Rural Prehospital Trauma Systems Improve Trauma Outcome in Low-Income Countries: A Prospective Study from North Iraq and Cambodia

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Background: A five-year prospective study was conducted in North Iraq and Cambodia to test a model for rural prehospital trauma systems in low-income countries.

Results: From 1997 to 2001, 135 local paramedics and 5,200 lay First Responders were trained to provide in-field trauma care. The study population comprised 1,061 trauma victims with mean evacuation time 5.7 hours. The trauma mortality rate was reduced from pre-intervention level at 40% to 14.9% over the study period (95% CI for difference 17.2–33.0%). There was a reduction in trauma deaths from 23.9% in 1997 to 8.8% in 2001 (95% CI for difference 7.8–22.4%), and a corresponding significant improvement of treatment effect by year. The rate of infectious complications remained at 21.5 percent throughout the study period.

Conclusion: Low-cost rural trauma systems have a significant impact on trauma mortality in low-income countries.

Key Words: Prehospital trauma system, Trauma outcome, Severity score, Land mine, North Iraq, Cambodia

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Studies of trauma system effectiveness in western high-income societies indicate a 15 to 20 percent improved survival rate in seriously injured patients after trauma system implementation.[1,2] However, the "epidemic of trauma" is global, and 90 percent of the fatalities are found in low- and middle-income countries.[3] The pattern of mortality differs in less developed countries as demonstrated in a three-center study from Seattle, Monterey (Mexico), and Kumasi (Ghana). The trauma mortality was twice as high in Ghana compared with Seattle, a difference mainly due to the higher proportion of prehospital deaths in Ghana.[4] Implementation of prehospital trauma life support programs in low- and middle-income countries has demonstrated significant reduction in prehospital fatality rates.[5,6] However, the studies in non-western countries have so far been done on patient populations with prehospital transit times of under two hours—that is, in settings not representative for the populations hardest hit by the epidemic of trauma. Natural disasters, local wars, and large unmapped fields of land mines are concentrated in countries in the equatorial belt. Wars and civil unrest have damaged the infrastructure in the affected countries. Prehospital transit times for trauma victims of 4 to 8 hours are not uncommon, and surveys report trauma mortality rates as high as 40 to 50 percent, most fatalities being prehospital.[7,8,9] What should be the design of a prehospital "chain of survival" system able to provide minimal acceptable care in settings with long transfer times? And what would be the effect of such a system?

To explore this problem, we developed "The Village University" concept; a new teaching model aimed at local communities in the rural third world with overwhelming trauma challenges. In Afghanistan, one of the authors (H.H.) in cooperation with the Afghan resistance set up forward rescue systems from 1985 to 1992. The evacuation of war injured from inside Afghanistan to referral hospitals in Pakistan was protracted and rough, with few graduate local doctors to provide prehospital trauma care. Local non-graduate health workers were trained in advanced trauma life support techniques. The results was a decrease in prehospital mortality from 26 percent to 13.5 percent in a study population of 3,800 trauma victims.[8] The training concept was further developed in Burma from 1992 to 1995 where, on request from the Democratic Government of Burma, two of the authors (H.H., M.G.) trained local paramedics to set up chains of survival for war and land mine casualties from inside Burma to referral surgical centers in Thailand.

This low-cost rural rescue system was tested in a prospective study in the minefields of Kurdistan (North Iraq) and Cambodia. The target areas in both countries were rural districts with long prehospital evacuation times and high incidences of trauma due to land mines, local wars, and

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domestic violence. From 1997 to 2001, we examined the effects on trauma outcome of prehospital trauma life support provided by trained paramedics and lay Village First Responders. The outcome indicators were: (1) effect of treatment on prehospital physiologic severity levels; (2) trauma mortality; and (3) infectious complications.

MATERIALS AND METHODS

In agreement with the local ministries of health, three rural districts of the Battambang province in Northwestern Cambodia and three districts of the Suleimaniah province in North Iraq were selected as target areas. The target districts are located inside the dense mine belts at the Cambodian-Thai border and the Iraqi-Iranian border. In 1996, before the intervention, we surveyed the mine casualty management in the target districts and found an estimated mortality rate among 150 mine casualties at 40 percent or higher, based on reviews of patient files at district health centers and interviews with villagers and mine accident survivors. This figure is in accordance with results of a recent survey conducted inside the same mine belt from which we evacuated study patients in North Iraq.[9] The typical victims of land mines and war-related trauma are local farmers and their children. With the local health infrastructure severely weakened following years of war, the victims get little, if any, systematic prehospital life support. Most accidents happen far from the villages. Telephone lines are few, there are no ambulance systems; more often than not, evacuation takes place off-road in hammocks or on donkeys through mountains or jungle.

