

**The chain of survival**

**Studies of a pre-hospital trauma system in Iraq**

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*I expect to pass through life but once.*

*If therefore, there be any kindness I can show, or any good thing I can do to any fellow being, let me do it now, and not defer or neglect it, as I shall not pass this way again.*

William Penn



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## Abbreviations and definitions

ASA-PS	American Society of Anaesthesiologists, Physical Status Classification
ATLS	Advanced Trauma Life Support
AUC	Area under Curve; a measure of test accuracy based on ROC graphic plots
BLS	Basic Life Support
CI	Confidence interval for assessment of statistical significance
CPR	Cardio-Pulmonary Resuscitation
EMS	Emergency Medical services
GCS	Glasgow Coma Scale; index for grading of level of consciousness
IED	Improvised Explosive Device; homemade high-energy blast weapons such as roadside remote controlled mines or car bombs
KRG	The Kurdish Regional Government, legal authorities in North Iraq
LMIC	Low- and Middle Income Countries
MKM	Mudhafar Karim Murad MD (the author)
MTOS	Major Trauma Outcome Study. Retrospective study of large cohorts of US trauma victims to establish quality of treatment standards
NISS	New Injury Severity Score
Pd	Probability of death
PTS	Pediatric Trauma Score
Ps	Probability of survival
PSS	Physiological Severity Score; simplification of Revised Trauma Score used by the authors in my studies
ROC	Receiver Operating Characteristics. Statistical method to assess the accuracy of tests
RTA	Road traffic accidents
RTS	Revised trauma Score; index for characterization of physiological severity of injuries, a revision of the Trauma Score
TBSA	Total Body Surface Area, a measure of burn wound severity
TCF	Trauma Care Foundation
TMC	Tromsø Mine Victim Resource Centre
TRISS	Trauma and Injury Severity Score; index for characterization of physiological and anatomical severity of injuries
UXO	Unexploded ordnance.



## List of papers

1. Murad KM, Larsen S, Husum H. What makes a survivor? Ten-year results from a time-cohort study of prehospital trauma care in Iraq. *Scand J Trauma Resusc Emerg Med* 2012, 20:13; doi: <http://www.sjtreem.com/content/20/1/13>
2. Murad KM, Husum H. Trained lay first responders reduce trauma mortality: A controlled study of rural trauma in Iraq. *Prehosp Disast Med* 2010; 25: 533-39; doi: <http://dx.doi.org/10.1017/S1049023X00008724>
3. Murad KM, Issa DB, Mustafa FM, Hassan HO, Husum H. Prehospital trauma system reduces mortality in severe trauma: a controlled study of road-traffic casualties in Iraq. *Prehosp Disast Med* 2012, 27, 36-41; doi: <http://dx.doi.org/10.1017/S1049023X11006819>



## Summary of the thesis

The thesis is a summary of studies of a chain-of-survival prehospital trauma system in a low-resource setting with long prehospital transit times. The aim of the studies was to evaluate to which extent a low-cost prehospital trauma system reduces trauma deaths where prehospital transit times are long; to examine if early in-field first aid by lay first helpers contributes to reduced trauma mortality and better out-of-hospital treatment effects; and to identify specific life support interventions that contributed to survival.

The reference population for the studies is trauma victims in low-resource communities. The study population consists of trauma victims in Iraq during a ten-year study period from 1997 to 2006, land mine and war casualties as well as victims of road traffic accidents.

The main study was conducted with a time period cohort design, comparing trauma system mortality over ten years through three time periods. The second study of material from the same study population was a non-randomized controlled interventional study comparing treatment effect and mortality in patients managed by lay first helpers versus patients not managed initially by first helpers. The first two studies were conducted with historical controls, which make outcome estimates uncertain due to contextual changes during the study period. To avoid such flaws, the third study was conducted as a single-blinded, non-randomized prospective cohort study over a three-month study period, comparing treatment effect and mortality rates in road traffic accident casualties managed by trained prehospital life support providers versus casualties not getting any kind of prehospital life support.

The main study documented that the mortality rate was reduced from a pre-intervention level at 40% to near 5% at the end of the study period, survival especially improving in major trauma victims. In most patients with airway problems, in chest injured, and in patients with external hemorrhage, simple life support measures were sufficient to improve physiological severity indicators. The main causes of avoidable deaths were misdiagnosis of major injuries on the scene, and delay of proper primary surgical intervention at the referral hospitals. The second study showed that the mortality rate was significantly lower among patients initially managed in field by first responders compared to patients without first responder support. The third study documented that the mortality rate was significantly lower in the treatment group compared to the control group. Also, when adjusted for severity, prehospital care was a significant contributor to survival.

In conclusion low-cost prehospital trauma life support systems improve trauma outcome in low-resource countries with long prehospital transit times. In such scenarios lay trauma first responders should be an integral element in prehospital trauma systems.



# 1. Introduction

## 1.1 The Global Epidemic of Trauma

A worldwide, accelerating epidemic of trauma is going on, and injury accounts for a significant proportion of the world's burden of disease. Each year 5.8 million people die from injury and millions more are becoming disabled. Injury is now the fourth leading cause of global deaths, and WHO predicts a further 40% increase in trauma fatalities by 2020.<sup>1</sup> A Road traffic accident, war injuries, self-inflicted injuries, and domestic violence are the most common causes of traumatic death.

However, mortality rates differ significantly according to the country and socio-economic characteristics. Most natural disasters and local wars hit low-resource areas, and almost 90% of deaths due to injury occur in low and middle-income countries (LMIC),<sup>2</sup> Rural peasant communities and the urban poor in the South have become targets of high-tech warfare. In recent wars – as in Afghanistan, Lebanon, Gaza and Iraq – health facilities, roads, bridges, and irrigation systems are systematically destroyed. Land mines and cluster bombs add to the legacy of destruction by occupying the remaining fertile fields and grasslands. Despite major clearing operations, more explosive ordnances are laid than cleared, meaning that the epidemic of hidden explosives is accelerating and that the villages in the South will be victims for generations to come.<sup>3</sup> Surveys in mine infested countries demonstrate civilian mortality rates as high as 40-50%, with most fatalities occurring outside hospitals<sup>4, 5, 6, 7</sup> Also regarding the epidemiology of traffic accidents the global distribution is skewed: More than 80% of traffic accident deaths world are found in LMIC. In resource-constrained settings most road traffic accidents involve pedestrians. The car crash mortality in the population in the South is 23/100,000 compared to 16/100,000 in north (95% CI difference 5.9-6.1 per 100,000). Relatively more people are killed despite having few cars, indicating the effect of poverty on road safety.<sup>8, 9</sup>

### *Trauma systems – the challenge*

Realizing that is practically impossible to control the "trauma epidemic", we should aim at improving the probability of survival by helping the targeted communities to cope. Doing so we have to keep in mind that the qualities of most trauma scenarios in LMIC countries are fundamentally different from trauma scenarios from high-income countries. Most low-income countries are ridden by endemic diseases; years of war civil unrest and embargo have weakened health infrastructures leading to inadequate systems of hospital and community based emergency care.<sup>10, 11</sup> Also the distribution of human resources on a national scale is skewed with most physicians and medical facilities located in the cities, the rural population having poor access to emergency care.<sup>12, 13</sup> The flight of health professionals – brain drain – from the South to the North further adds to the problem. After graduation more than 50% of medical doctors are leaving low-income African countries for jobs in the West. For example, Ethiopia has a reputation for producing excellent medical doctors, but there are more Ethiopian MD doctors in Chicago than in Ethiopia.<sup>14</sup> Also Asian countries are severely affected. In 2006 the International Monetary Fund ranked Iran as the country most affected by brain drain of intellectuals among 90 LMIC countries examined. During the embargo of Iraq in the 1990's, the flight of medical professionals and university teachers increased. After the invasion 2003 hundreds of Iraqi doctors

and university professors have been kidnapped or killed in the country. These events have set off a massive brain drain, as more and more Iraqis left the country, perhaps never to return.<sup>15</sup>

### *The pre-hospital focus*

The risk of trauma death depends on the balance of injury severity versus the victim's physiological capacity. Malnutrition and pre-injury illness affect physiological capacity by weakening the immunological response to injury.<sup>16</sup> Also studies of trauma systems in malaria endemic areas demonstrate that poverty and malaria falciparum adds to the burden of trauma by increasing trauma morbidity.<sup>17</sup> Out-of-hospital time is another risk factor for a trauma patient in physiological imbalance. Within hours after injury, the primary tissue damage triggers devastating cascade responses. The longer the delay before physiological balance is restored, the heavier the derangement.<sup>18, 19</sup> Studies of Western trauma scenarios consistently report that reduced prehospital transport times and level-1 trauma centers are the essential components of a good trauma system.<sup>20, 21</sup> However, helicopter evacuations and high-cost surgical centers are not feasible in low-income societies and in countries where the social fabric is broken by war. For most trauma victims in the South the prehospital trauma care providers are non-graduates, ill equipped and hardly trained, and the route to surgical care can take hours – either due to remoteness or due to urban bombing and chaos. For optimal life support and also for reasons of sustainability the focus of attention in war and mine fields should be forward care.

**Figure 1**



Lay first helpers with villagers evacuating a land mine victim from the mountains at the Iran-Iraq border. Notice the compressive hemostatic dressing on the amputated leg.



### *Difficult access*

Most humanitarian actors admit that the humanitarian space in armed conflicts is contracting, especially so since the attacks on the United States on 11<sup>th</sup> of September, 2001. In the last decades Western governments and armies have used civilian relief interventions to further political and military aims, thus blurring the border between armed and humanitarian intervention and undermining principles of independent humanitarian access. Evidence for the shrinking of humanitarian space is easily found in recent high-profile wars. In Lebanon 2006 and Gaza 2009 – as in Iraq at present – deliberate armed attacks on ambulance staff, rescue workers, and medical doctors are well documented. Both in Afghanistan and Iraq the major humanitarian donors are also occupying forces engaged in high-intensity combat operations and psychological warfare.<sup>22, 23, 24, 25</sup> Given these circumstances, the only way to provide efficient minimum-quality trauma life support is to build indigenous local capacity of care in the most affected areas.

**Figure 2**



Israeli air-to-ground rocket hit on an ambulance. Lebanon July 2006.

## **1.2 The epidemiology of trauma in Iraq**

Iraq is a war torn country located in the deserts of the Middle East with a population of 31.5 mill. The country has a low GDP per capita, ranking as no.126 globally. The life expectancy is 70.3 years, ranking as no. 112.<sup>26</sup>

### *Wars and weaponry*

In 1977 during the running up to the Iran–Iraq War, the Saddam regime implemented severe anti-Kurdish policies and a *de facto* civil war broke out in the North where the Iraqi army destroyed more than 5,000 villages and collected large portions of the rural population in collective towns similar to the KZ-policy of the German Nazi regime. The Iraq-Iran war 1980-88 was the longest conventional war of the twentieth century. It was one of the deadliest wars since the World War II with an extreme cost in lives and materials. The Iraqi casualty estimates range between 250,000-500,000 killed and wounded.<sup>27</sup>

**Figure 3**



Civilian victim of chemical warfare during the Iraq-Iran war.

During the last period of the Iraq-Iran war the Saddam regime conducted a savage military campaign against the Kurdish population in the North called *Anfal* ("Spoils of War"). The Anfal-attacks led to destruction of 2,000 villages and the death of 50,000 – 100,000 Kurds.<sup>28</sup> During the war millions of land mines were laid, mainly on the Iraqi side, making the country one of the most affected land-mined nations.

The next war was the Gulf War 1990-1991 after the Iraqi army occupied Kuwait. An estimated number of 200,000 Iraqi civilians were injured during the war.<sup>29</sup> After the Gulf War a popular uprising against Saddam regime occurred in 1991 (Kurdish: "Raperîn"); a series of anti-government demonstrations took place all over Iraq. The uprising was suppressed by massive and indiscriminate force against the civilian population. During a few weeks in the Spring tens of thousands of people were killed and injured and nearly two million people fled through the mine fields cross border to Iran and Turkey, fatality counts from mine accident were never registered. To alleviate the situation, the Security Council established a "safe haven", no-fly zone, in North Iraq and the refugees started to resettle in their villages.

The third war started in March 2003 with the invasion of Iraq by United States and United Kingdom. Surveys of post-invasion deaths in Iraq estimates an excess death rate as a consequence of war corresponding to 2.5% of the population, gunfire and bomb blasts being the most common cause of death.<sup>30</sup>

With shifting pattern of war, also the weaponry and the epidemiology of war-related injuries changed. The Iraq-Iran war and the civil wars between Bagdad and the Kurds were fought mainly by guns and artillery, most victims suffering penetrating injuries. Also when it came to land mine injuries, the penetrating injuries to the torso caused by metal fragments or secondary projectiles (particles from the ground and pieces of the victim's body) represented the main medical problem – more than the traumatic amputation caused by the blast.<sup>31</sup> With the Gulf War and the 2003 invasion came the new generation of blast weapons, thermo-baric weapons and Dense Inert Metal Explosives, maiming and killing resulted mainly from high-energy blast waves. Also Improvised Explosive Devices (IED) used by the resistance and by terrorists mainly act by blast waves. Three factors make blast injuries a special challenge for life support providers: The scene is often one with mass casualties and chaos; the blast victims often have associated burns; and the clinical signs and symptoms of blast damage to the internal organs are hard to read during the first hours after injury.<sup>32</sup>

**Figure 4**



Bomb blast casualty, Iraq year 2007. The abdominal wall hematomas indicate massive internal injuries.

#### *A tsunami of traffic casualties*

After the invasion in 2003, North Iraq underwent rapid social changes. Dollars were pouring in, many families improved financial incomes, the borders opened – and as a consequence an unprecedented number of cars were imported and sold. However, the roads were damaged by decades of previous wars; the social fabric was broken and rules for traffic conduct and safety were not followed, with most drivers driving without training and licenses. As an effect, North Iraq faced a sudden increase in road traffic accidents, the majority of trauma victims brought to hospital being road traffic accident (RTA) casualties – and not victims of mines and war.<sup>33</sup>

In summary, an efficient trauma system in Iraq should be flexible and able to respond to changing patterns of injury epidemiology.

### **1.3 The health system and the medical education in Iraq**

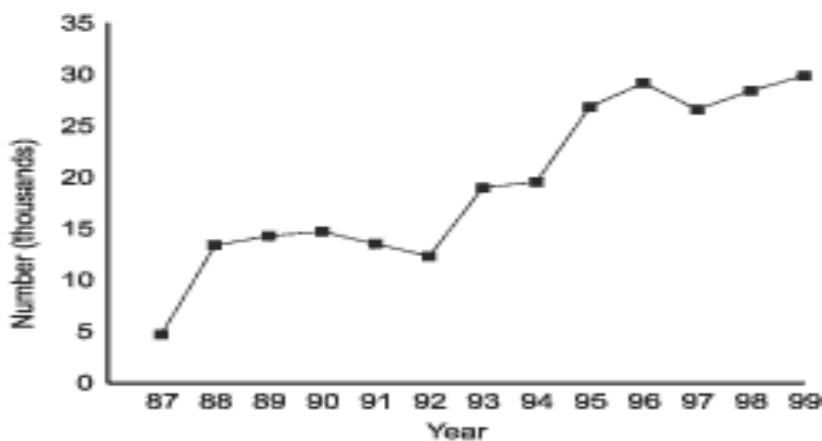
Before 1990, Iraq belonged to the group of middle-income countries. The state policy during the 1960's and 70's supported a well-organized social infrastructure. An extensive network of communications, including telephones, coupled with an efficient ambulance service for patient transportation in emergencies, allowed the health referral system to perform competently, and brought secondary and tertiary care within the reach of all those in need. Drugs, medical supplies and equipment were amply provided as needed to the health facilities. The health care system was based on hospital oriented and the capital-intensive model of care with extensive and expanding network of health facilities was linked by reliable communication and transport systems. Control systems for epidemic diseases were established on a national scale. Over 500 modern water treatment plants assured nearly universal access to abundant safe drinking water. Modern sewage treatment plants kept the sanitation system in the country at a relatively high level, comparable to that of the less developed countries in Europe. Medical conditions related to poverty and poor environment, such as cholera, typhoid, poliomyelitis and tuberculosis, had low incidence rates before 1990. Diseases related to affluence and inappropriate lifestyles were also not reported in any significant numbers. All in all, the Iraqi health system was probably one of the best in the Middle East at that time.

### *The UN embargo and wars – man-made disasters*

During the 1990's there was a dramatic deterioration of health system in Iraq as an effect of the Iraq- Iran war (1980-1988), the Gulf war in 1991, which was preceded by the imposition of economic sanctions by UN in August 1990, and lastly, the invasion of Iraq by the American and British forces in 2003. The economic embargo was imposed by the UN in August 1990, the Security Council (Res. 661), acting under Chapter VII of the UN Charter. The embargo was efficiently implemented and had severe effect on the daily life of the Iraqi people: exploding market prices for basic foodstuffs caused malnutrition and low-caloric intake. Decreased agricultural production, increasing black market trading caused galloping inflation and unemployment. The long-term damage to the fabric of society is hard to assess but widespread economic disruption caused heightened levels of crime, corruption and social disruption. Competition for increasingly scarce resources allowed the Iraqi state to use clan and sectarian rivalries to maintain its control, further fragmenting Iraqi society.

