables which were not registered at the other study locations. These variables concerned patients’ characteristics pre-hospital, on arrival, and in-hospital. Additional descriptive subanalyses were performed with these variables among pediatric patients treated in Peshawar and in Goma.

**Results**

The total database (adults included) contained 38,312 patients, of whom 5885 (15.4%) were children under 15 years. The number of pediatric patients who met the inclusion criteria was 2463 (Fig. 1). Regarding the highest wound grade per patient, most pediatric patients had wounds categorized as grade 1 (79.4%, 1956/2463); less often, patients’ wounds were graded as 2 or 3 (13.9%, 342/2463, and 6.7%, 165/2463, respectively).

Table 4 provides an overview of the study population’s characteristics. The age distribution was approximately the same among all three wound grades with a median of 10 years. There were no significant differences between the three wound grades considering gender distribution ($p = 0.191$, df = 2), with the majority being male: approximately 75% in each category. The number of anatomical sites injured per patient (median 1, IQR 1–2,
The time it took for patients to reach the hospital after sustaining the injury was significantly longer in patients with wound grade 3 ($p = 0.004$, $df = 6$); it took almost 50% (81/165) of these patients 72 h or more to reach the ICRC field hospital. A subsequent analysis comparing the time it took to reach the hospital for different age groups (0–2 years, 3–5 years, 6–9 years, and 10–14 years) revealed that it took pediatric patients of 0–2 years significantly more often over 3 days to reach the hospital (54.5%, 116/213; $p = 0.000$, $df = 9$). There were no significant differences between gender in the time it took pediatric patients to reach the hospital ($p = 0.050$, $df = 3$).

Data on patient outcomes per wound grade are listed in Table 5. When a pediatric patient’s wound was graded higher, significantly more surgeries and a longer duration of hospitalization were required (both $p = 0.000$, $df = 2$). Patients with wound grade 3 required the most blood transfusions with 72.2 units per 100 patients and differed significantly ($p = 0.000$, $df = 2$) from wound grades 1 and 2 (33.9 and 37.4 units per 100 patients, respectively). Patients with wound grades 1 and 2 did not differ significantly from each other ($p = 0.266$, $df = 2$).

Mortality rates did not differ significantly among wound grades ($p = 0.091$, $df = 2$).

Stratification analyses did not demonstrate any trend in the effect on associations between wound grades and outcome variables when stratifying by gender, age category (child or adult), time to reach the hospital since sustaining injury, mechanism of injury, and the presence or absence of a fracture.

### Table 4: Subject and injury characteristics per wound grade

| Wound grade 1 | Wound grade 2 | Wound grade 3 | Total |
|---------------|---------------|---------------|-------|
| **Total number of pediatric patients (%)** | 1 956 (79.4%) | 342 (13.9%) | 165 (6.7%) | 2463 (100%) |
| **Median age, years (IQR)** | 10 (7–12) | 10 (6.8–12) | 10 (8–13) | 10 (7–12) |
| **Gender, N (%)$^a$** | | | | |
| Male | 1508 (77.1%) | 276 (80.7%) | 122 (73.9%) | 1 906 (77.4%) |
| Female | 445 (22.8%) | 66 (19.3%) | 43 (26.1%) | 554 (22.5%) |
| Missing | 3 (0.2%) | 0 (0.0%) | 0 (0.0%) | 3 (0.1%) |
| **Mechanism of injury, N (%)$^a$** | | | | |
| Gunshot wound | 517 (26.4%)$^b$ | 195 (57.0%)$^a$ | 90 (54.5%)$^a$ | 802 (32.6%) |
| Mine injury | 474 (24.2%)$^a$ | 61 (17.8%) | 29 (17.6%) | 564 (22.9%) |
| Burn | 43 (2.2%)$^a$ | 0 (0.0%) | 0 (0.0%) | 43 (1.8%) |
| Fragment injury | 687 (35.1%)$^a$ | 73 (21.3%)$^b$ | 41 (24.8%) | 801 (32.5%) |
| Other | 187 (9.6%)$^a$ | 2 (0.6%)$^a$ | 4 (2.4%) | 193 (7.8%) |
| Missing | 48 (2.5%) | 11 (3.2%) | 1 (0.6%) | 60 (2.4%) |
| **Anatomic region of injury, N (%)$^a$** | | | | |
| Upper limbs (left and/or right) | 887 (45.3%) | 145 (42.4%) | 77 (46.7%) | 1 109 (45.0%) |
| Lower limbs (left and/or right) | 1 332 (68.1%) | 240 (70.2%) | 107 (64.8%) | 1 679 (68.2%) |
| Missing | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| **Fracture, N (%)$^a$** | | | | |
| Absent | 1 785 (91.3%)$^a$ | 87 (25.4%) | 31 (18.8%) | 1 903 (77.3%) |
| Present | 167 (8.5%)$^a$ | 253 (73.0%) | 131 (79.4%) | 551 (22.4%) |
| Missing | 4 (0.2%) | 2 (0.6%) | 3 (1.8%) | 9 (0.4%) |
| **Median time since injury, N (%)$^a$** | | | | |
| < 6 h | 480 (24.5%)$^a$ | 70 (20.5%) | 22 (13.3%)$^b$ | 572 (23.2%) |
| 6–23 h | 417 (21.3%) | 60 (17.5%) | 36 (21.8%) | 513 (20.8%) |
| 24–71 h | 276 (14.1%) | 66 (19.3%) | 22 (13.3%) | 364 (14.8%) |
| 72 h or more | 723 (37.0%) | 140 (40.9%) | 81 (49.1%)$^a$ | 944 (38.3%) |
| Missing | 60 (3.1%) | 6 (1.8%) | 4 (2.4%) | 70 (2.8%) |