Training Concept: The Village University

A core group of 22 health care workers were selected from each target area for a three-year training program. The students should live and work permanently inside the target area; they should have previous personal hands-on experience with land mine casualties; they should be literate and understand basic mathematics. All students had to be trusted by their local community and have high moral standing. The actual training program was conducted from 1996 to 1999 based on a teaching manual for prehospital care in low-resource communities.[10] The training consisted of three 150 hours of intensive courses at makeshift training camps at villages inside the catchment area (Village Universities) with working periods of 6 to 12 months in-between. The students got a medical backpack kit with equipment and drugs, the medical kits were supplemented according to the level of certification (Table 1).

We encouraged the students to build local networks of lay First Responders to reduce the in-field response time and to anchor knowledge and capability of treatment in the local community. Thus, during their working periods between each training course the students themselves should train at least 50 Village First Responders during 2-days village courses in their home area. Such First Responder-training consists of a two-days locally organized course in basic first aid followed by a one-day rehearsal training after 6 to 12 months with the Village University-students, single or in pairs, being instructors. The first-responder trainee groups should be 1/3 female, 1/3 male, and 1/3 children, selected by the village leaders.

The Trauma System

A core group of 44 paramedics were trained by the authors at the Village Universities in Cambodia and Kurdistan in the period 1997 to 1999 and certified to provide advanced trauma life support. The most experienced medics of the core group were appointed as instructors for new training courses. By August 2001, 91 new mine medics from other mine-infested districts in the target provinces were certified as paramedics, trained solely by local instructors. From 1998 to August, 2001, the 135 paramedics trained a total of 5,237 Village First Responders.

The First Responders and paramedics should reach the trauma victims as soon as possible after the injury, start resuscitation on-site, and continue throughout the evacuation (treatment protocol, see Table 1). The Village First Responders take the injured—including non-survivors—to the nearest paramedic for assessment and documentation. Light cases are managed at district hospitals or village health centers, major cases are evacuated to surgical centers. There is one surgical referral hospital in each country, both of them run by the Italian relief organization, Emergency. The Emergency Centers for War Wounded are well organized and follow established principles of trauma care.[11] Local coordinators with extensive hands-on experience in trauma care (Y.V.H., M.M.) collect the medical data and conduct monthly rehearsal-training sessions for the paramedics. The trauma system in North Iraq also managed emergency medical cases. For legal reasons, the rescue system in Cambodia do not manage medical cases.

Data Gathering and Statistics

The paramedics register diagnosis and prehospital treatment on a chart and with compact cameras. They also register the physiologic severity at first contact in-field, and, again, on hospital admission. The scene of accident is often chaotic and dangerous; the victim may be trapped inside a minefield or be under fire in a local combat. For this reason, we have introduced a simplified version of the Revised Trauma Score (RTS) where the Glasgow Coma Scale score is replaced with five-graded levels of consciousness. Based on this grading, we calculate the Physiologic Severity Score (PSS) using the standard RTS vectors, 0.9368GCS, 0.7326BP, and 0.2908RR.[12] The coordinators collect data for Injury Severity Scoring and infectious indicators at the referral hospitals. For quality control, we use the standards from The Major Trauma Outcome Study (MTOS) as “the gold standard” to identify and scrutinize unexpected survivors and unexpected non-survivors.[12] From 1997 to August 2001 the trauma system in the two countries managed a total of 1,378 patients. Cases with insufficient data for severity scoring and outcome assessment were excluded, which left a study population of