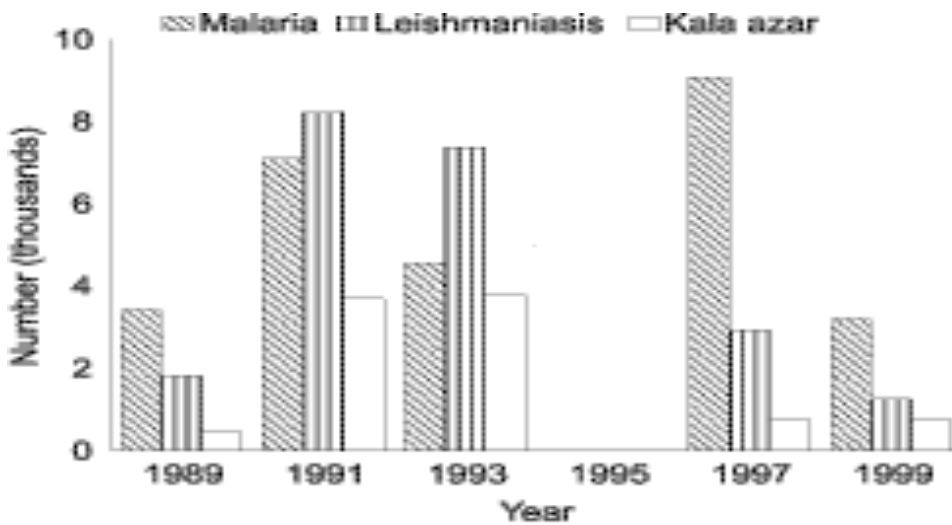
In 1997, the UN Committee on Economic, Social and Cultural Rights noted “The living standard of a large section of the Iraqi population has been reduced to subsistence level since the imposition of the embargo”. WHO confirmed in 2000 there were still about 800 000 children under 5 years who were chronically malnourished. They reported also high prevalence of anemia in schoolchildren. Waterborne and foodborne diseases such as cholera, poliomyelitis and typhoid, vector-borne diseases such as malaria and Leishmaniasis, and other bacterial diseases such as tuberculosis were on the increase. The numbers of infants with low birth weight and women with severe anemia also increased.<sup>34</sup>

**Figure 5**



Number of reported cases of tuberculosis, Iraq 1987-99 (Northern governorates excluded) (Source: Iraq, Ministry of Health).

Figure 6



Number of reported cases of malaria, leishmaniasis and kala azar, Iraq 1989-99 (Source: Iraq, Ministry of Health).

The most recent war, initiated by the US-led invasion in 2003, triggered a new wave of disruption in the country adding to the devastating effects of the UN embargo. The intensity of destruction has varied across provinces and districts in Iraq, the South and Centre being the most affected during the first years of war.<sup>35, 36, 37</sup> Most Iraqi civilian violent deaths during 2003–2008 of the Iraq war were inflicted by “unknown perpetrators”, primarily through extrajudicial executions that disproportionately increased in regions with greater numbers of violent deaths. Unknown perpetrators using suicide bombs, vehicle bombs, and mortars had highly lethal and indiscriminate effects on the Iraqi civilians they targeted. Unknown perpetrators caused an estimated 74% of all war related deaths. Deaths caused by Coalition forces of Iraqi civilians, women, and children peaked during the period 2003 - 2004, with relatively indiscriminate effects from aerial weapons.<sup>38</sup>

#### *Disruption of the health system*

As a consequence of the embargo and war all infrastructure was devastated - and especially the health care system. Insufficient numbers of medical personnel, shortages of essential drugs and vaccines, inadequate technical facilities, difficulties obtaining access to treatment, reduced availability of medical services in rural and remote areas, are all factors which contributed to the deterioration of the health system. Especially after the 2003 invasion the available human resources fell short of needs. While 34,000 physicians were registered with the Iraqi Medical Association in the 1990s, by 2008 there were only around 16,000, a trend that has unfortunately not been reversed since the government's 2008 appeal for medical staff to return to the country. Furthermore, while in most countries the standard nurse-to-doctor ratio is around three to one, in Iraq, according to government estimates, there are only around 17,000 nurses. While health-care facilities have been rebuilt in some urban centers recently, the health centers in rural and remote areas remain in dire condition. Facilities already coping with a poor supply of electricity or water frequently also have to deal with unreliable sewage or air-cooling systems and with inadequate solid-waste disposal. The equipment is often old, poorly maintained, and out of order.<sup>39</sup> “Iraq will need at least 10 years to rebuild its infrastructure. We

need help from everybody”, said Ali Al- Shamari, Iraq’s health minister on November 9, 2006. He also said: “ Each day we lost 100 persons, that means per month 3,000, so by three years 140,000 plus or minus 10 present”.<sup>40</sup> And maybe the death count is even higher - a Baghdad Central Morgue statistics office worker reported in 2009: “They do it on purpose. I would go home and look at the news, the ministry would say 10 people killed got killed all over Iraq. While I had received in that day more than 50 dead bodies just in Baghdad. It is always been like that – they would say one thing but the reality was much worse.”<sup>41</sup> In such situation with a heavy burden of trauma and ongoing war atrocities, one should assume that the rebuilding of a nationwide trauma system was a matter of considerable concern by the Iraqi government and the Ministry of Health. However, despite positive official declarations, no guidelines or protocols for trauma care currently exist on the ground in Iraq. Since 2010 ambulance centers have been rebuilt in the major cities, but dispatch emergency medical systems are still not in place.

#### **1.4 Trauma systems for Low- and Middle Income Countries – the gap of knowledge**

Experience from high-income countries has demonstrated that improvements in trauma survival depend on better organization and planning of trauma care services. Well-organized trauma systems have decreased mortality by 15%-20% and decreased medically preventable deaths by 50%.<sup>42, 43, 44, 45</sup> However, most trauma system guidelines and standardized trauma severity indices are based on studies of large populations of mainly urban and mainly well-fed western trauma victims, and would not be directly applicable to low-resource settings. One study examined costs and benefits of the EMS system in Kuala Lumpur and concluded that a system based on North American EMS standards would be costly and would only be expected to save a very small number of lives per year.<sup>46</sup>

Having searched the medical database for references to epidemiological and clinical studies of outcome of trauma care in LMIC, we found no set of standards to guide trauma system development in low-resource communities. A few reports are published from hospital based epidemiological studies of urban trauma in low-resource settings.<sup>47, 48, 49</sup> However, these studies results are based on self-reports from the trauma trainees, and not on medical outcome data. The literature searches revealed no reports on rural pre-hospital trauma systems from LMICS. As most studies on trauma system efficacy have been conducted based on historical controls in an unstable and shifting context, the results reported may be unreliable. Recent reviews rightly point to the fact that controversies regarding prehospital care models cannot be readily solved because most studies of the effectiveness of prehospital trauma care have been conducted with observational, retrospective and non-controlled designs.<sup>50, 51</sup> One controlled study is published from Iraq, reporting improved trauma survival where layperson first responders are integrated in the prehospital trauma system (paper 2); to the best of our knowledge no other controlled study of prehospital care efficacy has been reported from low-resource settings.

There is thus an urgent need to develop trauma care system models for LMIC. Such interventions should be conducted in a scientific manner with careful documentation of explanatory variables and outcome indices. Wherever possible controlled designs should be implemented.

## 1.5 The chain-of-survival – scientific foundation

The template for the trauma system implemented in Iraq was developed and tested in previous wars in Afghanistan and Burma.<sup>6, 52</sup> The model especially targets casualties with long out-of-hospital times, and rests on the assumption that early life support is the best life support.

### *Scientific foundation for the intervention*

Time is a critical factor in primary trauma care: the injured start dying at the time of injury. This is the physiological paradigm that sets the foundation of prehospital care models. Damaged tissues, blood loss, pain, and infection triggers a massive physiological post-injury stress response in the body. Unless controlled at an early stage, the stress response brings the physiology out of balance and may cause multi-organ failure and death. It accelerates rapidly within hours after the injury. Recent studies have documented that the systemic inflammatory response syndrome (SIRS) score is a useful predictor of outcome in critical surgical illness; the duration and severity of SIRS are associated with post-traumatic organ dysfunction and mortality.<sup>53, 54</sup>

The main triggers of post-injury stress are:

- **Damaged tissue:** The sympathetic nervous system is activated by chemical substances from crushed and injured cells, causes the release of catecholamine, epinephrine, and norepinephrine, intensifying: breathing speeds up, the heart rate and cardiac output increases. This compensatory mechanism is an effort to improve perfusion to the vital organs and tissues. On the other hand the activation also releases cytokines, potent mediators that trigger the immune system and acts on the endothelial cells. The capillary wall starts leaking which is very useful for white blood cells to pass through to the site of injury to catch and remove dead tissues and bacteria. This local cleanup response helps prevent infection, but on the other hand the activated phagocytes (white cells) further stimulate cytokine production.
- **Oxygen starvation:** Next to reperfusion syndrome (see below), a state of shock is the strongest trigger of cytokine production. The time factor is important here: if cells remain in a state of shock for more than 1-2 hours, anaerobic metabolism will be predominant, stimulating lactate production and subsequent metabolic acidosis.
- **Re-perfusion syndrome:** Re-perfusion is what happens when the blood circulation is re-established to body tissues after a period of poor blood supply. If reperfusion occurs after a period of two hours or more of hypoperfusion/ischemia, chemical substances washed out from the tissues trigger a massive cytokine response, which act both locally and globally. In the injured tissues the endothelial cells become damaged and the capillaries becomes blocked by clots of blood cells. The all-body effect of this potent trigger is coagulation failure and immune suppression.
- **Pain and fear:** Persisting pain and fear act as permanent triggers of cytokine release, thus causing immune suppression. Pain also acts directly on the autonomous nerve system to upgrade the stress hormone response (adrenaline, cortisol).

- Bacterial infection: The gram-negative infections (E-coli, pseudomonas, Klebsiella) are especially potent actors in the post-injury stress response; their membranes contain an endotoxin that acts on the endothelial system and triggers a general cytokine response, which can cause coagulation and immune failure.
- Burns: More than other tissue injuries, burns of more than 25% of total body surface area trigger a massive release of cytokines. This causes an immediate reduction in cardiac output and reduced blood flow through the lungs the first day post burn – and consequently global oxygen starvation, which is another trigger of stress. The cytokine release also act on the capillary wall and induces tissue edema, not only in the burn wound but also in unaffected tissues causing pronounced suppression of the immune system with high risk of post-injury infections and an enormous increase in energy requirements from the first week after injury. When severe injuries are associated with burns one should be especially aware of post-injury stress complications.
- Hypothermia leads to peripheral vasoconstriction, increasing systematic vascular resistance, reduced cardiac output and arrhythmia, consequently impairing oxygen delivery and increasing lactic acid production. Hypothermia also affects the adhesive function of thrombocytes causing coagulopathy.

In summary, the life support provider should aim at controlling the triggers of post-injury stress at an early stage.

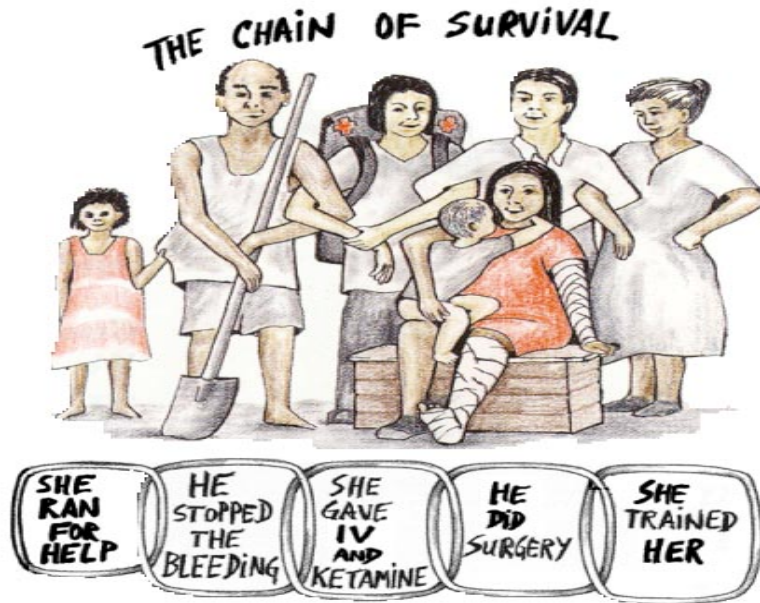
#### *The model, an outline*

We should organize the trauma system based on our understanding of the devastating physiological responses initiated by the primary injury. The answer to that challenge is a network model where life support is provided at three levels:

- Trauma first responders: We need an army of layperson villagers or soldiers to start basic life support as soon as possible on the scene, assist the patient all the way to paramedic, and assist the paramedic. First responder treatment protocol, see chapter 3.4
- Paramedics: We need at least one trained paramedic in every area where injuries are expected. The paramedics should train and work in a team with first responders. Within 30 minutes after injury the paramedic team should supplement basic life support measures with advanced techniques.
- Emergency room care and life-saving surgery: The actual model builds on the assumption that 80% of all injuries including traumatic brain injuries can be managed at district hospital – provided the teams are trained properly and equipped with a minimum of technical resources. Patients in need of extensive neurosurgery, vascular repair and microsurgery should be transferred to specialized level-I trauma centers.



Figure 7



The rural Chain of Survival.<sup>51</sup>

### 1.6 Trauma system quality control

Trauma scores are audited and research tools used to study the outcomes of trauma systems, rather than tools to predict the outcome for individual patients. In any trauma patient the outcome of treatment provided depends on two main variables: the severity of the actual injury in relation to the patient's physiological capacity. The combination of the two variables constitute the risk dismal result, it would be infection, organ failure or death.

To assess the risk of trouble and estimate success or failure thus requires an accurate description of the severity:

1. For triage: In poly-trauma cases and mass causality situations, patients must be sorted in order to identify the injury and the patient with first priority for life support and surgery.
2. To monitor the treatment effect: the life support efforts go on all the way from the scene to the hospital, and we need a simple and solid indicator, which can tell us if the patient improves, or deteriorates in our hands.
3. For trauma system quality control: the system coordinators should check the treatment quality over the time and also compare the efficiency of one system branch or one hospital against another. For this we need severity descriptors, which are accurate enough to ensure that subsamples of trauma patients really are comparable.

A key question to be answered in low-cost trauma systems is therefore: How can we estimate trauma severity in a simple, yet accurate manner?

### *Physiological severity scoring*

A physiological severity index assesses the impact of the tissue damage on the body's physiology. It is basically a measure of post-injury oxygenation. The "golden standard" for physiological severity scoring is the Revised Trauma score (RTS). The Trauma Score was introduced in 1981, and registers the respiratory rate, respiratory effort, systolic blood pressure, capillary refill time, and Glasgow Coma Scale (GCS). In 1989, the Trauma Score was modified and the Revised Trauma Score (RTS) was launched building on three clinical indicators: the respiratory rate, systolic blood pressure and Glasgow Coma Scale.<sup>55</sup> The physiological severity score status in given patient is not constant, but depends on the damaging impact of the primary injury and what is done for life support.

#### **Revised Trauma Score rating**

GCS	SBP(mm Hg)	RR (min-1)	Coded value
13-15	>89	10-29	4
9-12	76-89	>29	3
6-8	50-75	6-9	2
4-5	1-49	1-5	1
3	0	0	0

In the RTS system, each of the three indicators is given different weight. The total RTS is calculated as  $RTS = 0.9368 \times (GCS \text{ coded value}) + 0.7326 \times (SBP \text{ coded value}) + 0.2908 \times (RR \text{ coded value})$ . DEFINE SBP AND RR. The RTS for any patient at any time can thus take on values from zero (lifeless) to 7.8408 (normal physiological state). In clinical practice the RTS is used for triage, without calculating weights. The simple ranked Triage-RTS (T-RTS) is thus ranking from zero to 12. Recent studies have documented that the T-RTS is as accurate as the weighted RTS in trauma system analysis and death prediction.<sup>56, 57</sup> For this reason the non-weighted severity should be feasible in low-cost interventions.

Another concern is drawbacks regarding GCS accuracy. Scientific studies document that the GCS is a rather an inaccurate measure with poor inter-rater agreement also among trained trauma doctors. Besides, the GCS ratings are hard to remember and may thus be inaccurate in chaotic and rough settings. Further, it has been argued that the GCS motor response alone (rate from 1-5) measure severity as accurately as the complete GCS rating.<sup>58, 59, 60, 61</sup> One should thus consider replacing the original GCS variable with simplified ratings of consciousness levels.