$IQR$ interquartile range

$^a$Percentages calculated within the wound grades

$^b$Statistically significant higher percentage when compared to other wound grades within this variable category ($p < 0.05$)

$^a$Statistically significant lower percentage when compared to other wound grades within this variable category ($p < 0.05$)
**Table 5** Overview of patient outcomes

|                        | Wound grade 1 | Wound grade 2 | Wound grade 3 | Total |
|------------------------|---------------|---------------|---------------|-------|
| Median number of surgeries (IQR) | 2 (1–3)      | 2 (2–3)      | 3 (2–5)      | 2 (1–3) |
| Number of blood products/100 patients | 33.9         | 37.4         | 72.7         | 37.0  |
| Median LOS, days (IQR) | 15 (2–33)     | 30 (13–52)    | 40 (24–68)    | 18 (8–39) |
| Mortality rate, N (%) | 20 (1.0%)     | 0 (0.0%)      | 3 (1.8%)      | 23 (0.9%) |

IQR: interquartile range; LOS: length of stay in hospital

*Statistically significant different from the other wound grades (p < 0.05)

---

**Descriptive subanalyses Peshawar (2009–2012) and Goma (2012–2014)**

Sixteen pediatric patients were included in these analyses: 6 patients with wound grade 1, 2 patients with wound grade 2, and 8 patients with wound grade 3. Data on patient characteristics as recorded pre-hospital, on arrival, and in-hospital are listed in Table 6. The greater part of data listed in Table 6 was available only from Goma. Although on arrival all pediatric patients had a blood pressure within normal range for their age, the heart rate was elevated in 4 patients, suggesting (impending) shock. All patients’ wounds were classified as contaminated, and 1 patient with a wound grade 3 had foul odor and discharge from the wound at arrival. One patient developed a wound infection during hospital stay. The other patients had no registered complications.

Data on several performed surgical procedures were available from both Peshawar and Goma. An amputation above the elbow, an amputation below the knee, an external fixator, and a split skin graft were performed in patients with wound grade 3. One patient with wound grade 3 received two split skin grafts. Delayed primary wound closure was performed in all patients, except for 1 patient with wound grade 3. Most patients underwent at least one wound debridement. Six patients with wound grade 3 needed multiple debridement surgeries, up to five per patient. Re-debridement was not required in wound grades 1 and 2. A change of dressing was more frequently performed on patients with a higher wound grade: maximal one time for patients with wound grades 1 and 2, but up to 10 times for a patient with wound grade 3.

**Discussion**

This retrospective database study is the first to provide information on the correlation between the Red Cross wound grade of a pediatric patient’s extremity wound and treatment needs. It comprises a wide-ranging study setting with data from multiple conflict areas over a substantial time period. The results indicate that pediatric patients with higher-graded weapon-related extremity wounds generally require more surgeries per patient, more blood transfusions, and a longer period of hospitalization. This correlation exists independently from gender, age category, time to reach the hospital, mechanism of injury, and the presence or absence of a fracture. Descriptive subanalyses of patients treated in Peshawar and Goma revealed a trend of more invasive surgical procedures in patients with a higher wound grade.