Table 1 Paramedic training and treatment protocol

	1st training course: Basic Life Support 150 hours	2nd training course: Advanced Trauma Life Support 150 hours	3rd training course: Advanced Trauma Life Support 150 hours
Main objective	Exact clinical examination, BLS and CPR. Focus on limb injuries.	Advanced CPR. Focus on head injuries and "the difficult airway".	Nutrition for trauma victims. Focus on chest injured.
Free airway	Assessment: Look—listen—feel. Head tilt-chin lift. Recovery position. CPR on manikins and fellow students.	Endotracheal intubation, training on dummy. Emergency crico-thyrotomy on animals injured under ketamine anesthesia.	Rehearsal of course 1 and 2.
Support breathing	Assessment: Respiratory rate. Half-sitting position. Rescue breathing mouth-to-mouth. Bag-to-mask ventilation.	Gastric decompression using naso-gastric tube on fellow students and anesthetized animals. Bag-to-tube ventilation.	Clinical examination of chest injured. Chest tube placement on anesthetized animals with chest injuries. In-field antiseptic techniques.
Stop bleeding/Maintain circulation	Assessment: Heart rate, systolic blood pressure, body temperature. Stopping extremity bleeding with subfascial gauze packs and long compressive dressing. Training on extremity injured anesthetized animals. IV cannulation of limb veins on fellow students. Hypotensive fluid resuscitation (oral and IV). Hypothermia prevention using warm IV/per oral fluids and external warming.	Teamwork on anesthetized animals with combined airway-extremity injuries. Venous cut-down on animals. External jugular cannulation on fellow students.	Rehearsal of course 1 and 2. Teamwork on anesthetized animals with airway-chest-extremity injuries. Damage control laparotomy demonstrated and trained on selected animal cases.
Drugs and nutrition	Intermittent IV ketamine analgesia. Prophylactic antibiotics (penicillin for extremity injured, ampicillin-metronidazole for torso injured).	Learning intermittent IV ketamine anesthesia. Adrenaline for advanced CPR. Atropine as premedicant.	Conducting IV ketamine anesthesia on animals. Making high-energy diets based on local foodstuffs.
Exams and certification	Certification for BLS including ketamine analgesia and antibiotic prophylaxis.	Certification for endotracheal intubation and advanced CPR.	Certification for ATLS.
Equipment	15-kg medical backpack kit including self-inflating bag, suction unit, and drugs/infusions for 3 severely injured patients.	Supplement for medical kit: Laryngoscope and endotracheal tubes.	Supplement for medical kit: Chest tubes, simple surgical set, equipment for in-field disinfection.

1,285 patients. Of these, 224 patients were emergency medical cases and 1,061 patients were trauma victims.

Epi Info and CIA were used for analysis of the data.[13,14] The null-hypothesis (no difference in outcome) was rejected if the 95 percent confidence interval (95% CI) for differences did not include zero. We used MedCalc for analysis of Receiver Operating Characteristics plots.[15] Indicators for severity scoring is said to have high accuracy if the area under the ROC plot (AUC) is 0.9 or larger; AUC = 0.5 signifies a useless indicator.[16]

RESULTS

The rescue system in Cambodia managed 407 trauma victims. North Iraq managed 654 trauma victims and 224 emergency medical cases. The study populations in the two countries were comparable except for a somewhat shorter in-field response time in North Iraq (means 1.3 hours vs. 2.8 hours) and longer prehospital transit times in Cambodia (means 6.3 hours vs. 5.1 hours). Of the study patients, 17 percent were children (<15 years), 21.6 percent were women. The majority of the 1,061 trauma victims had penetrating injuries (85.7%); 708 patients were injured by land mines; 112 had gun shot wounds. Ten percent of the trauma victims suffered from blunt injuries, most of them caused by traffic accidents. There were 41 patients with burns.

Injury Characteristics

Most injuries were severe with median Injury Severity Score (ISS) at 9 (means 12.4, SD 15.1) and mean physiologic severity score at 6.1 (SD 2.5). The anatomic and physiologic injury severity did not change significantly by year during the study period, and 18.4 percent of the trauma victims had multiple severe injuries; 21.3 percent had injuries to the torso (head, face, neck, chest, abdomen, or pelvis); and 49.3 percent had limb injuries. Of the 523 limb injured, 318 patients had traumatic amputations.

Time Factors

The mean response time from injury to the first medical contact in-field was reduced from 2.9 hours in 1997 to 1.8 hours in 2001 (95% CI for difference 0.4–1.8 hours). The mean prehospital transit time was 5.7 hours (95% CI 5.4–6.0 hours) and did not change significantly during the study period; 60.6 percent of the trauma victims were evacuated to surgical centers, while 19.8 percent of patients were managed at local district hospitals, and 19.6 percent were managed at village health centers.