### *Physiological severity scoring in pediatric patients*

The normal values of respiratory rate and blood pressure are different in children and adults. Also children respond differently to blood loss; e.g. falling systolic blood pressure is a very late sign of

hypervolemia in infants and indicates a desperately dangerous condition. Thus the standard PSS may be an inaccurate severity measure in child victims as it systematically underestimates trauma severity. In child victims less than 12 years old one should consider the use of the Pediatric Trauma Score (PTS). A Normal PTS value depends on age and varies from 9 (infants <10 kg) to 12 (children >20 kg). Any injured child with PTS at 7 or less is considered to be in immediate danger and has priority for life support and urgent evacuation.<sup>62</sup>

### The Pediatric Trauma Score (PTS)

	+2	+1	-1
Body weight	More than 20 kg	10-20 kg	Less than 10kg
Airway	Normal	Moderate obstruction of airway	Obstructed or intubated
Systolic blood pressure	More than 90 mmHg	50-90 mm Hg	Less than 50 mm Hg
Conscious level	Awake	Moderate loss of consciousness	Deep unconsciousness
Open wound	None	Small	Large or deep
Fractures	None	Small	Open or several

However, trauma registry studies document that the RTS is at least as sensitive as the PTS in identification of major trauma victims among child patients.<sup>63</sup>

### *Anatomical severity scoring*

The extent of tissue damage is an independent risk factor in trauma care. The gold standard for assessment of the anatomical injuries is the Injury severity score (ISS). The ISS was originally developed for the study of automobile accidents, but has gained widespread acceptance and has been modified to cover most injury types.<sup>64</sup> The ISS is defined by severity grades listed in a comprehensive manual of surgical diagnosis set by the US College of Trauma Surgeons: *The Abbreviated Injury Scale (AIS)*. To set the ISS on any patient one needs exact surgical information on all organ injuries based on the operating theatre findings, X-ray documentation and autopsy findings. Unlike the physiological scores, the ISS is set in retrospect when the primary surgery is done. The ISS does not vary depending on blood loss and oxygen uptake, but is specific and constant for any patient.

In the AIS manual all surgical diagnosis diagnoses in trauma are listed with a specific number, eg. "Fracture of 2-3 ribs with hemo/pneumothorax: 450220.3". The six-digit number is a specific descriptor for each diagnosis and the severity classification for that specific diagnosis is indicated by the figure after the dot, the AIS code. However, there are unresolved problems with the use of this scoring index: Firstly, ISS ratings are commonly published as if the variable is continuous and linear.

However, the AIS scale does not represent a linear scale, i.e. the difference between AIS1 and AIS2 is not the same as the difference between AIS4 and AIS5. Secondly, the scale may be inaccurate in poly-traumatized patients. For ISS calculation in one single patient, only the most severe injury from each of maximum three body regions should be included. If one patient has gunshot injuries to the small intestines, colon and also the liver, only one and the most severe of these organ injuries is taken into the ISS calculation. Thus ISS may underestimate injury severity where there are multiple injuries concentrated to one body region. For this the New Injury Severity Score (NISS) is suggested. Like ISS, the NISS is based on severity grading by AIS codes, but NISS calculation is based on the three most severe injuries regardless if all three are concentrated in one single body region.<sup>65</sup> However, intermediate analysis of the Trauma Registry in Iraq, which includes a substantial subsample of patients with multiple injuries documented that both ISS and NISS had high and similar accuracy in trauma death prediction.<sup>66</sup>

#### *Identifying patients with unexpected outcomes*

Patients with unexpected outcomes are especially valuable clinical teaching cases and highly relevant clinical issues, and should be carefully audited: What went wrong in patients with high probability of survival that died? Why did certain severely injured cases actually survive, what was the key to success in those cases? The probability of trauma death (Pd), in any patient is a function of both anatomical and physiological severity. To identify cases with unexpected outcome, a combined anatomical-physiological severity calculator is required in order to define mortality probabilities. The international "gold standard" for Pd calculation is the Trauma and Injury Severity Score (TRISS).<sup>67</sup> TRISS estimates are based on emergency department RTS, ISS, age, and mechanism of injury (blunt vs. penetrating). The TRISS calculator is based on data obtained from a large American database of 81,000 trauma patients in 1987, the Major Trauma Outcome Study.<sup>54</sup>

#### *Limitations of TRISS*

Most textbooks and courses in trauma give the impression that the common severity indices can be applied in any setting. However, we would argue that most diagnostic tests should be calibrated for the study sample at hand. Looking at the TRISS calculator from this point, several flaws are evident: Firstly, both the AIS used for ISS estimation and the physiological index, RTS, are derived from Western urban trauma cohorts of mainly healthy patients being taken rapidly to well-equipped trauma centers – a context very different from war-torn Iraq. The TRISS includes an age variable building on the expected lifetime in Western countries. Further, there are methodological problems with the TRSS: for comparisons between trauma systems, the actual distribution of predictor values is crucial. The goodness-of-fit of the TRISS calculator may be low in the actual study population if the distribution of predictors (ISS or RTS elements) differs significantly from the distribution in the US reference population. Also the GCS parameter is dubious due to low inter-rater agreement, particularly for inexperienced raters.

Therefore evaluations of trauma system performance as well as audit of cases with unexpected outcomes should be based on probability models developed based on data from the actual trauma system, rather than probability calculators imported from other trauma populations.

## 1.7 Trauma training

The trauma training is village based and courses are conducted at makeshift locations inside the target area such as schools, district hospitals, tents or guesthouses. Still, the course content includes lessons in modern pathophysiology, updated protocols of trauma life support as well as practice on animal models equivalent to the training protocol for civilian and military trauma care providers in Western countries. Therefore the teaching model runs by the slogan “The Village University”.<sup>68</sup> Trauma training and rehearsals is the most important part of trauma system setup and coordination and takes more time and effort than treatment and treatment audit.

### *Criteria to select trainees*

Good plans alone do not make a change; the key for success is to select the best persons to implement the plan. The local paramedics make the core of the chain of survival – being care providers, teachers of first helpers, and organizers of difficult and dangerous rescue operations and evacuation. The criteria for selection of paramedic trainees are: the person should be living permanently in his/her village and have a good moral standing and trust among fellow villagers, speaking with “one tongue” and treating any person and family with kindness and respect. The person should have previous hands-on experience with mine- and/or war victims, should know how to read, write and be able to do basic calculations.

### *Teaching concept*

The teaching concept of the actual intervention builds on one basic assumption: the medical profession's copyright on life-saving intervention has to be broken; non-doctors are also able to provide advanced life support and life-saving surgery. The main features of the Village University strategy are:

- Always local: We all learn better when feeling confident and at home. The trainees and villagers are participating in setting up the training facilities, taking care of mannequins and animals.
- Learning by doing: Practice constitutes 75% of the course, lectures and theory maximum 25%. All practical sessions focus on real-life problems. Every day the trainees present real-life case stories for discussion and evaluation in the class.
- Team work: One by one the students train in the details of practical life support on dummies, and on one another. Then they students work in teams of 2 – 4 on dummies, animals, and real-life victims. Each practical session is followed by an evaluation by the fellow students where team work and leadership is focused.
- Trouble shooting – not flow charts: Most mine- and war victims have multiple injuries, and there is no victim with injuries similar to another. The site of the accident is often chaotic and dangerous and there is often shortage of equipment and drugs. In these settings strict treatment protocols and algorithms are not working. Therefore systematic and exact clinical examination is emphasized: how to see/hear/ feel signs of oxygen starvation and physiological derangement by exact clinical examination. Based on one thorough examination the main problem is identified and solved – and the victim (animal model) examined again to target the second most important problem and so on.
- Simple life, hard work: Classrooms, tables, and operating rooms are simple and cheap made from local materials. The work at the Village University for weeks is hard, courses running from early morning to

late night. The students stay evenings and nights together in large rooms in order to become familiar with each other and build networks.

### *What is a good teacher?*

The pedagogy of the Village University builds on the philosophy of Paulo Freire. The teacher should be a role model for his students, not only regarding medical matters but also by interacting in a responsive and respectful way. He should be close to them and learn know each student, collecting information from their home area about injuries, health facilities and transport problems. Hence, the teacher is also gaining new insight during the courses, becoming a “teacher-student ” (Paulo Freire). In his essay *The Banking Concept of Education*, Freire asserts that modern education is widely recognized as a chance for instructors (or "oppressors," as he calls them) to fill students with information that they submissively accept, an approach coined by Freire as “banking education” in which the scope of action allowed to students extends only as far as receiving, filing, and storing the deposits. “The more completely they accept the passive role imposed on them, the more than tend simply to adapt to the world as it is and to the fragmented view of reality deposited in them.”<sup>69</sup> In the banking concept of education, knowledge is a gift bestowed by those who consider themselves knowledgeable upon those whom they consider to know nothing. The teacher thus presents himself to his students as their necessary opposite; by considering their ignorance absolute, he justifies his own existence.

The alternative is the Problem-posing education model, in which students are encouraged to think and tackle problems presented to them on their own. This model views the student as one with prior knowledge that may be capitalized upon to reach greater results than a banking model that fails to take advantage of this capital. According to Freire education must begin with the solution of the teacher-student contradiction, by reconciling the poles of the contradiction so that both are simultaneously teachers and students, hence the term “teacher-student” (Freire P. Page 53). Especially in a scenario of ever changing patterns of injury and political instability, flexibility and cultural sensitivity is a condition *sine qua non* to set up sustainable and efficient trauma systems. Building genuinely local capacity in trauma training should thus be considered an integral part of trauma system implementation.

### **1.8 Responding to the knowledge gap**

Due to high land mine casualty rates in North Iraq after the Iraq-Iran war, a humanitarian relief intervention was implemented in Suleimaniah province in 1996 after a request from the local health authorities. The author (MKM) with Norwegian colleagues set up a prehospital trauma system in the minefields in the North, which was systematically expanded to include also the war zones in Central Iraq. The intervention was based on the three-tier model and designed as a prospective study, diagnosis, treatment and outcome variables being consecutively gathered in a comprehensive trauma registry. Due to infrastructural breakdown, long out-of-hospital times and high counts of severe trauma, the study area represents a challenging testing ground for new rescue system models.

## **2. Study aims**

The overall aim of this study was to evaluate the effect of pre-hospital trauma care on survival of trauma victims in Iraq. This was accomplished through three studies with specific study questions:

1. Papers 1 and 3: To what extent does a low-cost prehospital trauma system reduce deaths where out-of-hospital times are long?
2. Paper 2: Does early in-field first aid by lay first helpers contribute to reduced trauma mortality and better out-of-hospital treatment effect?
3. Paper 1: Is it possible to identify specific prehospital life support interventions that enhance survival?

### 3. Material and methods

#### 3.1 Pre-intervention surveys

It is documented that many trauma-training programs failed to achieve significant gains in health outcomes because of poor selection of participants and inadequate methodology. The key factors for success lie in better pre-interventional planning: who should be trained, locating the training as close as possible to the workplace of trainees; appropriate inclusion of the community; and coordination with other health system interventions.<sup>70</sup> Careful adaptation to the local context is essential, and prior to selection of target areas and trainees in Iraq pre-intervention surveys were conducted at three levels:

1. The epidemiology of trauma: Firstly, the trauma system coordinator (MKM) went village by village in the target districts to locate the areas with high incidences of trauma, gathering information from lay persons, village leaders, police and military personnel, and scrutinizing medical files at health centers and district hospitals. The informants told case stories of accidents the last two years and reported outcomes, patients dying and patients surviving.
2. Mapping prehospital evacuations: The coordinator also registered the exact location of the accidents, transport times, transport means, and difficulties faced during the evacuation (military check points, mine fields, weather conditions). Based on this information, a map was set up where the hot zones and areas of priority were located.
3. Finally, the coordinator visited the villages of the target area, reported the findings to the inhabitants, and presented an outline of the planned rescue system intervention. The village meetings were focus points for local support and local input in the coming training programs.

The pre-intervention survey conducted in 1996 in the three mine-infested districts of Suleimaniah demonstrated a total mortality rate of approximately 40% in land mine victims, most fatalities occurring on-site or during prehospital transport. This figure was used as baseline for further studies of trauma system outcome.<sup>71</sup>

#### 3.2 The intervention: staged trauma system development

##### *Study period 1 – land mine casualties*

Based on the results of the pre-intervention survey, twenty-two paramedics from the three districts were selected and started training for advanced trauma life support with special reference to mine casualties. The selection of medics was based on three criteria: (1) Areas with high incidence of mine accidents were given priority; (2) focus on remote areas with poor transport facilities; (3) the trainees' personal qualities. Having undergone the first of three training courses, the paramedics started to train hundreds of lay first helpers in the villages of their area (training curriculum, see chapter 3.4 below). Gender was a matter of concern in selecting paramedics for training. In the first group of Village University medics 1997-99 all trainees were male. During further training courses we aimed to get at least 1/3 female trainees. The medical reason for this priority is that female care providers have better access to female trauma victims due to cultural traditions. Also the rural paramedics manage



emergencies related to pregnancy and delivery. Besides, the instructors experienced that female trainees often had better finger skill than their male companions. After three years, preliminary results of the intervention demonstrated better survival, the villagers of the target area were satisfied with the program, and the author received several requests from other mine-affected districts to set up similar rescue programs. Preliminary analysis in 2001 documented significant reductions in trauma mortality that was why the trauma system was expanded to include six other districts, all being remote and reporting high incidences of land mine and UXO accidents.

#### *Period 2 – RTA casualties*

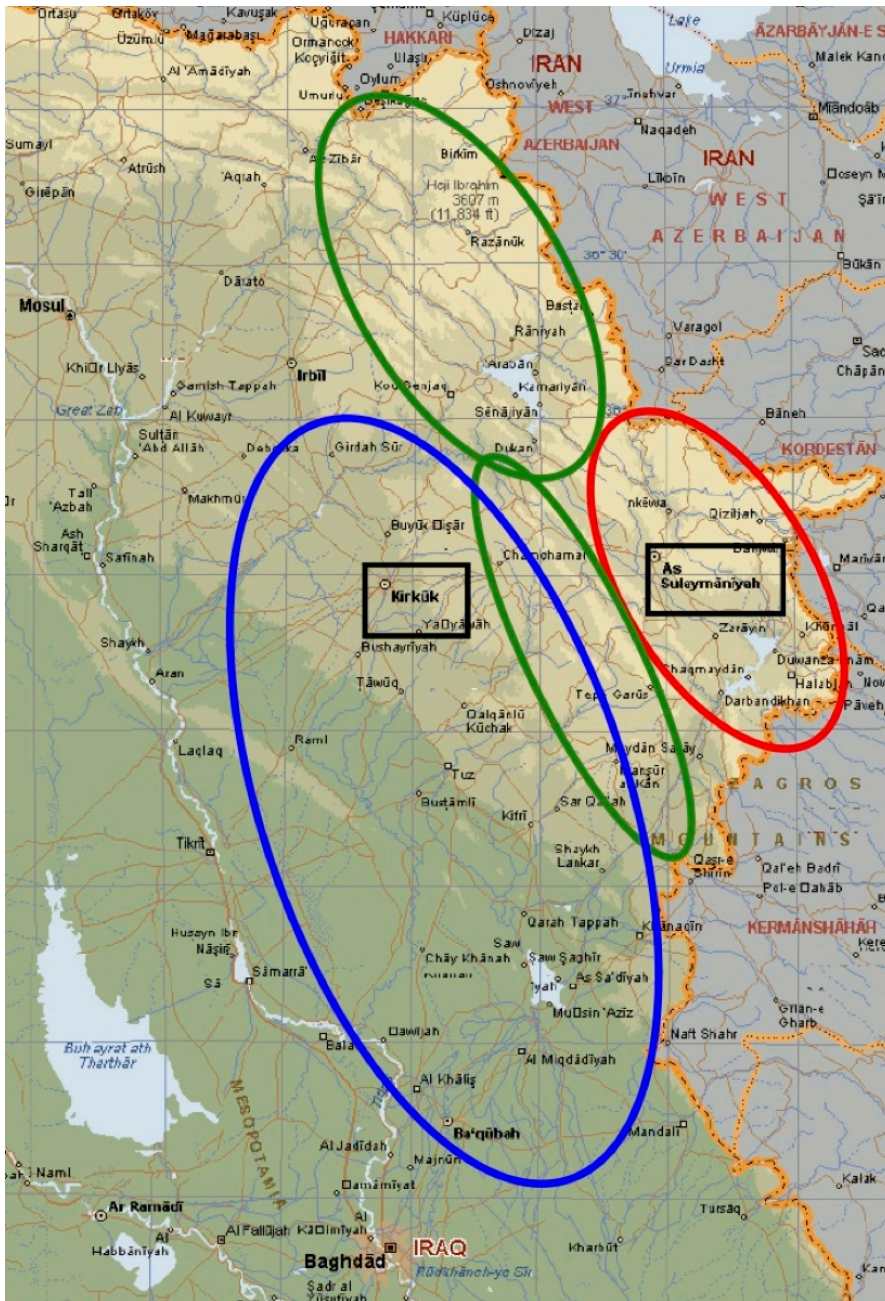
Due to the deterioration of the health services after wars and the embargo, there was no proper EMS system in place to respond to the high numbers of RTA accidents occurring after the 2003 invasion. The health authorities with the MKM and instructors from the mine injury management courses responded by training paramedics in health centers and emergency rooms of the district hospitals along all main roads in Suleimaniah province. During 2003 and 2004, more than 80 paramedics and nurses underwent courses in basic and advanced trauma life support. The health centers and hospital emergency rooms were equipped with mobile ATLS sets (backpacks).

#### *Period 3 – war casualties*

Since the invasion in March 2003, Iraq has suffered high casualties caused by military combat and so-called unknown perpetrators, suicide bombers. Especially the provinces of the central zone were affected: Salhadeen, Kirkuk, Dyala and Mosul. On request from the health authorities the intervention was expanded in 2003-2004 to include also Krkuk and Dyala provinces. The training program similar to the original curriculum for mine casualty management was conducted for emergency room staff as well as ambulance and health center paramedics.

By 2006 the entire trauma system thus comprised of six MD instructors, 135 paramedics/nurses, and around 7,000 trained lay first helpers.

Figure 8



Trauma system expansion by time periods. In period 1 (1997 – 2000, red), the trauma system targeted landmine accidents; in period 2, (2001 – 2003, green), the system was expanded to also include highway road-traffic accidents; in period 3 (2004 – 2006, blue) the system additionally focused on war victims. The referral hospitals (Kirkuk and Suleimaniyah Teaching Hospitals) are marked in boxes.