A correlation between the wound grade and mortality was not identified, with the study population showing low in-hospital mortality rates. This could be due to natural triage, which causes more severely injured patients to decease in the field before reaching the medical treatment facility. A previous study by Coupland did demonstrate a statistically significant correlation between a higher wound grade (grade 1 versus grade 2) and mortality in patients with conflict-related abdominal wounds with penetration of the peritoneum or organ injury [31]. Again, the extent of this correlation was also limited due to natural triage, as patients with a wound grade 3 did not show any in-hospital mortality.

In contrast with pre-hospital selection of more stable patients, delay in patient arrival could have increased patients’ treatment needs as their condition has worsened over time. A longer time since injury might lead to presentation with a higher wound grade, since soft tissue damage is often progressive due to microvascular perfusion failure and inflammatory response [32, 33]. No pre-hospital data was available in this study to assess the effect and extent of a possible patient delay. The way this affects the predictability of the RCWC should be subject for future studies.

Remarkable in this study was that each wound grade category consisted of 3 times more boys than girls, while gender distribution of the total population was nearly equal in the countries studied [34]. The unequal in-hospital gender distribution has already been demonstrated by our previous study on pediatric casualties in conflict zones [21] and in other literature [19, 35, 36]. It is thought to be mostly attributable to cultural aspects that cause fewer women to get injured or to access a hospital.

Literature on the predictive value of other wound scores revealed that a higher AO classification of soft
tissue injury correlated with a lower primary healing rate, a greater impairment in lifestyle, and a greater likelihood of a second surgery [6]. Whereas that study did not show a correlation between the Gustilo-Anderson classification and patient outcomes, other studies did [7, 8]. It is noteworthy that comparisons between the predictive value of the Red Cross wound grading system and that of other wound classifications can be difficult or misleading, because other wound classifications are mostly related to underlying fractures and corresponding research was often conducted in a civilian setting [6, 7, 9, 10].

When providing medical assistance in a conflict setting, Eshaya-Chauvin and Coupland recommend that at least a certain minimal quantity of blood units should be available at the hospital based on the encountered mechanisms of injury in the hospital region [37]. Our data add to this, suggesting more units of blood are needed for pediatric patients with a higher wound grade. Thus, when a high wound grade is determined during primary assessment, it can support the decision to start preparing blood products or to transport them to the resuscitation room.

The authors realize that the RCWC was initially designed as a descriptive tool and not as a clinical triage tool. Including vital parameters into the RCWC could make it a more suitable tool for triage, which has been previously discussed by Bowyer et al. and Coupland [15, 38]. However, the RCWC should remain easily applicable and vital parameters are already

| Table 6 Sub analyses Peshawar (2009–2012) and Goma (2012–2014) | Wound grade 1 | Wound grade 2 | Wound grade 3 | Total |
|---|---|---|---|---|
| Number of pediatric patients (%) | 6 (37.5%) | 2 (12.5%) | 8 (50.0%) | 16 (100%) |
| Type of pre-hospital care received, N (%)§ | | | | |
| None | 3 (75.0%) | 1 (50.0%) | 1 (25.0%) | 5 (50.0%) |
| First aid | 0 (0.0%) | 0 (0.0%) | 1 (25.0%) | 1 (10.0%) |
| Medical/emergency care | 1 (25.0%) | 1 (50.0%) | 2 (50.0%) | 4 (40.0%) |
| Surgery | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| Time to surgery, N (%)§ | | | | |
| 0–6 h | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| 7–12 h | 0 (0.0%) | 1 (50.0%) | 1 (25.0%) | 2 (20.0%) |
| 13–24 h | 3 (75.0%) | 1 (50.0%) | 1 (25.0%) | 5 (50.0%) |
| 1–7 days | 1 (25.0%) | 0 (0.0%) | 2 (50.0%) | 3 (30.0%) |
| Unstable pulse on arrival, N (%)§§ | 1 (25.0%) | 1 (50.0%) | 3 (75.0%) | 5 (50.0%) |
| Unstable blood pressure on arrival, N (%)§§ | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| Glasgow coma scale§ | | | | |
| 13–15 | 4 (66.7%) | 2 (100%) | 4 (50.0%) | 10 (62.5%) |
| < 13 | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| Unknown | 2 (33.3%) | 0 (0.0%) | 4 (50.0%) | 6 (37.5%) |
| Body temperature on arrival§ | | | | |
| 35–36.9 | 3 (75.0%) | 1 (50.0%) | 1 (25.0%) | 5 (50.0%) |
| 37–38 | 1 (25.0%) | 1 (50.0%) | 2 (50.0%) | 4 (40.0%) |
| > 38 | 0 (0.0%) | 0 (0.0%) | 1 (25.0%) | 1 (10.0%) |
| Wound type§ | | | | |
| Clean | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| Foul odor and discharge | 0 (0.0%) | 0 (0.0%) | 1 (25.0%) | 1 (10.0%) |
| Contaminated | 4 (100%) | 2 (100%) | 3 (75.0%) | 9 (90.0%) |
| In-hospital complications§ | | | | |
| None | 4 (100%) | 2 (100%) | 3 (75.0%) | 9 (90.0%) |
| Infection | 0 (0.0%) | 0 (0.0%) | 1 (25.0%) | 1 (10.0%) |