Medical Treatment

In the majority of torso injured, the prehospital trauma care consisted of basic procedures only. Just three patients had endotracheal intubation done in-field. Crico-thyrotomy was done in two cases with massive face injuries. Four patients with chest injuries had the chest tube placed on-scene. Six patients with penetrating abdominal injury had naso-gastric tube decompression done; damage control laparotomies were not performed during the prehospital phase. Most hypotensive torso injured received warm IV fluids during the evacuation (n = 40/68); moderate volumes were used for fluid resuscitation, the median consumption of intravenous electrolytes was 3 liters electrolytes. There were 221 limb injured with systolic blood pressure below 90 mm Hg at the first contact in the field. In all these victims, gauze packing of wound tracks and amputation wounds combined with long compressive dressing and proximal artery compression was used to control the bleeding. The median prehospital consumption of intravenous electrolytes was 3 liters. For hypothermia prevention, most of these patients (n = 135/221) were given warm intravenous infusions (40° C) during the evacuation. With this resuscitation regime, all but 21 patients were admitted at the referral hospital in normotensive state. Half of the patients (55%) with ISS ≧9 had ketamine transport analgesia, mean total dose was 38 mg ketamine. There were no reports of adverse effects of ketamine.

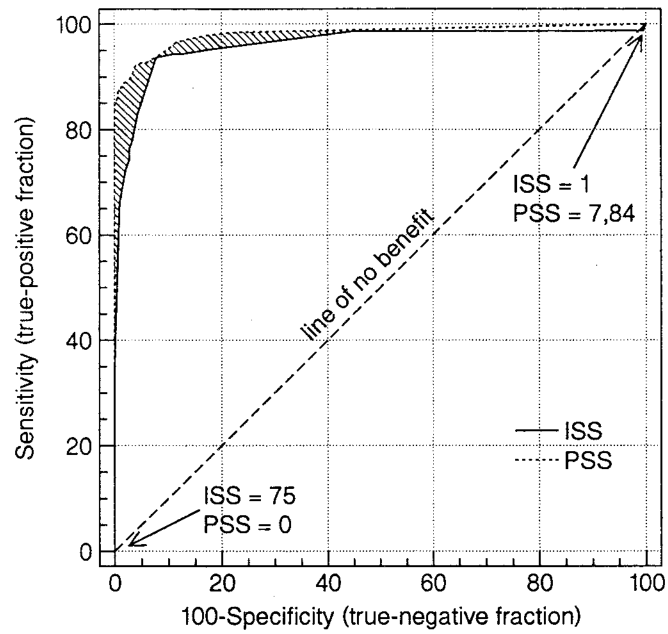

FIG 1. *Death-risk prediction, Physiologic Severity Score and ISS compared (n = 1,061). Receiver operating characteristics plot for two death-risk indicators, ISS and the Physiologic Severity Score on hospital admission (PSS). For both indicators the value for the area under the curve (AUC) is higher than 0.9, indicating high predictive accuracy. The global performance of the two indicators is equal (95% CI for AUC difference −0.001–0.045).*

Outcome Indicators, Trauma Victims

1. Effect of treatment: ROC plots demonstrated that the Physiologic Severity Score (PSS) yields high accuracy in death risk-prediction (area under ROC curve 0.98). This accuracy is equivalent to that of the ISS (difference between AUC for PSS and ISS is 0.002, 95% CI for

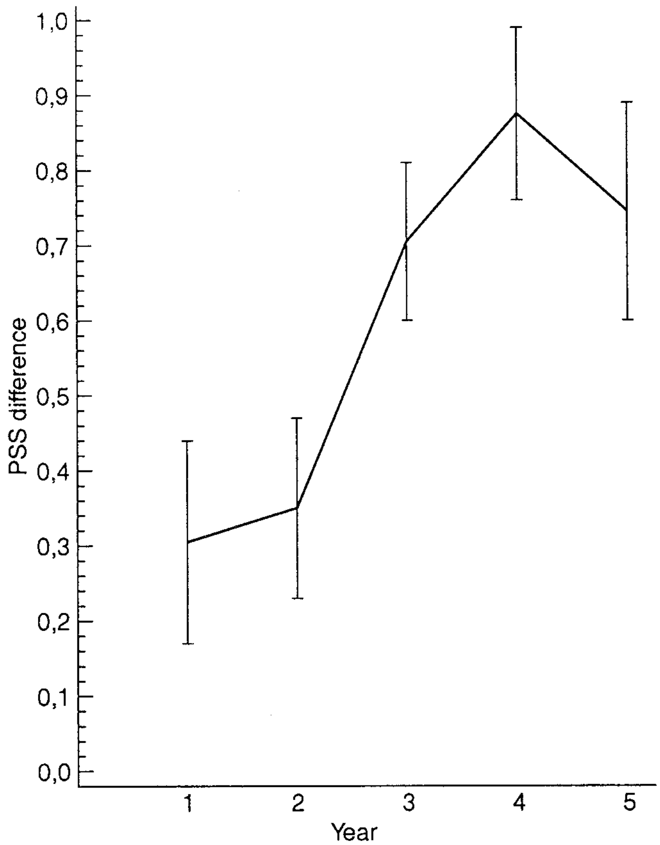

FIG 2. *Effect of prehospital treatment by year (n = 1,061). The effect of treatment is calculated by prehospital changes in physiologic severity score, condition on hospital admission compared with first in-field encounter. The error bars represent 95 percent confidence intervals for the differences.*