### 3.3 The intervention: trauma training

#### *Kurds teaching Kurds*

Norwegian trauma instructors trained the first group of paramedics 1997-99 in English with translation to Kurdish language by MKM. However, we all do best and learn best when we feel confident and “at home”, ref. the pedagogy of Freire.<sup>68</sup> Consequently the manual of the Village University, *Save Lives, Save Limbs*,

were translated, adapted and produced in Kurdish edition by MKM. Since 1999 local Kurd instructors have performed all educational efforts of the actual intervention. Both the training curriculum and the medical treatment protocol were modified when the local instructors took over the program in 1999. For example, initially the trainees were informed that the backpack of life support equipment should be used exclusively for mine- and war victims. This was a cultural misconception; in a remote village area with few resources, the care provider cannot refuse to give optimal treatment to other emergencies as well – be it snake bites or complicated deliveries. Also the training curriculum was adapted to the local account of reality by the Kurdish take-over: initially village first helpers were trained in one-day courses. However, the local teachers changed this set-up; in the Kurdish countryside it is simply impolite not to spend the night, drinking tea and sharing narratives with your hosts.

### *Course curriculum at the Village University*

All paramedics were trained in three intensive courses of two weeks to provide basic and advanced prehospital trauma life support, and also to learn how to train lay first responders in their home area.

The first paramedic course is on basic life support, I.V. volume treatment, and ketamine pain relief. The course also includes gathering of medical documentation, and training lay first helpers. At the end of the course, the chief instructor selects a few of the best students as supervisors for the others. The supervisors should make detailed arrangements on how to gather and validate medical data, get supplies of medical items to all actors of the trauma system, and set up plans for training of village first responders. Completing the final exam, the paramedic trainees receive a backpack stocked with life support equipment and drugs according to their actual skill level.

The second course takes place after 8-12 months of trauma care practice. Case stories from the period are discussed and evaluated. The second focuses on advanced trauma life support and includes endotracheal intubation, airway cut-down (crico-thyrotomy), ketamine anesthesia, cannulation of the external jugular vein, venous section, and fasciotomy. Animal models are used extensively.

The third course is a rehearsal of the first and second courses with emphasis on case story audit and hands-on training on animal models. Having observed the trainees closely for 18 – 24 months – during Village University sessions and in real-life trauma care - the trainees who qualify are certified as “mine medics” at the end of course no. 3.

For curriculum details, see Appendix 1.

**Figure 9**



The Village University. A team of female paramedic trainees has given in-field life support on-site, and now carry the patient (a goat) to the “hospital Emergency Room” where another team will make a secondary assessment and supplement resuscitation.

#### *The animal model*

Several types of animals are useful for hands-on training in trauma care. In the actual intervention we used what was available at a reasonable price. The anatomy of a dog's abdomen is closer to humans'. Training in venous cut-down and fasciotomy is best done on dogs, but also goats are useful for training basic procedures and advanced procedures such crico-thyrotomy and chest tube placement. Cultural and religious considerations had to be taken in the study area: The foundation for the intervention – life-saving on humanitarian grounds – was discussed with village elders and religious heads before their permission was granted. Even if dogs are regarded “dirty” in Islam, dogs were extensively used during the intervention without any problems once approval by local religious heads was granted.

Animal ethics was a main concern. Unstressed animals that are well cared for have fewer physiological complications when under anesthesia. The trainees at the Village University were also trained in animal anesthesia. A team of two trainees conducts the anesthesia and monitors heart rate, respiratory rate, color of the tongue (cyanosis) and body temperature recording the clinical signs on an Anesthesia Chart. After induction with atropine and diazepam, doses of ketamine are given I.M. until the animal is in deep anesthesia. Then the animal is taken to the gallows where injuries are inflicted according to the aim of the actual training session. When injured, the training team shifts to I.V. anesthesia, giving intermittent doses of ketamine as long as the training session runs. The team under training is responsible to continuously assess the amount of blood loss and need for I.V. fluid replacement. The team is responsible to keep the animal warm as hypothermia may provoke coagulation failure; the animal is covered with blankets and given a warm I.V. infusion (42°C) throughout the session.

**Figure 10**



The author (MKM) instructing a team of paramedic trainees at the Village University. The patient (goat) has a traumatic amputation of the upper extremity controlled by compressive dressing. There is also a penetrating injury to the chest which is why the team is placing a chest tube in-field before evacuating the patient to the “hospital”.

### **3.4 Trauma first responders**

The first responder is a layperson without any kind of formal medical training. His job is to get to the victim as soon as possible after the injury and help the victim survive until the trained paramedic arrives. The first helper’s instruments are his two hands and five rolls of elastic bandages. Basic life support provided by first responders consists of keeping the airways open, supporting breathing, stopping external bleeding, and keeping the victim warm.

The trauma system design is based on the hypothesis that the most efficient resuscitation is life support provided early. Consequently, scores of laypersons should be trained so that there will probably be a first helper nearby whenever an accident happens. Priority was given to the areas that have the most accidents – be it land mines, RTA or actions of war. For optimal access the trauma system coordinators decided that 1/3 of the first helpers should be schoolchildren (> 12 years old), 1/3 female adults, and 1/3 male adults.

We assumed that close connection and teamwork between first helpers and the paramedic is crucial. Therefore the first helpers were selected by the paramedic in cooperation with the villagers, and trained and supported by the local paramedic of the area. From the first Village University course in 1997, each paramedic student was told to train at least 100 locals/year as first responders.

### *Village training courses*

Having explained the rationale of first responder training to the local community, 20 – 25 persons are selected to participate in a two-day training course. The hands-on training is done on mannequins or on fellow villagers. Basic trauma physiology is taught by large flip-over illustrations and printed handouts.

The first day of the course:

- Role play: One trainee act as a mine victim with a bleeding limb injury while the paramedic instructor plays the part of the village first helper, examining the airways, breathing and circulation, calls for assistance by some other villagers and demonstrates the basic life support techniques.
- Lesson one, oxygen starvation: The candle flame dies without oxygen. Describing the airways and pump function of the lungs. Practice the half-sitting position.
- Lesson two, airways and breathing: Practice the head tilt-chin lift maneuver. Indication for and practice of rescue breathing and chest compression in infants, children and adults.
- Lesson three, controlling bleeds: Practice bleeding control by elevation, compression of the proximal artery, sub-fascial gauze packing of penetrating wounds and traumatic amputations, plus tight compressive dressings by elastic bandages from distal to proximal on upper and lower limbs.
- Lesson four, post-injury hypothermia: Explaining that hypothermia (core temperatures < 35° C) is a common feature in major trauma with protracted evacuations, and the effect of hypothermia on coagulation. Practice measures to keep the patient warm.
- Case stories from real life: After dinner there will be tea drinking and informal discussions of previous accidents that has happened in the area: *If you knew then what you know now – could you have saved lives in those cases? Would you feel more confident assisting at an accident now? Work out feasible ways of calling out the first responders and the mine medic in case of future accidents.*

The second day of the course:

- Rehearsal of day 1: Ban the tourniquet! Explaining the adverse effects of improvised limb tourniquets by photos and case stories of mine accidents from the area. Showing photos of injured with tourniquet book. Repeating yesterday's lesson on how to stop the bleeding.
- Lesson five, CPR: The students learn to check one another's carotid pulse beat, and the brachial artery pulse beat on village infants. Indications and practice of CPR on infants, children and adults – alone and in team of two – using CPR mannequins and dummy training on fellow villagers.







definitive surgical care. For this, two different charts have been used – one field chart and one hospital chart, see appendix.

Factors and variables collected throughout the study period are:

- Demographic factors
- Injury descriptors including photo documentation
- Time factors
- Physiological variables
- Trauma death.

The trauma system supervisors, all MD doctors, validated the data initially. Then the field charts were scrutinized at monthly meetings with the paramedics. The supervisors then gathered end-point data at referral hospitals before the data was processed and loaded in one central Trauma Registry under supervision by the trauma system head (MKM).

#### *Severity variables*

Before initiating the intervention in 1997, the instructor team decided to use the non-weighted physiological severity indices in the actual intervention. Also the GCS rating was replaced with a plain rating of consciousness level:

Awake = 4

Drowsy = 3

Coma, reacts to sound = 2

Coma, reacts to pain only = 1

No reaction = 0

The original RTS was thus replaced with a more straightforward physiological scoring system: Physiological Severity Score, PSS.

**Data gathering form for paramedics to estimate the PSS, a severity scoring index ranging from zero (lifeless) to 12 (normal physiological condition).**

Before treatment		4 points	3 points	2 points	1 points	0 points	Sum	When was this examination done:	
	Breaths per minute	10–24	25–35	more than 35	less than 10	no breathing	▶		
	Systolic blood pressure	more than 90	70–90	50–69	less than 50	no pulse			
	Mental response	normal	confused	to sound	only to pain	no response			
Rectal temperature before treatment:		°C		time:					

Data gathering form for paramedics to estimate the PSS, a severity scoring index ranging from zero (lifeless) to 12 (normal physiological condition).

Intermediate analysis of the actual study population in Iraq documented that the PSS predicted trauma mortality in the subset of pediatric patients with very high accuracy, ROC Area Under Curve 0.98. For this reason the PSS was used for severity scoring of all child victims as well.

Treatment effect:  $\Delta$ PSS

The PSS was used as a tool for the paramedic to monitor the treatment, with fluctuations of PSS values reflecting the efficacy of ongoing treatment at any time. The difference,  $\Delta$ PSS = (PSS at admission – PSS at first in-field encounter) was regarded as an overall indicator of the out-of hospital treatment effect, and was used to control system performance during the study period. The  $\Delta$ PSS calculator was also used in the treatment of individual patients: Cases with negative  $\Delta$ PSS values on hospital admission are considered to be risk cases; these patients should be identified by the Emergency Room staff and given priority for urgent life-saving surgery. Negative  $\Delta$ PSS cases are regarded as potential treatment failures and were scrutinized carefully at the monthly meetings between supervisors and medics.

Anatomical severity

As ISS and NISS proved to have the same high accuracy in predicting trauma death, ISS was used as anatomical severity index. For cultural and religious reasons, autopsy is seldom done in the study area in Iraq. Also the quality of the medical documentation in the referral hospital was dubious at times. In cases of doubt, the lowest and most conservative grading was consistently chosen.

Identifying patients with unexpected outcome

The model of death risk prediction was constructed based on the study data. Unexpected survivors were defined as survivors with predicted probability of trauma death ( $P_d$ )  $\geq 0.5$ . Unexpected fatalities were defined by two criteria:  $P_d < 0.25$ , and in-field PSS  $\geq 6$ .

### 3.6 Material and methods in the actual studies

Two scientific reports are previously published from the actual trauma registry in Iraq:

- Husum H, Gilbert M, Wisborg T, Heng YV, Murad M. Rural prehospital trauma systems improve trauma outcome in low-income countries: a prospective study from North Iraq and Cambodia. *J Trauma* 2003; 54: 1188-96. The article reports the set-up, the training curriculum, and trauma system outcome of a four-year project.
- Wisborg T, Murad MK, Edvardsen O, Husum H. Prehospital trauma system in a low-income country: system maturation and adaptation during eight years. *J Trauma* 2008; 64: 1342-8. The article reports changing epidemiological patterns of trauma and corresponding modifications of system design.

The study matter of the two previous articles are thus different from three articles making up the actual thesis, which reports system performance over a long period, and uses statistical models to identify specific life support measures with impact on trauma survival.

#### *Reference population*

The reference population for the studies is trauma patients in low-income countries with long pre-hospital transport times.

#### *Paper 1*

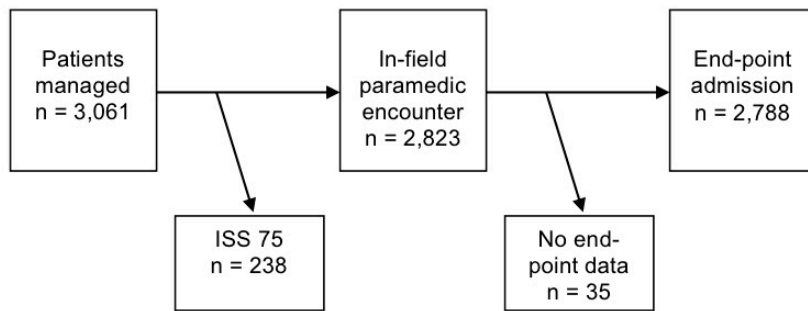
##### Study design

The study was conducted with a time-period cohort design defined by a stepwise expansion of the actual trauma system: In period 1, from 1997 to 2000, the catchment area of the prehospital trauma system was the rural mine fields of Northern Iraq; in period 2, from 2001 to 2003, the trauma system was expanded to also target highway traffic accidents in the Northern sector while still being operational in the rural North; from 2004 to 2006 the trauma system developed further to include the war zones of Central Iraq, while still in action in the previous catchments areas (figure 8).

##### Study sample

All trauma patients managed by the system from January 1997 through December 2006 were consecutively included in a trauma registry,  $n = 3,061$ . By definition, patients with ISS = 75 have injuries incompatible with survival, and this subset ( $n = 238$ ) was excluded from analysis. End-point data could not be collected in 35 patients evacuated to surgical centers outside the study area or cross-border to Iran; these patients were also excluded from the study, which left a study sample of 2,778 patients.

#### **Figure 11**



Study patient flow chart, paper 1.

## Paper 2

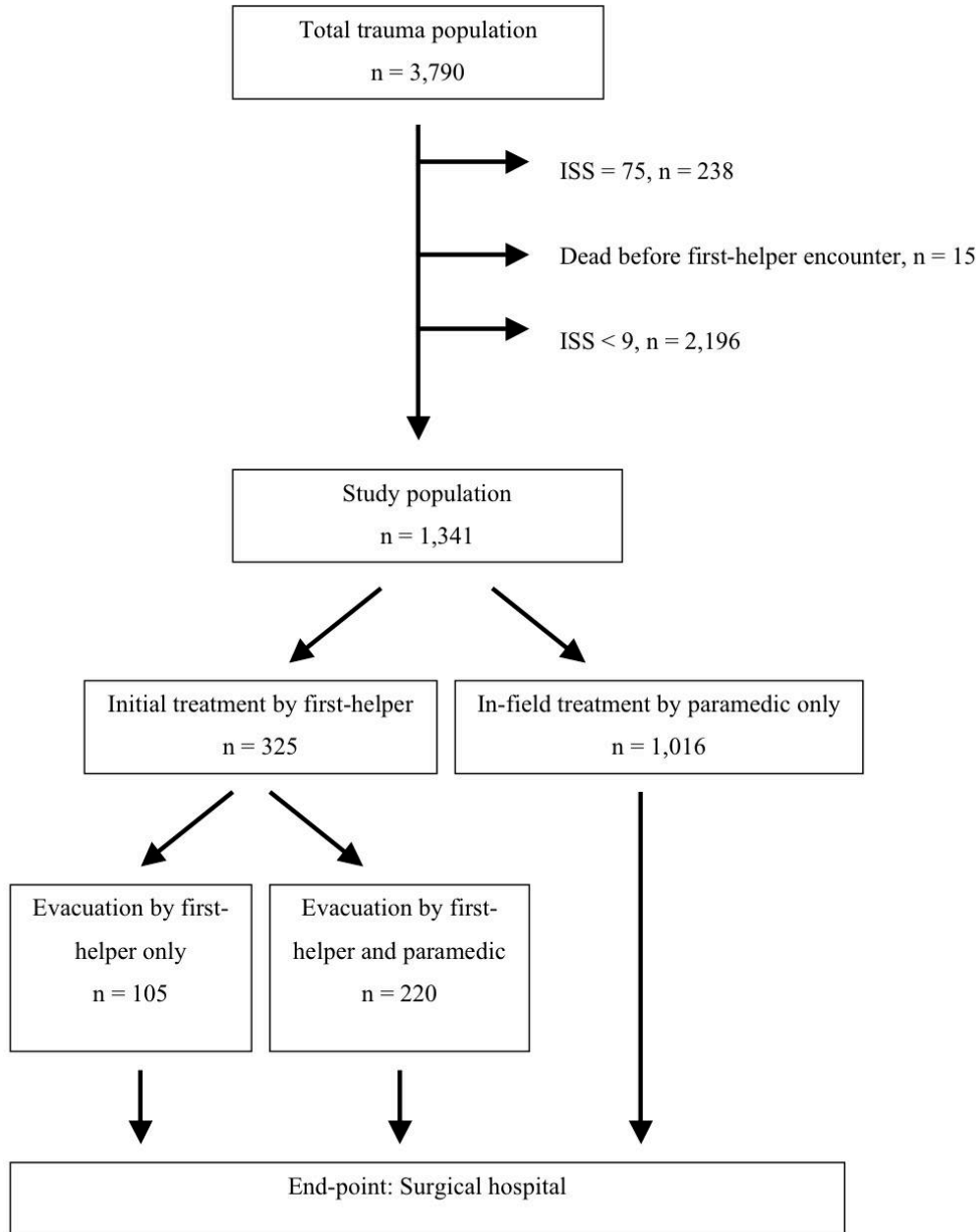
### Study design

The study was conducted as a non-randomized controlled clinical trial with parallel-block design.