Note that not all percentages in this table add up to 100%. This indicates the missing values

§Heart rate and blood pressure were categorized as within normal range or not, based on the reference values per age category as listed in the Advanced Trauma Life Support (ATLS) manual [25]
§Data missing from Peshawar
The Red Cross wound grade of a pediatric patient

Conclusions

server variability. Could be further assessed by calculating the interob-
putation rate and short- or long-term functional
ists with additional patient outcomes, such as the am-
is recommended to identify whether a correlation ex-
from multiple hospitals and time periods.
study results might be diminished by the large
evolved over time and could differ between hospitals
the type of care at the ICRC-supported hospitals has
children.

First, it can be challenging for surgeons to collect
data during deployment due to the austere working
environment, which may reflect on the accuracy and
completeness of the data. The handwritten patient
files had to be manually converted into an electronic
database, which is an error-prone process. Second,
subcategories of wound severity (i.e., the wound
grades) were based on three features: wound size (less
or more than 10 cm), cavity existence, and fracture
type (if any). It is possible that this might not be the
most appropriate way of categorizing wound severity,
as there could be other cut-off values or features
which correlate more strongly with treatment needs
than was found in this study. Nevertheless, the wound
grading system is a previously acknowledged classifi-
cation and was therefore retained. Third, the results
are applicable only to pediatric patients with isolated
extremity wounds, because patients were excluded if
they sustained wounds at other anatomical sites. Last,
the type of care at the ICRC-supported hospitals has
evolved over time and could differ between hospitals
or even between surgeons, which could partly account
for differences in patient outcomes. Nevertheless, the
influence of time and hospital differences on our
study results might be diminished by the large
amount of data included in this research, originating
from multiple hospitals and time periods.

Future research on the RCWC and wound grading
is recommended to identify whether a correlation ex-
ists with additional patient outcomes, such as the am-
putation rate and short- or long-term functional
impairment. Validity and reliability of the RCWC
could be further assessed by calculating the interob-
server variability.