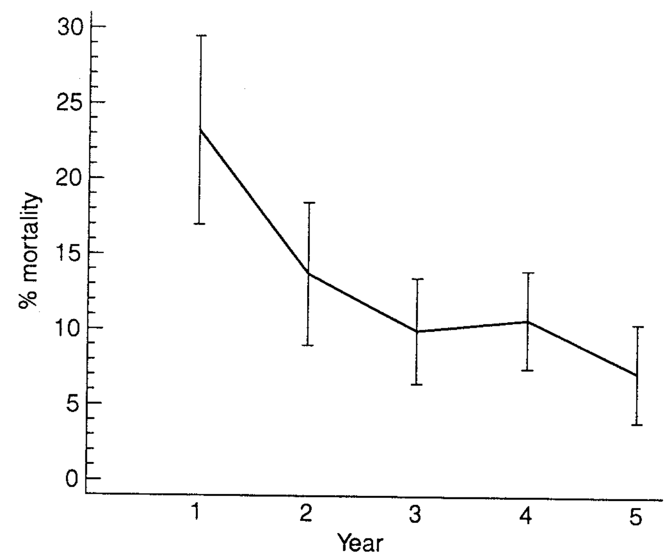

FIG 3. *Trauma mortality by year (n = 1,061). The error bars represent 95 percent confidence intervals for the mortality rates.*

difference −0.001–0.045, see Fig. 1). As an indicator of treatment effect in the trauma patients, we registered the PSS-difference between hospital admission and first encounter in the field. In the majority of cases (94.5%) the physiologic score improved during the prehospital period (treatment-positive group). The PSS-difference increased during the study period from 0.3 in 1997 to 0.7 in 2001 (95% CI for difference 0.2–0.6). This tendency was consistent in both countries (Fig. 2). The improvement in treatment effect was more pronounced for torso injured than for extremity injured. In 58 patients, the difference between the hospital and in-field severity scores was negative (treatment-negative group). The mortality rate in the treatment-negative group was 31.9 percent as compared with 14.5 percent in the treatment positive group (95% CI for difference, 7.5–27.2%).

2. Mortality: there were 158 fatalities (14.9%), which is a significant reduction in trauma mortality compared with the preintervention level at 40 percent (95% CI for difference 17.2–33%). There was a significant reduction in trauma mortality by year during the study period from 23.9 percent in 1997 to 8.8 percent in 2001 (7.8–22.4%). This tendency was consistent in both countries (Fig. 3). The reduction in fatalities was pronounced for torso injured (from 61.5% in 1997–19.1% in 2001, 95% CI for difference 28.1–56.8%), and non-significant for limb injured (95% CI −0.01–6.4%). Most non-survivors (123/158) died on the scene before the first medical contact. The on-scene fatalities were severely injured, median ISS 36 (range 16–75). Fourteen non-survivors died under prehospital resuscitation and 21/158 died after hospital admission.
3. The rate of infectious complications was 21.1 percent (difference between countries NS) and did not change significantly during the study period.
4. Outcome indicators, emergency medical cases: all registered medical cases were from North Iraq (n = 224), 64.7 percent were women, and 14.3 percent were children. The most common medical diagnosis was extreme dehydration caused by dysentery and severe blood loss during delivery or abortion. There was just one fatality among the 224 medical cases. The effect of treatment (PSS-difference) was higher for medical cases (means 1.6 vs. 0.5 for trauma cases in North Iraq, 95% CI for difference 0.9–1.2).