### Study sample

All trauma patients managed by the trauma system from January 1997 to December 2006 were consecutively included for study. The system managed a total of 3,790 patients during the study period. According to the Abbreviated Injury Scale protocol, ISS-value of 75 was given only to patients with injuries incompatible with survival; therefore, patients with ISS = 75 (n = 238) were excluded from the study. As the primary outcome variable for the first-responder treatment effect is trauma death, all patients found dead at the scene (n = 15) were excluded from the study. Life support measures were not expected to make a difference in survival for patients with moderate injuries, and no trauma deaths were registered for this group of patients. Therefore, patients with ISS <9 were excluded from study. This left a study sample of 1,341 trauma patients made up of two main subsamples: (1) patients receiving initial first-responder treatment ("first-responder group", n = 325) and (2) patients going directly for paramedic treatment ("no- first-responder group", n = 1,016). A third subset of patients was exclusively managed by first responders; either the paramedic was not available or the first responder found that the evacuation via the medic would unreasonably prolong the evacuation, so the first responder alone undertook prehospital care and evacuation up to the end-point ("first responder- only group", n = 105) (Figure 3.7). The allocation of patients to these treatment groups was not randomized, but given by the conditions at the actual time and place.

**Figure 12**



Study patient flow chart, paper 2.

### Paper 3

#### Study design

The study was conducted as a non-randomized controlled clinical trial with parallel-block design. Due to resource limitations the training program in 2003 – 2005 targeted just the most remote districts of Suleimaniah province; several districts of the province remained without any prehospital trauma systems. The situation in 2005 thus provided the chance to design a limited controlled study on a separate study sample. The end-point was the single referral surgical hospital in the province. The treatment group consisted of RTA casualties managed on-site and evacuated by trained first helpers and paramedics. The control group consisted of RTA casualties admitted without any prehospital medical care being provided.

### Study sample

The study population comprised of all road-traffic casualties admitted at Suleimaniah Emergency Surgical Hospital, Iraq from 2005. Sample size estimation was based on previous studies of trauma mortality in the area (paper 1). Assuming a mortality rate at 30 % in the control group and 8% in the treatment group, a total sample size of 160 (80 x 2) would be required to detect such a mortality difference with significance level 0.05 and test power at 0.9. Supposing that prehospital life support would not have significant impact on trauma outcome in minor injuries, all patients with ISS < 9 were excluded from study. After a three-months' study period 205 patients with ISS  $\geq$  9 had been admitted at the end-point, and the study was closed. Of the 205 study patients, 128 patients had been treated prehospital by trained medics and first helpers (treatment group) and 77 patients were admitted without prehospital treatment (control group).

### 3.7 Statistical platform

The Iraqi trauma registry was established in an Excel database and analyzed with JMP 7.0 software package.<sup>72</sup> The cause of injury was registered in 16 different categories including types of land mines, types of weaponry, RTA, falls from height, and domestic violence. Diagnosis was grouped in penetrating or blunt injuries, and also by body region according to the AIS manual: extremities, burn, head and neck, chest, abdomen and pelvic cavity, spinal cord, plus on additional group of major multiple injuries.<sup>73</sup>

Continuous variables were checked for normality by examining their distribution and subsequently appropriate parametric or non-parametric methods were used in their analysis. All assumed continuously distributed variables are expressed by mean values with 95% confidence intervals (95% CI) constructed by Student's procedure. For variables of skewed distribution the median and inter-quartile ranges (IQR) were reported. Analysis of variance was used to compare groups regarding continuously distributed variables. The Kruskal-Wallis test was used for variables of non-normal distribution.<sup>74</sup>

Categorical variables were described by frequencies and percentages. Proportions were described using the exact 95% calculated confidence interval. Contingency table analysis was used for comparison of categorical data.<sup>75</sup>

Receiver Operating Characteristics (ROC) analysis was used to estimate the accuracy of trauma death predictors. We consider a predictor to be accurate if the area under the ROC curve (AUC) is larger than 0.8; AUC close to 0.5 signifies a useless indicator.

Logistic regression was used for identification and analysis of mortality predictors. The analysis was done by first including all potential death predictors; a backward selection process identified the heaviest predictors of mortality; statistical significance level of 5% in the likelihood ratio test was

required for the independent variable to be included in the model. The logistic model was evaluated using the Hosmer-Lemeshow test and ROC analysis.<sup>76</sup> Having identified the patients with unexpected death or survival, each case was re-explored by trauma registry data, data charts and photo documentation.

### **3.8 Ethical considerations**

The implementation of the actual intervention was done in cooperation with the Ministry of Planning, Kurdistan Region. All studies based on the actual trauma registry were conducted by ethical approval from the Directorate of Health of Suleimaniah (Ref. no. 1799 and ref. no. 22082). During the study period and at the time being there is no formal legal institution for medical research ethics in the study area. The data were stored and processed according to ethical permission and guidelines from Norwegian Social Science (NSS) data service (ref. no. 2006-13702).

Both paper 1 and paper 2 are based on ordinary medical data, which any medical care system is obliged to gather as part of treatment quality control. Analysis of mortality and morbidity is thus an integral part of any hospital or medical system, and informed consent from patients is not required. However, photo documentation is a sensitive matter and informed consent was obtained from all patients and or their escorts (family or friend) for taking photos for treatment quality control, assuring the patient about the confidentiality of the information provided. According to the guidelines set by the NSS data service, all written documentation (data gathering charts) and patient photos was stored in locked steel shelves, only the trauma system coordinator (MKM) having access to the material.

The Village University strategy of delegating life-saving medical skills to non-doctors remains controversial despite the fact that the training concept and curriculum has been based on best available medical knowledge. However, in 2010 the actual trauma training program was adopted by the Directorate of Health, Suleimaniah when setting up the new Emergency Medical Center for the province (Ref. no.19431). Also it is well documented that trauma life support measures by non-graduate medical staff and also by laypersons improve patients' outcomes in low- as well as high-resource communities.<sup>20, 77, 78, 79, 80, 81, 82</sup> The strategy of delegating skills to non-doctors has also been applied in obstetric care. Since 1995 Mozambique has carried out a national program at rural district hospitals where medical assistants with four years of prior formal medical education completed a comprehensive training program in emergency obstetric surgery. At the time when the trauma system intervention in Northern Iraq was designed in 1996-97 the instructor team had close contact with Professor Fernando Vaz at Eduardo Mondlane University, Mozambique who conceived and headed the new training program in Mozambique. Using mortality and postoperative infection rate as results indicators, the Mozambican team reports that the district hospital care providers did as well as trained obstetricians at the university hospital after completing the training program.<sup>83</sup>

There are thus good reasons why a strategy of non-formal, non-Western training models should be further explored to enhance the quality of trauma care, especially in low-resource settings. However, an absolute condition for this approach is strict focus on medical ethics. Any health-care provider,

whether working inside or outside hospitals, is obliged to act in the best interests of his patients and to respect the limits of his skills, never undertaking procedures he is unqualified to perform. At the Village University courses the personal ethical qualities of trainees are observed carefully. Also by tight supervision during field visits and at monthly rehearsal meetings, the trauma system coordinators monitor the professional and ethical standards of the paramedics. A paramedic will be permanently sacked for any fault, which cannot be corrected. Such ethical discipline is even more important because the paramedics also train and guide layperson assistants. Also in the echelon of village first responders medical ethics is a matter of has to terminate the position.

Paper 3 reports a controlled study of RTA casualties. For ethical reasons the study was non-randomized; selecting control cases from the districts with established EMS would not comply with established guidelines: "Members of any control group should be provided with an established effective treatment, whether or not such treatment is available in the host country".<sup>84</sup>

In the process of approving the intervention, the health and the religious authorities in the study area had no objections to the use of live anesthetized animals in training invasive medical procedures. We have not applied to European institutions to obtain ethical approval for the animal model. Our reason for not doing so is that those institutions have a very restrictive attitude to the use of animals for research purposes. We, on our side, are convinced that hands-on training in teams of life-saving procedures on injured animals is an essential element in the actual program; without such training, graduate as well as non-graduate lifesavers can not perform up to standards in a chaotic setting with severe injuries. The instructors for the animal training and the Village University have stuck strictly to biomedical ethics, and have used each animal case also for training basic anesthesia procedures so that the animals did not suffer pain at any time. In this conflict of ethical interests, the participants' interest to protect themselves against European mines and jet fighters counts heavier than some Europeans' concern for animal ethics.



## 4. Results

### Paper 1

One third of the study patients had serious injuries with Injury Severity Scores  $\geq 9$ . The mean prehospital transport time was 2.5 hours (95% CI 1.9 - 3.2). The epidemiology of trauma shifted during the study period, a massive increase in the number of RTA casualties was observed in period 3; also the proportion of burn patients increased in this period.

#### *Outcome variables*

During the ten-year study period trauma mortality was reduced from 17% (95% CI 15 -19) to 4% (95% CI 3.5 - 5), survival especially improving in major trauma victims. Most pre-hospital deaths occurred on-site before the first in-field contact with the paramedic (75/175) while 23 patients died in the hands of the prehospital care provider. There were 77 in-hospital deaths, 37 of them being burn cases.

The in-field response times were reduced from 1.6 hours in period 1 to 0.7 hours in period 3 (95% CI diff 0.7-1.1) and there was a reduction in total out-of-hospital time from 4.4 hours to 2.3 hours (95% CI diff 1.8 – 2.4).

#### *Trauma audit*

A probabilistic model identified patients with unexpected outcome. Twenty seriously injured patients with ISS from 9 to 30 were identified as unexpected survivors; all 20 patients were in poor physiological condition at the first in-field encounter with a PSS  $\leq 6$  but had improving physiological indicators during the prehospital phase. There were 44 unexpected fatalities, all of them major trauma victims with ISS  $>15$ . Twelve patients with traumatic brain injury were among the unexpected fatalities with critical area injuries were, all twelve dying within 48 hours after injury. These deaths occurred before neurosurgical service was established in 2006. In the same group were three cases with abdominal hemorrhage dying immediately on admission after two-hours' prehospital transit time. All six unexpected fatalities diagnosed as "extremity injury" had deteriorating physiological indicators due to associated head injuries. Among the unexpected deaths with multiple major injuries (n = 13) seven patients were admitted with close to normal physiological scores but died from internal hemorrhage in hospital hours after admission.

There were 36 "prehospital treatment failures" defined as seriously injured on-site survivors (ISS  $\geq 9$ ) with deteriorating physiological severity scores despite prehospital life support. In eight cases diagnosed in the field as "extremity injury" the level of consciousness deteriorated during the prehospital phase despite effective bleeding control due to undiagnosed brain injuries. In the other cases in the treatment-failure group, the main reason for deteriorating PSS values was worsening respiratory rate scores.

Most patients with airway problems were managed by basic measures only; endotracheal intubation was done only in 19 patients, crico-thyrotomy in one. Forty-seven patients had severe chest injuries (ISS  $\geq 9$ ). In this group, 39 patients had less than optimal respiratory scores in-field but 30 of the 39 had normal

respiratory rate at end-point. Of 82 patients with severe limb bleeds (in-field BP <70 mm Hg), 69 patients were normotensive at hospital admission.

#### *Sustainability and cost-efficacy*

Despite adverse working conditions the overall retention rate of 180 trained paramedics was high, 75 %. The treatment costs per patient including medical treatment, evacuation, data gathering and quality control, varied during the study period from US\$130 to US\$180.

#### *Conclusion*

In case of long prehospital transit times simple life support measures by paramedics and lay first responders reduce trauma mortality in major injuries. Delegating life-saving skills to paramedics and lay people is a key factor for efficient prehospital trauma systems in low-resource communities.

### **Paper 2**

The trauma severity in the study sample was high; 70% of the patients had ISS 9 – 15, and 30% were Major Trauma Victims with ISS > 15.

Even if the total out-of-hospital time was higher, the mortality rate was significantly lower among patients initially managed in-field by first responders (n = 325) compared to patients without first-responder support (n = 1,016), 9.8% versus 15.6%, 95% CI = 1.3–10.0%. Most deaths occurred in the group of Major Trauma victims. Also in this subset the mortality rate was significantly lower in the first-helper group, 38% compared to the no-first-helper group, 51% (95% CI diff 1% – 24%).

#### *Conclusion*

Trained layperson first responders improve trauma outcomes where prehospital evacuation times are long. This finding demonstrates that simple interventions done early—by any type of trained care provider—are crucial for trauma survival. Where the prevalence of severe trauma is high, trauma first-responders should be an integral element of the trauma system.

### **Paper 3**

The study sample comprised of severe injuries with mean ISS at 15; also the physiological condition was adversely affected. The total prehospital transit time was long, a mean of two hours being reported for the treatment group; for the control group there were no reliable data on time variables.

The mortality rate was significantly lower in the treatment group, 8 %, compared to the control group, 44 %, 95% confidence interval for difference 25 % to 48 %. Also when adjusted for severity differences between treatment and controls, prehospital care was a significant contributor to survival. The pattern of fatalities differed between the treatments and controls; in the treatment group few patients died during the prehospital phase, while most fatalities in the control group occurred outside hospital.

### *Conclusion*

Where the surgical center is far away, a two-tier prehospital system of trained paramedics and layperson first responders reduces trauma mortality in severe RTA injuries. The findings are probably valid for civilian EMS interventions also in other low-resource countries.

## 5. Discussion

### 5.1 Does prehospital trauma system reduces deaths where out-of-hospital times are long?

The main study (Paper 1) shows that prehospital trauma care has significant impact on trauma mortality when transportation time is long. The overall mortality rate in the study population was reduced by 35 % during the study period and there was a reduction of prehospital mortality rates from 16% in period 1 to less than 2 % in period 2 and 3. We found that the main contribution to the positive outcome was improved survival rates in critical area injuries and patients with multiple major injuries. The assumption of better survival with prehospital care is supported also by the findings in the controlled study of RTA casualties (Paper 3), patients in the treatment group being admitted to hospital in better physiological condition. The pattern of fatalities is a further indication of the benefit of early prehospital care; relatively more fatalities in the non-treatment group occurred outside hospital while in the treatment group most fatalities were in-hospital.

However, several methodological flaws of the actual studies should be addressed.

#### *The problem with historical controls*

Recent review articles rightly point to the fact that debates of the efficacy of prehospital care models cannot be readily solved because most trauma system studies have been conducted with observational, retrospective and non-controlled designs.<sup>85,86</sup> The main weakness of study 1 belongs to the time-cohort design; contextual changes may occur over a long study period of ten years, especially in a society undergoing dramatic social changes.

Firstly, we should question the validity of the pre-intervention baseline mortality rate. The survey of mine accidents conducted in the target area in 1996 set the mortality rate at approximately 40 %. The estimate is supported by another study from the Kurdistan region, Dahok province in 1993, which reported a mortality rate in 103 mine casualties at 33 %. This is probably an underestimate because the study included only casualties admitted to hospital and did not include fatalities on-site and during the prehospital evacuation.<sup>87</sup> The estimate from Dahouk is in accordance with the Mine Advisory Group (MAG) report in 1992, which reported a mortality rate of 35 % among 8,327 mine casualties in Northern Iraq.<sup>88</sup> Another study conducted in Iran, in the same mine belt along the border, reports a total of 36.4% of casualties from landmines over a ten year period from 1989 – 99, most fatalities occurring in outside hospital.<sup>7</sup> The estimates also correspond with other landmine surveys conducted in communities with long prehospital transit times. A household survey in mine-infested districts in Mozambique reported a case fatality rate at 48%, most fatalities being prehospital.<sup>89</sup> A rapid appraisal survey in Afghanistan, Bosnia, Cambodia and Mozambique gathering data by household questionnaires, qualitative data from key informants, from institutional reviews and focus groups of mine accident survivors, reports that one third of mine victims died at the site of explosion. There are reasons to believe that this estimate probably is too low because the data for this study were gathered only in readily accessible areas.<sup>90</sup> We therefore contend that the pre-intervention mortality estimate used in Study 1 is solid.

Secondly, we should look at the study design. For ethical reasons Study 1 was conducted without randomization and case controls; variations in trauma epidemiology, transport and treatment facilities, and cluster effects have definitely occurred during the study period, affecting outcomes. However, a randomized controlled study was not feasible in the actual setting. Offering life-saving treatment in a humanitarian crisis is an urgent ethical obligation; setting up parallel systems of meticulous data gathering without offering required acute medical care would seem highly unethical in this setting. Selecting control cases from the districts with established EMS would not comply with established guidelines: "Members of any control group should be provided with an established effective treatment, whether or not such treatment is available in the host country."<sup>83</sup> Being aware of the flaws of time cohort studies, MKM found the opportunity in 2005 to conduct an ethically qualified controlled study of RTA casualties, single blinded (Paper 3). Even if this study was not optimally designed – in-field data and time variables not being gathered in the control group – the study was robust due to short study period, narrow catchment area, and uniform composition of the two study subsamples.