Conclusions

The Red Cross wound grade of a pediatric patient’s
extremity wound independently correlates with the
required number of surgeries, blood transfusions, and
hospitalization time. The application of this easy-to-
use grading system ensures systematic evaluation of
the wound even in challenging environments, and it
could guide clinical decision-making. Healthcare pro-
viders in conflict settings should therefore consider
implementing the Red Cross wound grade as an es-
sential adjunct in the initial clinical assessment of
children.
treated with open reduction and internal fixation. Arch Orthop Trauma Surg. 1999;119(6):276–9.
10. Ovaska MT, Makinen TJ, Madanat R, Huotari K, Vahlberg T, Hirvensalo E, et al. Risk factors for deep surgical site infection following operative treatment of ankle fractures. J Bone Joint Surg Am. 2013;95(4):548–53.
11. Coupland R, The Red Cross wound classification: International Committee of the Red Cross; 1991. 18 p.
12. Cernak I, Savic J, Zunic G, Pejnovic N, Jovanick O, Stepc V. Recognizing, scoring, and predicting blast injuries. World J Surg. 1999;23(1):44–53.
13. Coupland RM. The Red Cross classification of war wounds: the EX.C.F.V.M. scoring system. World J Surg. 1992;16(5):910–7.
14. Vassallo D, McDermott G. Modification to Red Cross wound classification. Injury. 1995;26(2):131–2.
15. Bowyer GW, Stewart MP, Ryan JM. Gulf war wounds: application of the Red Cross wound classification. Injury. 1993;24(9):597–600.
16. Edwards MJ, Lustik M, Burnett MW, Eichelberger M. Pediatric inpatient humanitarian care in combat: Iraq and Afghanistan 2002 to 2012. J Am Coll Surg. 2014;218(5):1018–23.
17. Afghan civilian casualties: a grim reality. Lancet. 2013;382(9891):480.
18. Borgen M, Matos RJ, Blackbourne LH, Spinella PC. Ten years of military pediatric care in Afghanistan and Iraq. J Trauma Acute Care Surg. 2012;73(6 Suppl 5):S509–13.
19. Idenburg FJ, van Dongen TT, Hoencamp R, Demeters G, Hamming JH, Leenen LP, et al. Prepared for mission? A survey of medical personnel training needs and experiences among deployed personnel. World J Surg. 2014;38(7):1713–8.
20. Haverkamp FJC, van Gennip L, Muhrbeck M, Veen H, Wladis A, Tan E. Global epidemiology of casualties treated at the Dutch role 2 enhanced medical treatment facility at multi national base Tarin Kowt, Afghanistan in the period 2006-2010. World J Surg. 2014;38(7):1713–8.
21. Haverkamp FJC, van Gennip L, Muhrbeck M, Veen H, Wladis A, Tan E. Global surgery for paediatric casualties in armed conflict. World J Emerg Surg. 2019;14:55.
22. Gausche-Hill M. Pediatric disaster preparedness: are we really prepared? J Trauma. 2009;67(2 Suppl 1):S73–6.
23. Trudeau MO, Rothstein DH. Injuries and surgical needs of children in conflict and disaster: from Boston to Haiti and beyond. Semin Pediatr Surg. 2016;25(1):23–31.
24. American Academy of Pediatrics. Pediatric terrorism and disaster preparedness: a resource for pediatricians. Agency for Healthcare Research and Quality 2006.
25. Pediatric trauma. Advanced trauma life support student course manual. Tenth ed. Chicago; American College of Surgeons2018. p. 186-213.
26. Finnegar A, Finnegar S, Bates D, Ritsperis D, McCourt K, Thomas M. Preparing British military nurses to deliver nursing care on deployment. An Afghanistan study. Nurse Educ Today. 2015;35(1):104–12.
27. Haverkamp FJC, Veen H, Hoencamp R, Muhrbeck M, von Schreeb J, Wladis A, et al. Prepared for mission? A survey of medical personnel training needs within the International Committee of the Red Cross. World J Surg. 2018;42(11):3493–500.
28. Hoencamp R, Idenburg FJ, Hamming JF, Tan EC. Incidence and epidemiology of casualties treated at the Dutch role 2 enhanced medical treatment facility at multi national base Tarin Kowt, Afghanistan in the period 2006-2010. World J Surg. 2014;38(7):1713–8.
29. Idenburg FJ, van Dongen TT, Hoencamp R, Demeters G, Hamming JH, Leenen LP, et al. Prepared for mission? A survey of medical personnel training needs and experiences among deployed personnel. World J Surg. 2014;38(7):1713–8.
30. Andersson P, Muhrbeck M, Veen H, Osman Z, von Schreeb J. Hospital workload and quality of care: a comparison between different levels of care in Afghanistan. World J Emerg Surg. 2015;10:50.
31. Coupland R, Abdominal wounds in war. Br J Surg. 1996;83(11):1505–8.
32. Schaser KD, Vollmar B, Menger MD, Schewior L, Kroppenstedt SN, Raschke M, et al. In vivo analysis of microcirculation following closed soft-tissue injury. J Orthop Res. 1999;17(5):678–85.
33. Tull F, Borelli J Jr. Soft-tissue injury associated with closed fractures: evaluation and management. J Am Acad Orthop Surg. 2003;11(6):431–8.
34. The World Factbook. 2020. Washington, DC: Central Intelligence Agency; 2020.
35. Bitterman Y, Benov A, Glassberg E, Satanovsky A, Bader T, Sagi R, Role I pediatric trauma care on the Israeli-Syrian border-first year of the humanitarian effort. Mil Med. 2016;181(8):849–53.
36. Hylden C, Johnson AE, Rivera JC. Comparison of female and male casualty cohorts from conflicts in Iraq and Afghanistan. US Army Med Dep J. 2015: 80–5.
37. Eshaya-Chauvin B, Coupland RM. Transfusion requirements for the management of war injured: the experience of the International Committee of the Red Cross. Br J Anaesth. 1992;68(2):221–3.
38. Coupland RM. Gulf war wounds: application of the Red Cross wound classification. Injury. 1994;25(7):485.
Publisher’s Note
Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Ready to submit your research? Choose BMC and benefit from:
• fast, convenient online submission
• thorough peer review by experienced researchers in your field
• rapid publication on acceptance
• support for research data, including large and complex data types
• gold Open Access which fosters wider collaboration and increased citations
• maximum visibility for your research: over 1000 website views per year

At BMC, research is always in progress.
Learn more biomedcentral.com/submissions