Two Independent Variables Had Effect on The Outcome

1. Injury severity: with increasing injury severity, less patients responded on the in-field resuscitation (PSS-difference negative: AUC for both ISS and PSS = 0.65, 95% CI 0.59–0.69). Anatomic and physiologic injury severity predicted non-survival with high accuracy (trauma death: AUC for ISS and PSS > 0.9).
2. Experience: some medics have more experience and

Table 2 Trauma System Comparison, Survival by Physiological Severity Score-interval

Physiological Severity Score Intervals	Survivors MTOS[12]	Survivors North Iraq and Cambodia	95% CI for Difference*
<5	572/1849 (30.0%)	15/156 (9.6%)	16.2–26.4%
5–<6	884/1035 (85.4%)	24/30 (80.0%)	−9.1–19.9%
6–<7	1292/1380 (93.6%)	112/121 (92.6%)	−3.8–5.9%
7–7.84	17667/17882 (98.8%)	752/754 (99.7%)	−1.3–−0.5%

* 95% CI difference: 95% confidence interval for difference of proportions.

higher load of patients (>75 patients during the study period) than other (<20 patients). The trauma mortality during the study period was less for patients managed by experienced medics (11.3% vs. 17.7%, 95% CI for difference 2.1–10.6%).

The in-field response time and total prehospital transit time did not affect the outcomes. The in-field response time was less for patients primarily managed initially by Village First Responders (1.0 hours vs. 1.9 hours, 95% CI for difference 0.6–1.2 hours). There was, however, no difference in outcome between patients managed initially by lay First Responders and patients managed by trained paramedics.

Quality Control, Unexpected Trauma Outcomes

We have compared the outcome of the actual trauma system to the MTOS data,[12] see Tables 2 and 3. Our outcome compares well for moderately severe injuries; for patients with ISS > 15 and PSS/RTS < 5 (in-field score) the actual system has significantly fewer survivors than MTOS standards. Plotting the patient's ISS-PSS coordinates in a scatter diagram, we could use the isobar of 50 percent probability of survival given by the MTOS data to identify unexpected fatalities and unexpected survivors among the patients who were alive at the first medical contact in-field.

There were 22 non-survivors who—according to injury severity characteristics—should have 50 percent or better probability of survival. Four of them were prehospital fatalities: two patients with thoraco-abdominal injuries could for security reasons not be evacuated to the surgical center and two patients with penetrating skull injuries died during the evacuation due to lack of airway control (not intubated). Eighteen of the unexpected non-survivors died after hospital admission: four patients died from missed diagnosis and/or surgical failures; four patients died in hemorrhagic shock during surgery, all of them were hypothermic on admission; seven patients died from infectious complications (peritonitis, tetanus, postoperative malaria falciparum relapse); and three patients had extensive burns (>70% of TBS).

Six patients, aged 15–25 years, survived with injury severity indicating 50 percent or less chance of survival: Two patients with extensive limb injuries and associated skull injury had crico-thyrotomy done in-field. Four patients were found inside mine fields >3 hours after the injury, hypothermic and with low physiologic scores; they were treated with warm IV infusions and had temperatures > 37° C on hospital admission.

DISCUSSION

We report for the first time the results of a prospective study of trauma outcome in a setting where resources are few and prehospital transfer times long. The study demonstrates that rural prehospital trauma systems have a significant impact on trauma mortality under such conditions. The fatality rate in our study population fell from pre-intervention level at 40 to 15 percent during the five year-study period. Having established the "chain of survival"-rescue system, we observed a gradual and significant decrease in mortality by year. The paramedics who gained most hands-on trauma experience had better results than colleagues with less experience. The delayed effect on mortality after trauma system implementation is also reported in other studies.[17,18] Regular rehearsals and systematic scrutinizing of cases with unexpected outcome is an essential part of the present system; improved effect by maturation thus seems to be based on a learning-by-doing effect. The study also demonstrates that rural prehospital trauma systems may serve certain emergency medical cases effectively.

Table 3 Trauma System Comparison, Survival by ISS Interval

Injury Severity Score	Survivors MTOS[12]	Survivors North Iraq and Cambodia	95% CI for Difference*
1–8	2151/2153 (99.9%)	487/490 (99.4%)	−0.2–1.2%
9–15	1011/1028 (98.3%)	318/322 (98.8%)	−1.9–1.0%
16–24	677/752 (90.0%)	67/98 (68.4%)	12.2–31.1%
25–40	470/798 (58.9%)	29/91 (31.9%)	16.9–37.2%
41–74	42/115 (36.5%)	2/28 (7.1%)	16.4–42.4%
75	8/63 (12.7%)	0/32 (0.0%)	44.8–20.9%

* 95% CI for difference: 95% confidence interval for difference of proportions.