Study 3 also carries methodological weaknesses: for ethical reasons the study was non-randomized. A random effect of the cohort design was uneven ISS distribution in the treatment versus the control group; the ISS is a sensitive predictor of trauma death and the higher fatality rate in the control group may partly be explained by higher counts of very severe injuries. However, adjusting for severity by regression analysis prehospital treatment is still a significant contributor to survival. Secondly, the study cohort was small; especially the size of the control group did not quite match the required sample size estimate ( $n = 77$  observed,  $n = 80$  required). Thus the results potentially lack external validity and should be interpreted with caution. For example, the study sample is too small to identify specific types of injury where prehospital life support could be of special importance. Thirdly, contextual variations cannot be ruled out. Fourthly, there are poorly controlled risk variables. Time is a critical factor in the management of severe trauma, especially where prehospital transit times are long as they were in the actual study. Within a time span of two hours, patients with extensive tissue damage and persisting hypo-perfusion may develop massive post-injury stress responses. It was not possible to obtain reliable data on the time variable for patients in the control group of Study 3. However, the prehospital trauma system under study was deliberately established in the most remote districts of the study area, while districts closer to the referral hospital remained without EMS facilities at the time of study. Most likely, the prehospital transit times therefore were longer in the treatment group, which further emphasizes the efficacy of prehospital care.

In conclusion, we contend that the main results reported in Paper 3 are reliable and further demonstrates the beneficial effect of forward life support outside hospital. However, the findings and recommendations of the study are hardly directly applicable to a war scenario with complex injuries caused by modern weaponry and IEDs.

Another methodological problem of Study 1 and 3 belongs to uncontrolled or poorly controlled explanatory variables:

The quality of care

Despite running the system on well standardized treatment protocols, the quality of prehospital life support may

well have differed between paramedics – some having better hands-on skills, some having better support on-scene from locals and trained first helpers, some medics had managed a lot of trauma casualties (> 100) while some medics operated in areas of less accidents. Still we contend that these variables had minor impact on trauma outcome, this due to the fact that all paramedics were trained, closely observed and supported by the same team of instructor-supervisors throughout the study period; any medic not performing up to standard was warned, and eventually dismissed. Study 2 demonstrates that first-responders working in team with the prehospital paramedic make a difference in survival probability. However, analysis by the author and mine instructors who knew all medics closely (MKM), ranking all medics according to estimated skills, demonstrated that individual “medic skill” was not a significant contributor to survival.

The quality of in-hospital care is another uncontrolled variable. The quality of care differs between hospitals: During the study period the patients were transported to several surgical hospitals, some in the Northern sector which was less affected by the war, some to hospitals in the Central sector where few senior doctors were left after the 2003 invasion. Also the overall standard of care changed during the study period: Persecution of doctors, and abuses of human rights caused many senior doctors and teachers to leave the country. During most of the study period the referral hospitals were short of trauma specialists; there were no neurosurgeons, no vascular surgeons, no cardio-thoracic surgeons available. This also corresponds to the findings of the case study analysis of patients with unexpected deaths in Paper 1: Several of the cases probably died due to shortage of specialist surgical care and the lack of an updated surgical approach being applied.

### *Changing patterns of trauma*

In Study 1 there was an uneven composition of the three time cohorts when it came to types of injury, relatively more blunt injuries and burn cases being included for study in periods two and three. In the third time cohort there were relatively more war injuries, especially blast injuries by IED and suicide attacks, causing clusters of penetrating injuries often combined with burns with injury severity higher than RTA casualties.

### **Comparison of injury severity (ISS) for penetrating versus RTA injuries**

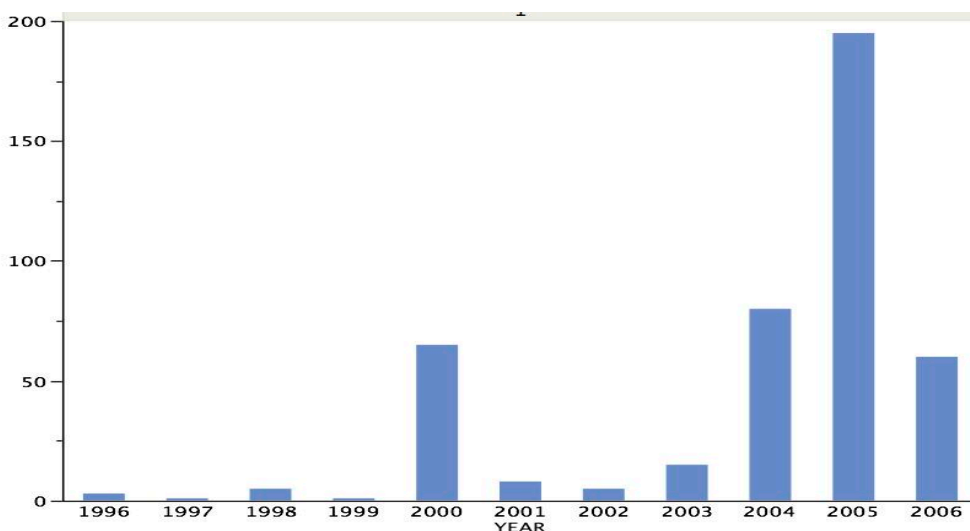
Category	Number	Mean	Lower 95%	Upper 95%
Penetrating	806	9.5	9.0	10.0
RTA	1297	6.2	5.8	6.7

Because the probability of death is generally higher in penetrating than in blunt injuries, episodes of war with high rates of penetrating injuries may thus act as time clusters with effect on the main outcome variables. The fact that mortality rates were stable in cohort 2 and cohort 3, except for increasing mortality in burn victims which is accounted for later in this thesis, emphasize the efficacy of the system since there were clusters of high-risk injuries in these cohort. This interpretation is also supported by multivariate analysis: adjusting for pattern-of-injury changes by time cohort and severity variations, there was still a steady improvement of trauma outcome by time. Also an intermediate study of a six-year patient cohort confirmed that the system adapted well and produced improved survival rates despite such epidemiological changes.<sup>91</sup>

## Blast injuries

Blast injuries constitute a particular type of trauma causing tissue damage different from penetrating and RTA blunt injuries. Several local wars were fought in North Iraq during the first years of study; however, these wars were fought with traditional weaponry and high-energy blast injuries were seldom seen. In time cohort two, during and after the 2003 invasion, multiple incidents occurred where modern blast weapons caused mass casualties in the study area. Injuries caused by thermobaric weapons (fuel-air explosives) and IED have different injury complexity, increased severity and casualties usually present with more than one body region involved. Terrorist bombings tend to target sites that are often highly visible and play an important operational and symbolic role in the community. These include commercial, government, military and transportation assists. The objective is to cause a great number of injured and dead victims. Often the terrorist attacks are organized with double explosions; when rescue work starts on the site of the initial explosion, another blast is set off to create chaos and injuries among the rescuers.<sup>92</sup> Triage and diagnosis of blast injuries is difficult as the early clinical signs of brain injury, lung injury and abdominal bleeds may be discrete and easy to miss.<sup>93</sup> The case studies conducted In Paper 1 are illustrative; six blast injured patients diagnosed on-site by the paramedic as “extremity injury” suffered unexpected deaths. In these patients the level of consciousness deteriorated during the prehospital phase despite efficient control of the external bleeding. The finding indicates that associated injuries (traumatic brain injury, internal hemorrhage) went undiagnosed by the paramedic. Not only are the anatomical injuries in high-energy blasts special, but also the scene of injury poses particular features. Most blast incidents cause mass casualties in the range of twenty to one hundred persons being simultaneously injured, most of them civilians. These are thus true “mass casualties”, which by definition involve such large numbers of victims, or such severe or unique injuries that local medical resources cannot fully cope with them.<sup>94</sup> In mass casualties (MC) failures in triage are often made due to chaos with lack of security and communication, and also the life support treatment may be inadequate due to lack of time, security and shortage of resources. Most mass casualties in the study period occurred in time cohort 3.

**Figure 13**



Numbers of persons/year in Study 1 injured in mass casualties (incidents with > 4 patients simultaneously injured).

Review studies of terrorist bombings claim that there is a biphasic distribution of mortality in such mass casualty incidents; high immediate mortality rate followed by low early and late mortality rates. It is therefore suggested that the rescue personnel rarely will be confronted with many life-threatening injuries.<sup>95, 96, 97</sup> These assumptions do not correspond to the experiences from the wartime scenario in Central Iraq during and after the 2003 invasion. Scientific studies of the on-site response in mass casualties were beyond the scope of the actual study. However, feedback from the trauma system medics engaged in blast injury mass casualties during the study period indicates that the incident scenes were chaotic with high numbers of immediate fatalities but also significant numbers of severely injured immediate survivors; the scene control was inadequate with poor access, police and bystanders evacuating casualties without cooperation with professional medical rescuers. The epidemiology of mass casualties as seen in the recent and ongoing war thus seems to be different from patterns reported from low-intensity war scenes, eg. in Israel. In 2012 MKM conducted a case study of a typical war scene mass casualty, which illustrates the controversy:

May 19, 2011 a car bomb went off in the city center of Kirkuk, in the street 200 meters from the ambulance station of Kirkuk Teaching Hospital. The first bomb went off at 0900 a.m. and another larger bomb was detonated at the same site 30 minutes causing further injuries to persons hit by the first blast and also affecting rescue workers and bystanders. A total of 167 persons were injured by the bombs; 42 of them died.

**Figure 14**



The scene of the blast incidents in Kirkuk, May 2011



**The distribution of injuries and fatalities in a car bomb mass casualty, Kirkuk May 2011**

Dead on scene	Dead on admission	Critical injuries, died in hospital	Critical injuries, survivors	Non-critical injuries, survivors
25	5	12	25	100

The total number of patients with critical injuries at the scene was thus 42, which makes 30% of all immediate survivors. This is a high load of patients, demonstrating the challenge of providing triage and life support, as well as collecting reliable medical data in blast mass casualties of this type.

Due to difficult access and lack of on-scene information it is hard to assess the cluster effect of mass casualties in the actual study. However, there are reasons to believe that there may be significant counts of unregistered fatalities due to the chaotic setting. Assuming that most immediate deaths are due to injuries of extreme severity, ISS = 75, which are by decision excluded from the trauma system analysis, such cases would not affect the outcome analysis. However, there may also be immediate survivors evacuated to hospitals outside the study area and victims dying during evacuation in private cars, thus escaping registration in the actual trauma registry.

*Post-injury hypothermia, an uncontrolled explanatory variable*

Clinical studies show that core temperatures < 34 °C in combination with moderate acidosis adversely affect the coagulation system and are predictors of trauma death in major trauma victims. Hypothermia occurs commonly in severely injured patients and has been identified as a significant risk factor also for organ complications in traumatic injury.<sup>98, 99</sup>

Even in warm climates trauma patients are predisposed to hypothermia unless precautions are taken. A previous controlled study in a subsample of the actual study population demonstrated that hypothermia after penetrating injuries is not uncommon when prehospital transportation is prolonged. In accordance with international guidelines, hypothermia was defined as body core temperature < 36°C in this study.<sup>100</sup> One quarter of landmine casualties (n = 42/170) had hypothermia on admission unless in-field life support included preventive measures. Simple preventive measures during the prehospital phase – removing wet clothes, shielding against wind, buddy warming, and warm IV infusions – effectively prevented the complication.<sup>101</sup> Recently, a prospective multicenter study reported that the key risk factor for the onset of hypothermia was the severity of injury but environmental conditions and the medical care provided by EMS were also significant factors. Changes in practice could help reduce the impact of factors such as infusion fluid temperature and mobile unit temperature. The studies confirm that hypothermia is a common complication in trauma and even when the hypothermia is moderate, it can be associated with a poorer prognosis and increasing mortality rates.<sup>102</sup>

Throughout the ten-year study period, the protocol for trained medics and first responders included hypothermia prevention with passive rewarming plus central warming by warm IV infusions. However, the compliance with

the protocol was piecemeal; in mass casualties the protocol could not be fully implemented for logistical reasons; also in emergency room triage and treatment, efforts by trained paramedics to work on rewarming was often turned down by ignorant doctors in charge of the treatment. The exact effect of random treatment failures are hard to assess, but we cannot rule out that hypothermia might have been one of contributors to some of the unexpected fatalities observed in Study 1.

For better and more systematic implementation of the hypothermia prevention protocol, MKM and his team of instructors (since 2010) educate and train all newly graduated medical doctors in post-injury hypothermia and preventive measures.

### *Prehospital analgesia, a poorly controlled explanatory variable*

In the treatment protocol for paramedics ketamine is the recommended analgesic for prehospital life support, in adults as well as child victims of trauma. Ketamine is dissociative agent characterized by potent analgesia, sedation and amnesia while increasing cardiac output and preserving spontaneous respirations and protective airway reflex. Opioid drugs, on the other hand, may depress respiration and the gag reflexes and cause hypotension in hemorrhagic patients. Ketamine has therefore been the single most popular agent to facilitate painful emergency department procedures in children for nearly last two decades, and the analgesic of choice in many military trauma systems.<sup>103</sup> A previous study of a subset of the actual study population demonstrated that intermittent intravenous low dose ketamine yielded efficient analgesia; with this regime, not one single case of aspiration was reported in more than 600 patients.<sup>70</sup> The findings are confirmed in a recent controlled study of ketamine versus morphine in a prehospital trauma system in Vietnam. The two drugs had similar analgesic effect, but in ketamine patients (n = 169) the rate of vomiting was 5 % versus 19 % in the morphine group. In hemorrhagic patients, a larger increase in systolic blood pressure was observed in ketamine patients.<sup>104</sup> Ongoing studies of the trauma registry in Iraq confirm that ketamine has a beneficial effect on the circulation in seriously injured trauma victims; compared to patients given tramadol or pentazocine outside hospital, the ketamine patients had significantly higher systolic blood pressure on hospital admission. Final analysis and publications are pending.

However, as many hospital-based doctors were unfamiliar with ketamine analgesia, some paramedics were obliged to divert from the protocol and other analgesics instead. In the rural scenario the medics were fully in charge of treatment, and ketamine was used according to the protocol. Thus various analgesics have been used outside hospital and in emergency room treatment during the ten-year study period – ketamine, opioids, and NSAID; it could happen that different analgesics were applied in one patient outside hospital. As protracted pain is an important trigger of post-injury stress pain relief is thus another poorly controlled risk variable in Study 1 and 3. We cannot rule out that incorrect analgesia may have been a contributing cause of death in some of the observed unexpected fatalities due to hemorrhage (n = 7), and also one reason for the prehospital treatment failures observed in Study 1 (seriously injured on-site survivors with deteriorating out-of-hospital physiological severity scores despite care being provided).

### *Data gathering, a challenge in war*

The study area was chaotic due to political unrest and war, and access to the scenes of injury was at times risky and difficult. Under such conditions secondary validation of patient data is problematic and we cannot rule out unregistered prehospital fatalities. For several reasons we believe that the counts of unregistered deaths were low. Firstly, due to social and religious traditions it is mandatory to take anybody injured for medical treatment; and anybody dead should be buried within 24 hours. The paramedics of the trauma system are well rooted in the local community with extensive networks of informants; very few local accidents and hardly any trauma fatality will escape their attention. Secondly, one should question if the prehospital variables gathered by non-graduate paramedics are reliable. Parts of the key data are registered at dangerous and chaotic scenes and during rough evacuations. However, the paramedics were well trained in physiological trauma scoring, a simple case record form was used all the way through the study period (Appendix 2), and the documentation in each and every case was scrutinized in retrospect at monthly meetings with MKM. Further, in a previous study of a subsample of the study population (n = 1,678), the reliability of paramedic registrations were controlled. The study reported excellent agreement between registration of physiological severity indicators (PSS) done by the prehospital paramedics and registrations done in hospital emergency rooms.<sup>90</sup> Thirdly, the anatomical severity grading by ISS may have been inaccurate. Exact ISS grading is based on X-ray documentation, findings during surgery, and autopsy. For religious reasons autopsy of fatalities was seldom done in the study area. Also the medical archives at referral hospitals were inadequately organized, making it hard to collect end-point data. Further, for patients dead on-site or during the prehospital phase, not being taken to hospital, the ISS scoring was done based on information registered by the paramedics. In the vast majority of study patients, the information for ISS grading was adequate and sufficient. In cases of doubt, the severity scoring was done conservatively. For example, one study patient suffered penetrating injuries to the torso after a landmine accident; he was alive at the first encounter with the paramedic, but died during transport and was taken back to his village for the funeral ceremony. The paramedic described penetrating wound to the lower part of the chest. A thoraco-abdominal injury could not be ruled out, but still the ISS grading was based exclusively on the chest injury assuming that there would be at least two rib fractures with hemo/pneumothorax. The patient was given an ISS of 9; had hemorrhagic abdominal organ injury also been included, the ISS would have been 18.

### *Summary, study aim 1*

Having considered weaknesses and methodological problems with Study 1 and 3, we contend that the studies demonstrate that low-cost prehospital trauma systems improve outcome where prehospital transit times are long. Especially in severe injuries, forward life support contributes to better probabilities for survival. However, the efficacy of the in-field response to blast weapon mass casualties remains unclear and deserves further studies. One third of seriously injured study patients were initially managed by lay first responders (Paper 2); the impact of such first response cannot be assessed based on Study 1 and 3.

## **5.2 Does in-field first aid by lay first helpers contribute to reduced trauma mortality and better out-of-hospital treatment effect?**

Paper 2 documents that the mortality rate was significantly lower among patients initially managed in-field by first responders compared to patients without early first-responder support in-field. Several methodological faults in the study should be addressed:

1. The study was done without randomization over a long study period of ten years. Significant contextual changes occurred during the study period and the catchment areas shifted. Randomization would have partly controlled for such alterations. However, randomization would imply that close to half of trauma victims would have been denied treatment of assumed impact on survival, which had been unethical. Also the injury severity, ISS, and patterns of injury varied over the study period with increasing numbers of RTA casualties, burns and mass casualties from blasts seen in later part of the study period. However, adjusting for severity alterations and categories of injury – blunt versus penetrating – by multivariate analysis, the positive effect of early first helper care was still significant. This is further emphasized by the fact that the first-responder group had significantly longer prehospital transport times than did the control group.
2. Some explanatory variables were poorly controlled: In-field response times and total prehospital transit times are variables with an assumed effect on trauma outcome. As the program expanded and steadily more first helpers were trained, there were also changes in time variables. However, regression analysis demonstrated that time variables did not have a significant impact on survival probabilities in neither subsample. Even though the first responders and paramedics are trained in hypothermia prevention, core temperatures were not registered in Study 2, neither in-field nor on admission. We cannot rule out cluster effects in this regards; study patients managed by rural paramedics did probably get better hypothermia prevention as compared to RTA casualties initially managed at district hospitals where doctors often denied the patient treatment according to updated protocols. However, the differences in trauma mortality between treatment and control groups is so clear that it is highly unlikely that hypothermia was an important bias in the analysis.
3. Validity of the main explanatory and outcome variables: since the prehospital physiological severity variables are registered by non-graduate paramedics under rough conditions and during difficult evacuations, no independent validation was possible. However, the paramedics were trained well in physiological trauma scoring. Also, the medical documentation in each case by first responders as well as by medics was scrutinized in retrospect at monthly meetings with MKM. In most cases, the ISS scoring of in-field fatalities are based on clinical examination only; for religious reasons, autopsies could not be done. Hence, severity grading in these cases was systematically conservative. There may be unregistered prehospital fatalities. However, according to prevailing religious beliefs, people who die should be found and buried as soon as possible. As the trauma system consists of medics and first responders rooted in the local communities, it is unlikely that trauma fatalities will escape the attention of local health workers and trained laypersons.
4. Small study cohort: There were relatively few study patients in the first-responder-only subset (n = 105) and only two trauma deaths. The results thus potentially lack external validity and should be interpreted with caution. The sample size was still sufficient for analysis of variance, and the treatment subset came out with statistically better outcomes than did the control group. Still, when it comes to the medical significance

of the findings it may be that a larger cohort would prove differently. Therefore, it should not be concluded that first responders alone would suffice in rural trauma care. Also generalizations to other study populations in other trauma scenarios are not justified.

*Teamwork, a key factor for success*

For the secondary outcome indicator in the study, the physiological condition of prehospital survivors on hospital admission, there were no significant differences between patients managed by first helpers and patients not receiving such forward care. This may seem inconsistent, but two reasons may explain the discrepancy. Firstly, the treatment and the control groups were not similar regarding patterns of injury; there were relatively more penetrating extremity injuries in the first helper subset, and relatively more torso injuries in the control group. Extremity injuries, even serious injuries, are more readily controlled by basic life support measures as compared to torso injuries. Secondly, the team effect – a variable hard to measure – probably affects outcomes; in the subset of first helper patients the patients were managed initially by first helpers alone, and thereafter by a team of trained paramedics plus first helpers. The first helpers are selected, trained and supported by the local paramedic. The teams in question are thus not only professional care providing teams, but locals knowing each other and each others' families, sharing trouble and challenges, not only in trauma care but in daily life.

**Figure 15**

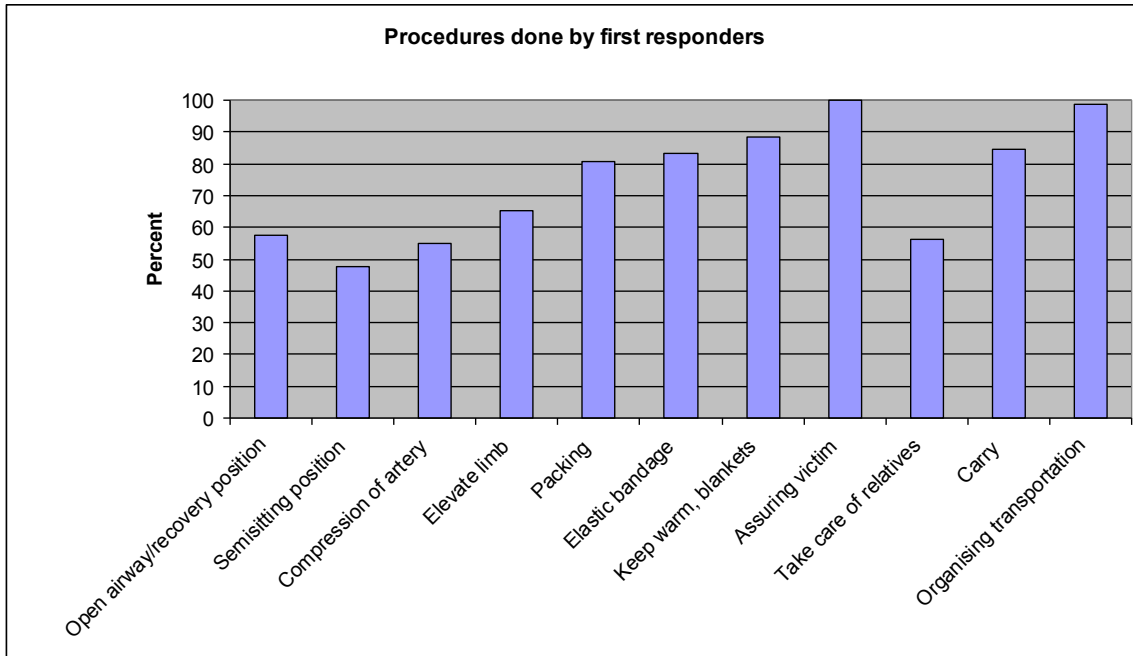


Paramedic with his team of first helpers evacuate a land mine victim to hospital after primary life support was implemented at the scene.

A crucial feature of mine field and wartime trauma care is the evacuation of victims, extractions from mine fields and combat zones, organizing transport where EMS service is not available, passing checkpoints and

security trouble etc. A study of a subsample of the actual study population in 2006 documents that organization at the site and during transport was the most common task done by the first helpers.

**Figure 16**



Life support procedures performed by lay first responders.<sup>105</sup>

Three previous studies of subsets of the actual study population confirm that a tight care providing team with deep local knowledge is evidently a key factor for success in rural trauma care.<sup>90, 105, 106</sup> Since the 2003 invasion the role of trained first responders has been even more evident. In most bomb blasts local first helpers rush to the site and are often the very first care providers on the scene. When trained paramedics arrive they help securing access, assist in triage and preparations of equipment and evacuation, and also follow serious cases during ambulance transport to hospital. In the war zones in Central Iraq scores of police officers and fire brigade personnel are also trained as first helpers, an intervention which greatly enhance the cooperation between security staff and medical care providers on site.

We therefore contend that there are several reasons why teams of paramedic-first helper improve outcomes as demonstrated by mortality rate comparisons in Study 2. However, we should not presume this difference to be read by physiological indices; because all study patients were seriously injured, ISS >8, full normalization of physiological indicators should not be expected despite good life support outside hospital, which explains that the treatment and controls had different mortality outcomes but similar treatment effects.

### *The impact of time variables*

The dogma “time is a critical factor in trauma” is universally accepted. The association between pre-hospital transit times trauma outcome has been widely studied. It is claimed that reduction in time between injury and definitive treatment improves outcome, which is the concept behind the concept of the “Golden Hour” in trauma.<sup>107, 108</sup> Several other studies have shown no benefit for survival with longer pre-hospital on-scene times in settings where pre-hospital care is available, setting the ground for the “scoop-and-run” rather than the “stay-and-play” approach to prehospital care.<sup>109 110</sup> However, most studies of the kind have been done on urban trauma population with response times of ten minutes and less than one-hour out-of-hospital times, a scenario completely different from the scene in Iraq. All studies of the trauma registry in Iraq document that out-of-hospital time is not a significant risk factor for trauma death as long as minimum quality of prehospital care is provided. This is also documented in Study 2, first helper assisted patients having higher probability of survival despite having longer total out-of-hospital times.

Should trauma first responders be institutionalized?

Other studies also report positive effects of trauma care by layperson trauma first responders. A study from the city of Kumasi in Ghana indicates that taxi drivers, after a six-hour training course were able to provide some basic life support. Also Shah et al. reports improved knowledge in basic trauma care among village healthcare workers in rural Nepal after participating in local training workshops. However, the study results are based exclusively on self-reports from the trainees and not on medical outcome data. A major multi-center study from Canada concludes that emergency medical technicians were able to provide adequate life support in major, but survivable, trauma. However, the study was conducted on an urban population with access to Level-1 Trauma Centers. As prehospital transit times are not given in the report it is difficult to assess the relevance of the study for the actual reference population.<sup>111</sup>

A recent study from Uganda reported that the use of lay first-responders is a practical and effective first step toward developing a formal emergency system.<sup>112</sup> Also WHO recommend that lay first responders should be institutionalized as the first step toward developing formal emergency services in settings without formal prehospital system.<sup>113</sup> On the other hand past training programs have failed to achieve significant gains because of poor selection of participants, inadequate teaching content and pedagogy, which raises the problem of sustainability: Training thousands of first responders is a major undertaking – and can we expect positive effects also on long-term? The solution seems to depend on several factors, such as better planning of ‘who’ to train and ‘what’ to be trained; effective methods based on adult learning principles; alternative methods that maximize learner input and locate training as close as possible to the workplace and its problems; appropriate inclusion of the community; and coordination with other health system intervention. Thus, the focus in training programs must shift from the trainer’s teaching to the participant’s learning and “transfer of learning”.<sup>69, 114, 115</sup> Such strategies are in line with David Werner’s groundbreaking work, *Helping health workers learn* which set the base also for the education of paramedics at the Village Universities in Iraq.<sup>116</sup> The quality of paramedics – both as teachers and care providers – is essential for the first-responder echelon to work well. Such quality requires experience and local knowledge, hence high retention and low turnover.

**Figure 18**



Basic life support training with villagers, Iraq 2002.

We contend that the high retention of paramedics in the trauma system in Iraq (135/180) despite tough working conditions is made possible by careful selection of target areas and trainees, feasible teaching content and efficient pedagogy. Not only in teams of paramedics with laypersons providing trauma care, but also in teaching, a mutually respectful relationship between teachers and students is essential; frequent field visits, giving first helper feedback and support and encouragement, debriefing based on recent trauma cases are required to keep the first helper echelon going on long term. Only if these requirements can be met by the trauma system supervisors and senior paramedics should first helper training programs be implemented on large scale; rapid one-time training courses and distance-monitoring will not yield sustainable gains.

#### *Summary, study aim 2*

Study 2 documents that early in-field first aid and teamwork with paramedics contributes to reduced trauma mortality where out-of-hospital times are long. Despite methodological faults of the study, we contend that the observed difference between treatment and controls is real and valid. The positive effect of the first-responder intervention is supported further by the case examination of fatalities; all seven patients who died outside of the hospital in the first-responder group had injuries of high anatomical and physiological severity, five of them with severe traumatic brain injury. The study did not prove that first helper assistance improved prehospital treatment effects, but neither can we rule out such beneficial effects of early lay first aid. There are good reasons to conclude that training of scores of first helpers should be an integral part of rural trauma systems. The study documents that early first-responder intervention by itself reduces trauma



mortality, but this does not imply that rural trauma systems could be built without trained paramedics. Where the hospital is far and the scene of injury difficult, the backbone of a prehospital trauma system is the network of and teamwork between paramedics and first responders. The paramedic who gains the best results is the one who is able to build good local teams of first responders, support, guide and give self-confidence to the first responders, and on these grounds orchestrate an integrated and effective response in any emergency.

### **5.3 Prehospital life support interventions that enhance survival**

A good trauma system is a process-driven organization, not rigid and conservative, but always in a state of change. There are two reasons why the system has to be flexible. Firstly, the scenes and epidemiology of trauma change and consequently the system has to adapt. The conditions for such adaptability are discussed previously. Secondly, there is always room for improvement regarding medical approach and treatment. It is the obligation of the system coordinators to recommend the best possible treatment, given the resources at hand. For this we have to identify the interventions that enhance survival probability, and the interventions that are of less importance and carry potential adverse effects. There are two ways to study the efficacy of specific interventions. The outcome of two specific interventions – be it treatment effect measured by physiological indicators, or trauma mortality – can be compared; eg. simple control of airways by head tilt-chin lift and positioning versus airway intubation in unconscious patients; or subfascial packing plus compression versus hemostatic agents in limb bleeds. This method requires well-controlled settings to adjust for confounding variables and large study populations, conditions not readily at hand in the actual study area. Another approach is by trauma audit: identifying patients with unexpected outcomes, be it patients with moderate injuries who died – why did they die and how could their deaths have been avoided? And patients who survived despite severe injuries and high probability of death – can we find the main contributors for success? The method of trauma audit thus contains two elements: 1 – an exact risk-of-death calculator. 2 – careful case studies of patients with unexpected outcomes identified by the risk calculator.

In Study 1 the trauma audit approach was applied. This raises the question of trauma severity – how to measure it, and to which ends.

#### *Severity scoring for triage*

For triage the scoring index should be simple, building on variables, which can easily be collected at the scene, during the prehospital evacuation and during the secondary assessment when the patient is admitted at the surgical hospital. In particular, for triage at risky scenes and in chaotic mass casualty settings, indicators used for scoring should be simple and reliable. Obviously, triage indices cannot include assumed severity indicators gathered in retrospect or after surgery, such as the ISS. Yet, the index should be as accurate as possible for any kind of trauma. In the actual studies ROC curve analysis demonstrated high accuracy of a model including the pre-intervention PSS (PSS 1) and the change in PSS during the prehospital phase ( $PSS\ 2 - PSS\ 1 = \Delta PSS$ ) as predictor for death in penetrating injuries. The ROC AUC for this predictor was 0.98. For blunt injuries the accuracy of the same model was also good, but lower, AUC at

0.88. The accuracy of the model was also lower in burn injuries as compared to non-burns, ROC AUC 0.85 versus 0.96. This inaccuracy in burns is the reason why rather high rates of unexpected burn deaths was observed using the probabilistic model in the main study (Paper 1).

Exclusively paramedics, many of them non-graduate health personnel, register the severity rating at first in-field encounter. Still, the reliability of paramedic scorings proved to be high; intermediate analysis of the trauma registry in 2006 compared the PSS ratings on hospital admission done by the out-of-hospital care providers and the Emergency Room personnel respectively, and found a high index of agreement, 91%.<sup>90</sup> We should thus conclude that the PSS registered at the scene and changes in PSS during the prehospital treatment phase is a feasible indicator for triage in the Iraq scenario. In particular, the simplification of the T-RTS, making the scale user-friendlier by replacing the full GCS with a simple scale for consciousness rating and yet achieving reasonably good risk prediction, is a finding of medical significance.

There are reasons to believe that the PSS for triage would make an even more accurate risk predictor if co-morbidity variables were also included such as pre-injury illness and malnutrition. A trauma registry study in Norway reports that the pre-injury ASA-PS score (American Society of Anesthesiologists, Physical Status Classification) is an independent trauma mortality predictor.<sup>117</sup> This study builds on diagnostic data gathered at level-1 surgical centers, but also in the actual intervention data gathering of co-morbidities such as known diabetes, coronary heart disease or evident malnutrition could have been feasible; however, the paramedics were not trained for that purpose.

It is well established that also post-injury hypothermia is a risk factor for death in major trauma. Analysis of a subsample of the Iraqi trauma registry in 1999 proved that hypothermia is also a risk factor during protracted evacuations in Iraq, but hypothermia is preventable by simple preventive means: 19 % of patients in a non-prevention group had core temperatures < 35° C on hospital admission versus 3 % in the prevention group.<sup>100</sup> MKM considers to include the hypothermia variable in future studies of trauma system efficacy in Iraq. Also, inclusion of laboratory variables would probably enhance the accuracy of the risk prediction model. For example, high levels of serum lactate and base deficit at an early stage after injury seems to be independent predictors of severe trauma.<sup>118, 119</sup> However, due to restraints on financial and technical resources laboratory data was not gathered during the actual study in Iraq.

#### *Severity scoring for system quality control*

Including also ISS in the probabilistic model for severity scoring improved predicted death risk accuracy, the ROC AUC being 0.94 (95% CI 0.9-0.99) for penetrating injuries and 0.98 (95% CI 0.97–0.99) for blunt injuries (Paper 1). This indicates excellent test performance and shows that the decision to use ISS instead of NISS scoring was correct in the actual study setting, see chapter 1.6. Even though the prediction model performs well in the actual study population of long prehospital transit times, one should be careful to apply it directly in future time cohorts due to contextual changes over time. Firstly, a selection bias may occur if the inclusion/exclusion criteria of study cases vary, eg. are dead-on-scene patients included? Are medical emergencies like snake and scorpion bites included? What is the proportion of old patients in the datasets, and how are “elderly patients” defined? Old age is not a universal characteristic, but depends on public

health conditions. Are patients intubated in-field included or excluded? Simply excluding cases with missing data generated biased parameter estimates.<sup>120</sup> Also the Major Trauma Outcome Study documented that exclusion of patients with intubation on arrival to US trauma centers strongly biased test results.<sup>121</sup> In the actual intervention, patients intubated on arrival are given the same PSS on hospital admission as they had before the intubation. Secondly, information bias arises if essential data cannot be obtained for certain subsets, eg. in mass casualties of bomb blasts or patients being transferred outside the referral area for security or political reasons. Such bias may strongly affect the test performance because it does not occur randomly but will often include cases of high severity.