Some Variables in Our Study need to be Discussed

1. The study areas have poor communications and are at times chaotic due to unrest and war. There may thus be unreported prehospital fatalities. For several reasons we do not believe there are large dark numbers. First, due to prevailing religious rules in the study area, persons who die should be buried within 24 hours; it is therefore mandatory to find and evacuate them immediately after an accident. Secondly, the backbone of the trauma system, the paramedics, are village people themselves and they have an extensive social network in their area. Third, 5,000 Village First Responders are an integrated part of the trauma system and constitute a major information-gathering network in the catchment area.
2. There may be unregistered post-hospital fatalities. If so, the figure is probably very low. The treatment at "Emergency Center for War Wounded" is free, including physical rehabilitation and prosthesis fitting; the patients will therefore stay at the hospital throughout the post-operative rehabilitation. The most likely post-hospital fatality would be due to a second mine accident; as poor farmers, they have no other choice than to re-enter mined areas to collect firewood and cultivate rice.
3. Estimates of pre-intervention trauma mortality may be incorrect. If so, the mortality is probably greater than 40 percent rather than less. Most land mine non-survivors are found dead at the scene, and will be buried without reports to hospitals or central authorities. For this reason, our pre-intervention survey was conducted in the mine-infested villages and at local health centers. The estimate at 40 percent or higher also corresponds to careful grassroots surveys performed in other mine infested countries.[7,9]
4. In several victims who were found dead at the scene without autopsy being performed, we had insufficient data for correct grading of anatomic injury severity. In cases with unclear diagnostic data, we systematically coded the ISS conservatively. For example, an on-scene non-survivor with multiple penetrating abdominal injuries was systematically assigned AIS code 3–despite he is probably an AIS-4 case.
5. We used a simplified version of the Revised Trauma Score (RTS) for severity grading. ROC plots demonstrate that this simplified score yields high accuracy (AUC $>$ 0.9). Also other studies have demonstrated equivalent or improved accuracy in severity score when the Glasgow Coma Scale is substituted with simple grading of consciousness levels.[19]

We, therefore, hold that the main conclusions in our study are based on solid evidence.

To be sustainable, trauma systems in low-income countries should be low-cost and rely on the existing infrastructure. We invested heavily in training and teaching aids rather than expensive ambulance systems. The improvement in trauma outcome thus reflects an increasing coping capacity of the existing primary health care network. But even if costs are a crucial issue for sustainable improvement, we cannot compromise with the principle of minimal acceptable trauma care. Can we define the content of a minimal acceptable standard in low-resource societies with long prehospital transit times? Our study gives some answers to the question.

First, in more than 90 percent of our study patients, the physiologic severity score improved during the transport indicating that the present rescue model is efficient. However, improvement of vital signs is not a very solid outcome indicator. Firstly, ROC plots for this indicator in predicting non-survival yields an AUC at 0.7, indicating not more than fair overall accuracy. Second, other factors than effects of medical interventions may affect vital signs; one such factor may be the capacity of young and healthy patients to maintain central blood perfusion despite major blood loss. Third, there may be significant inter-observer variability in measurements of vital signs (e.g., for registrations of tachypnoe, kappa values at 0.6 are reported).[20] Still, the significant improvement of "treatment effect" by year, in parallel with significant reduction in mortality, indicates that the gain in treatment effect for the actual trauma system is real.

Second, the basic life support procedures remain the foundation of effective trauma care; advanced interventions were performed in less than 3 percent of our study patients. Systematic positioning of the patients can control most airways. Torso injured patients breath better when they are placed in a half-sitting position and get efficient analgesia.

Third, temporary bleeding control is essential during long evacuations; there is no place for the "scoop-and-run" strategy.[21] The sequence of actions should be: first, stop the bleeding; secondly, give volume replacement; then, prevent further loss of temperature and start rewarming. We advise against the use of improvised tourniquets in limb injuries. Most tourniquets do not compress deep arteries, and they never compress the bone marrow; in addition, tourniquets may cause reperfusion syndromes. The study demonstrates that paramedics, as well as trained lay First Responders, are able to control severe extremity bleeding by meticulous packing of the wound tracks and long compressive dressings supplemented with manual pressure on the proximal artery if necessary. With this treatment regime, more than 90 percent of initially hypotensive extremity injured had improved physiologic scores after moderate consumption of intravenous electrolytes. In hypotensive torso injured, we applied the principle of hypotensive fluid resuscitation; the aim of volume replacement should be systolic blood pressure at 90 mm Hg.[22]

Fourth, cold trauma victims bleed more; hypothermia prevention and simple rewarming should be part of the prehospital protocol where transport times are high. We did a study on a subset of the study patients, and found that–even in warm climate—core temperatures at 35° C on hospital admission is not uncommon after long off-road evacuations. Preventing further heat loss (removal of wet clothes and use of dry blankets) and rewarming (plastic bottles of warm water under the blankets, infusions at 40° C) during the evacuation had a significant impact on admission core temperature.

The total time of evacuation had no impact on survival probability in our study population, indicating that trauma victims can take long and rough evacuations once the physiologic damage is controlled with adequate in-field life support measures. We, therefore, hold that the actual prehospital treatment protocol is in accordance with the principle of "minimal acceptable care."

Can we just transfer the key elements of western trauma systems into trauma scenarios in the low-income countries? To answer this question, we have compared our results with the standards set by the MTOS data.[12] For moderately severe injuries, our results compare well; for the severely injured, the trauma mortality is significantly higher than MTOS standards. However, direct comparison of western and non-western system outcome is not justifiable:

1. The MTOS data are derived from western trauma systems with ambulance systems, shorter prehospital transfer times, and well-equipped surgical centers—that is, an infrastructure much superior to the low-tech standards in our study area.
2. The RTS standard for physiologic severity scoring is based on MTOS data and may not accurately reflect the physiologic imbalance in populations where transport times are long. Fifty percent of the unexpected non-survivors in our population had prehospital evacuations of 8 hours or more. Within this time span, the post-injury stress syndrome and immunodepression is activated—that is, dramatic physiologic imbalances inadequately characterized by the RTS indicators.
3. The RTS standards are based on populations of adequate nutrition where endemic diseases are few. In our study area, people suffer because mine fields occupy fertile land, irrigation systems have been damaged by years of war, and imposed embargo causes shortage of technical facilities. Malnutrition, endemic diseases, and anemia are, therefore, not uncommon in our study patients. As these factors affect postinjury immunodepression, they will also probably affect survival probability.
4. In malaria endemic areas with stable transmission of malaria parasites, postoperative relapses of malaria may complicate injury and surgery and affect hospital mortality. One third of severely injured trauma victims (ISS > 15) from the study area in Cambodia had postoperative relapses of Falciparum malaria.[24]

These factors should be considered when we evaluate the quality of trauma systems in low-income countries.

Notwithstanding, there are shortcomings in the subject system that—when corrected—could improve trauma outcome. Having scrutinized cases of unexpected non-survivors, we would like to focus on three problems:

1. Airway control is crucial where evacuations are rough and protracted. Paramedics are able to do in-field cricothyrotomy safely under ketamine anesthesia. The procedure should be done on ready indications in head/face injured where endotracheal intubation is difficult.
2. One should pay attention to postinjury hypothermia also in "warm" countries. Hypothermia is a significant risk factor during surgery on patients in circulatory shock.[24,25] Four of our study patients with estimated probability of survival >50 percent died on the operating table from exsanguinating torso injuries—they were all hypothermic due to lack of prehospital hypothermia prevention.
3. In rural trauma with protracted evacuation, we should rethink the ATLS concept in light of the "damage control philosophy." Victims with exsanguinating abdominal injuries would probably profit from damage control laparotomies being done at district hospitals before undertaking a 4 to 8 hour transport to the surgical center. The laparotomy should exclusively focus on bleeding control and be considered as an ATLS procedure.[22] Studies from low-resource communities demonstrate that trained assistant medical officers can do such surgical procedures.[26,27]

The rate of postoperative infectious complications remained rather high throughout the study period at 21 percent. This is a poorly controlled variable; the registrations are based on retrospective studies by the local supervisor of patient files at the referral hospitals. However, rates of postoperative infections at 20 percent are reported also from other wartime scenarios with protracted evacuations.[28] In scenarios with short prehospital transit times, the rates of infectious complications are less.[29]

Concluding a recent review of trauma system effectiveness, Mullins and Mann rightly comment that trauma mortality is an insufficient indicator of system effect.[1] Measures such as functional recovery and return to work should be monitored as well. We fully agree; we examined a subset of our study patients and found that 75 percent of seriously injured survivors suffered from chronic pain syndromes that made physical rehabilitation difficult or impossible. The rate of pain syndromes did not relate to the quality of trauma care, but it did relate to social factors such as loss of income and lack of coping strategies.[30] Assessing trauma system effect in low-income countries with broken infrastructures is thus a complex matter that requires further studies of outcome indicators beyond mortality and hospital morbidity.

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