The ISS is the heaviest variable in the death prediction model and ISS scoring has to be exact and reliable. However, anatomical severity scoring is not straightforward during war and periods of social unrest and infrastructure breakdown. Close cooperation with trauma center staff, a minimum standard of medical documentation at the hospitals, and an experienced trauma doctor are three conditions required for reliable ISS rating. Throughout the actual intervention the same team of MD trauma instructors did the ISS scoring, and cases with unclear rating were discussed in the instructor team. In the study area, autopsies of cases with unclear diagnosis was seldom done due to religious and cultural restrictions. We therefore contend that the anatomical severity data of the Iraqi trauma registry are reliable despite contextual changes during the study period.

The definition of the study end-point also affects model performance: when and where is data about the main outcome variable, trauma death, collected? In the actual study we defined trauma death as any death related to the primary trauma occurring during the prehospital phase, in hospital or after hospital discharge. Because the comprehensive network of paramedics was mobilized in data validation and case audits, the trauma registry operators would probably obtain anecdotal information from hospitals even if the medical files were incomplete. Some study patients may well have been prematurely discharged from hospital after primary surgery due to failing hospital routines, or for reasons related to treatment costs or security. In these cases post-hospital deaths would probably have been registered by the paramedic and the team of first responders in charge of the primary in-field treatment, and reported to the trauma registry operators. This approach to data differs from most US-based trauma studies in which the end-point often is ill-defined or defined as the “end of acute care”.<sup>122, 123</sup> Such discrepancies in definitions of essential variables are another reason why comparison of outcomes between trauma systems should be done with utmost care.

#### *Treatment outcomes – the definition of end-point*

One may well question why mortality is used as the main outcome variable in the actual studies. Comparing to Western high-income countries, the impact of trauma is probably different and heavier in societies where the household economy is labor intensive, where many are living on marginal income, the social infrastructure is affected by decades of war, post-injury rehabilitation services are non-existent – and the accident survivors have no real rights. Having run the intervention for three years, disturbing reports came from the medics and villager first responders: many survivors complained of chronic pain and post-traumatic psychological depression, and medical treatment had no effect on the condition. In 1999-2000 the author

examined a subset of the study patients and found that 75 % of seriously injured survivors suffered from chronic pain syndromes one year after the accident; in most cases the pain was so severe that physical rehabilitation or return to previous jobs was impossible. The study demonstrated that the rate of pain syndromes did not relate to the quality of trauma care, but it did relate to social factors such as poverty, loss of income and lack of coping strategies.<sup>124</sup> Also other studies recommend that outcome measures such as functional recovery and return to work should be monitored as well.<sup>125</sup>

However, assessing long-term treatment results in societies with broken infrastructures is a complex matter, which requires further studies of outcome indicators beyond mortality and hospital morbidity. The end-point for quality control of trauma system would then be the poor peasant village or urban slum, months and years after injuries. Responding to the findings in the study of post injury pain, MKM initiated self-help groups for mine accident survivors in Northern Iraq in 2001. The groups would get micro-credit financial support and vocational training; the group should also be a forum for mutual psychological buddy support. However, the US led war on Iraq caused a massive increase in casualty loads, and the self-help group initiative had to be closed after three years due to capacity restraints.

#### *Severity scoring in child trauma victims*

Infants and children react to trauma differently from adults; also the normal vital sign values differ. In the actual study the Pediatric Trauma Score (PTS) was not applied in pediatric victims but standard severity scoring indices for adults, ISS and PSS. Receiver Operating Characteristics (ROC) analysis of the ISS and PSS-accuracy in death risk prediction showed that these two scoring systems had high accuracy both in the pediatric subsample and in the adult subsample, ROC-AUC 0.91 and 0.98 respectively. Also other studies of pediatric trauma victims confirm that the Revised Trauma Score system is at least as sensitive as the PTS in identifying major pediatric trauma victims. Several studies have suggested that pediatric triage scores (using physiological measures) are not more predictive of serious injury than adult triage scores when applied to injured children.<sup>62</sup> A retrospective cohort study of injured children of 14 years or younger report that the prehospital GCS and respiratory compromise were the most important physiological measures in identifying high-risk injured children.<sup>126</sup> In a retrospective survey of the trauma registry in Iraq we examined the predictive accuracy of individual indicators in the PSS index, and found that consciousness level at first in-field encounter as one single indicator predicted pediatric trauma death with high accuracy, ROC AUC at 0.85 while systolic blood pressure at first in-field registration had a prediction accuracy estimated at ROC AUC at 0.92. One reason why the test accuracy in child victims was not far from adults may be that there were few infants (< one year, n = 37) in the subsample of children in the registry (< 15 years, n = 629) even if the age distribution was normal with a mean of 7.1 years.

We conclude that the difference in accuracy in death risk prediction in adult versus pediatric trauma victims is without medical significance. The finding may have implications for Trauma Registry set-up in general; using the same severity scales across age groups makes things simpler with less risk of registration failures. In Study 1 the PSS based risk predictor was consequently developed on a composite population of pediatric and adult study patients.

### *Defining unexpected outcomes*

The model of death risk prediction was constructed based on the study population in Paper 1. All assumed predictors of trauma death were included in a logistic regression model using a backward selection process with inclusion at significance level of 5%. The model was evaluated using the Hosmer-Lemeshow test and ROC analysis. Diagnosis, category (blunt/penetrating), ISS, and PSS explained 77% of the variation in trauma mortality and gave a good fit with a ROC-AUC value of .99. Instead of using risk predictors based on foreign trauma cohorts such as the TRISS, we could now calculate risk of trauma death for any patient included for study based on the actual probability distribution in the Iraqi theatre. By decision by the trauma system operators, unexpected survivors were defined as survivors with predicted probability of trauma death ( $P_d$ )  $\geq 0.5$ . A main aim of the audit was to identify and scrutinize a wide range of failures, that is patients dying despite reasonable probabilities for survival. Hence, unexpected fatalities were defined by two criteria:  $P_d < 0.25$ , and in-field PSS  $\geq 6$ . Based on these criteria we found that there was high rate of unexpected deaths in our study population, 44/177, 25% of all fatalities. The figure clearly indicates why trauma audit was warranted.

### *Traumatic brain injuries*

With modern blast weapons, traumatic brain injuries have become more common in war casualties. At close range high-energy blast waves engulf the entire body and may cause brain injury without making fractures to the skull. Correct management of wartime head trauma is thus essential in modern warfare. The risk calculator identified 13 cases of unexpected deaths in head trauma patients. They were all dying within 48 hours after injury, before neurosurgical treatment. One main cause of early deaths in survivable head injury is airway block, but of these 13 unexpected deaths no one died from airway obstruction. The cause of death was probably secondary brain injury – increased intracranial pressure due to delayed primary surgery. Until 2006 the general surgeons at the referral hospitals managed all traumatic brain injuries; there was no neurosurgical expertise present in the study area. Another factor is lack of X-ray services; until 2006 CT services was not established at the referral hospitals. Decompressive craniotomies can well be done on clinical indications, but that requires extensive clinical experience and close ICU monitoring. In modern trauma care, especially where casualty loads are high, brain CT has become part of the ATLS standard protocol.<sup>127</sup> Also adequate ICU services with ventilators were lacking during most of the study period. We therefore contend that the unexpected deaths observed in the head injured study patients belonged to in-hospital treatment faults rather than out-of-hospital flaws.

### *Triage*

Six patients diagnosed in-field as “extremity injury” suffered unexpected deaths. In these patients the level of consciousness deteriorated during the prehospital phase despite efficient control of the external bleeding. The finding indicates that associated injuries (traumatic brain injury, internal hemorrhage) went undiagnosed by the paramedic. This is a triage failure, which emphasizes the importance of triage as a primary tool for good trauma life support. Especially in high-energy blast injuries from car bombs and fuel-air explosives, early clinical signs of

brain injury and abdominal bleeds may be discrete and easy to miss.<sup>62,92</sup> During the first years of the intervention – time cohorts 1 and 2 – mass casualties occurred, but those incidents were mainly caused by anti-personnel fragmentation mines; seldom were more than five persons injured, and the injuries were of the penetrating type, easy to identify by clinical examination. Consequently triage training was not a focus of attention during the Village University courses. From 2003, in time cohort 3, the incidence of blast weapon mass casualties increased, and the necessity of systematic training in on-site and emergency room triage became evident. Since 2004 triage training according to the START methodology (Simple Triage and Rapid Treatment) has been an integral part of all paramedic courses. For better implementation on a chaotic scene, also police and security forces have been educated in the importance and practice of triage in mass casualty incidents.

However, the mass casualty and disaster preparedness is still below standard, and the health authorities have no plans or protocols for such management. Better understanding of the problem might make for a change. For this we need specific studies of mass casualty incidence responses.

#### *Damage control surgery*

Sixteen cases with abdominal bleeds were admitted to referral hospitals with close to normal physiological scores but died from internal hemorrhage hours after admission, despite  $Pd < .25$ . Also the findings in Study 3 indicate in-hospital faults in patients with cavity bleeds; in the patients with blunt injuries from RTA accidents not receiving prehospital care, 82% of fatalities occurred in hospital. There are thus good reasons to believe that the patients with ongoing internal bleeding were not identified early enough, which is a failure of emergency room triage. And they were not operated soon enough; there is just one way to stop internal bleeds in a low-resource setting, and that is by immediate surgery. Scrutinizing the unexpected fatalities, MKM surveyed the actual referral hospitals and discussed each and every case with the responsible staff. It was evident that the emergency rooms were disorganized with shortage of equipment and drugs for immediate life-saving interventions; the doctors and paramedic on duty were not in place and not prepared for emergencies; nor were trauma teams organized at any of the referral hospitals.

**Figure 18**



Chaos in the Emergency Room after bomb blast mass casualty, Iraq 2011.

Finally, the strategy of damage control surgery is not known or not paid attention to; rather the surgeons stick to the old traditional strategy of protracted and elaborate laparotomies with massive transfusions of blood products, with high risk of hypothermia and intra-operative complications.

Major trauma patients exposed to the triad of hypothermia, metabolic acidosis and coagulopathy are at high risk of organ failure and death.<sup>128, 129, 130</sup> We therefore conclude that damage control surgery should be provided at an early stage at a district hospital or immediately on admission at the referral hospital. In particular, where prehospital times are long, such intervention would probably reduce the counts of avoidable deaths. This raises the question: is anybody there qualified to provide damage control interventions?

Studies from low-resource communities demonstrate that trained assistant medical officers, i.e. non-doctors, are able to provide most types of primary trauma surgery provided they are well trained. A study from Cambodia reported that systematic training of non-doctors at rural district hospitals improved trauma outcome. An equivalent study from Mozambique reported similar experiences.<sup>81, 82</sup> Iraq carries the traditions of a developed society, despite being broken by embargo and wars. Models from less developed countries should therefore not be implemented directly to the Iraqi setting. However, the positive experiences of delegating life-saving skills to non-doctors points at the necessity of finding new ways, breaking old-fashioned traditions of treatment. Consequently MKM and his team of trauma instructors have included generations of newly educated young MD doctors in damage control courses at the Village University as an effort to challenge established and conservative medical regimes in the study area.

Expect for using the risk calculator to identify cases with unexpected outcomes among the study patients, also patients reported to have respiratory problems and cases with external bleeds were scrutinized.

### *Airway and breathing*

Most patients with airway problems were managed by basic measures only; head tilt-chin lift, suction, oral airway, and positioning. In very few study patients with potential airway obstruction, 1%, advanced airway life support was provided – endotracheal intubation or crico-thyrotomy. Of four prehospital deaths from traumatic brain injury, one might have been prevented by in-field tracheal intubation. In the group of non-head injured unconscious patients we could not identify any preventable deaths caused by airway block. The findings indicate that basic airway measures are sufficient to control the airway in most risk cases. However, in battlefield trauma care, with high number of blast wave injuries, rough transportation and less opportunity to monitor patients, advanced airway procedures should be provided on more ready indications.

The treatment protocol in the actual intervention did not include in-field chest tube drainage. Forty-seven patients had severe chest injuries (ISS  $\geq$  9). In this group, 39 patients had less than optimal respiratory scores in field, but 30 of the 39 had normal respiratory rate on hospital admission. All 39 cases were treated by basic measures, occlusion of open chest wounds, I.V. ketamine pain relief, half-sitting position, and hypothermia prevention. One patient with a large chest wall wound died in the hands of prehospital care providers; there were no other prehospital deaths among the immediate survivors in this subsample. Also for chest injured it seems that basic life support measures done early are the key to survival. The findings are not in line with

reports from other war scenes. Husum reports significant better survival rates in penetrating chest injuries after forward chest tube placement; 36 % of patients with penetrating injuries were managed by in-field thoracostomy drainage. Similar experiences are reported from the Iran-Iraqi War. No cases with tension pneumothorax were observed in the study population. This is remarkable and may indicate cases with missed diagnosis, taking into account that high-energy blasts may leave the chest wall intact and still rupture the pleural membranes. Also high counts of chest injury in RTA cases warrant further and more refined studies of chest trauma management in the actual trauma system.

### *Bleeding and hemostasis*

Uncontrolled extremity bleeding is a leading cause of avoidable battlefield deaths despite homeostatic agents are now being applied on wide scale in advanced trauma systems. Acute hemorrhage accounts for about 50% of battlefield deaths in conventional warfare and for 30% of in-hospital deaths. A recent epidemiological study of 6,609 combat wounds in the US-led wars in Afghanistan and Iraq shows that extremities were the most common sites of injury among 1,566 casualties (54%). According to the Wound Data and Munitions Effectiveness Team (WDMET) database, exsanguination from extremity wounds accounts for more than half of all potentially preventable deaths in combat. Also, a recent evaluation of autopsy data from nearly 1,000 casualties from Afghanistan and Iraq shows that hemorrhage accounted for 85% of potentially survivable deaths, with 31% and 69% of these deaths representing compressible and non-compressible wounds, respectively.<sup>131, 132, 133, 134, 135</sup>

Improving our ability to control hemorrhage is an important challenge for reducing trauma mortality. In Study 1 a simple treatment protocol was implemented for extremity bleeds; no tourniquet but sub-facial packing plus compression plus hypothermia prevention. The protocol proved effective: 84 % of extremity- injured patients with severe in-field hemorrhage were normotensive on admission. Similar findings are reported from other war scenarios.<sup>136, 137</sup> In the actual study we did not gather data on core temperature. However, previous studies conducted on a subsample of the actual study population verified that at least one out of five patients with penetrating trauma was hypothermic on hospital admission if prehospital transit times are long and precautions are not taken. Simple in-field preventive measures reduced the incidence of hypothermia on admission to nearly zero.<sup>100</sup>

We can thus conclude that the protocol of subfascial packing worked well in the actual setting. Still we should consider if hemostatic agents were an alternative or adjunct to the packing approach. Several hemostatic medical devices and drugs have been developed lately and applied across the continuum of trauma care, prehospital, in the emergency room, and during surgery: Hemcon chitosan dressing, Traumastat, Woundstat, and Stasilon. During the last decade a number of studies in experimental animals have evaluated the efficacy and safety of these hemostatic products, benefits abut also limitations being reported:

1. The agents reduce bleeding as long the coagulation system is intact and in balance. In coagulation failure the effect is poor or negligible.
2. The hemostasis of normotensive artery bleeds is of short duration, less than one hour.<sup>138, 139</sup>



3. Most of the agents have exothermic reactions leading to significant thermal tissue damage in the wound.
4. Most of agents did not yield hemostasis in mixed arterial and venous bleeds at the proximal thigh.<sup>140</sup>
5. One of the newest products, Woundstat, was 100% successful in stopping artery bleeding and preventing exsanguination.<sup>141</sup> However it was found that Woundstat induces significant endothelial toxicity, necrosis of the vessels and surrounding tissues, as well as thromboembolism in distal organs, causing 100% mortality in the experimental animals after 24 hours.
6. One study demonstrated that a standard non-medicated gauze dressing was as effective as any of the hemostatic agents.<sup>142</sup>

Also taking into account the high costs of the new hemostatic products, it seems safe to conclude that the existing protocol, packing + compression is a simple, cheap and safe method to control extremity bleeds – also applicable in the hands of lay persons.

### *Bleeding and fluid resuscitation*

In patients with uncompressible bleeding inside body's cavities and also in patients temporarily controlled by packing for severe extremity bleeds, we applied the principle of hypotensive intravenous fluid resuscitation; the aim of volume replacement is to keep systolic blood pressure near but not much higher than 90 mm Hg. For a decade the debate on circulatory shock management has focused on two strategies: the traditional concept of intensive fluid resuscitation in order to restore normal blood pressure versus the "scoop and run" concept, getting patients with bleeding injuries to the operation table in hurry without prior fluid infusion. Experience from military medicine suggests that a strategy of limited fluid resuscitation aiming to maintain blood pressure at 60 mm Hg may be reasonable for patients in shock even when prehospital transit time is long.<sup>143, 144, 145</sup> However, none of these concepts has convincing clinical data to support it beyond any scientific doubt. In both strategies, neither the time from the accident to operation table, nor the body temperature are considered in actual studies and evidence-based reviews.<sup>146</sup> We should also keep in mind that a long out-of-hospital period of hypotension followed by rapid restoration of perfusion on hospital admission might trigger reperfusion syndromes. Reperfusion injury is a devastating hit, not only to organs damaged by the initial trauma, but to the entire physiological system.<sup>17, 147</sup>

Trauma audit proved that the vast majority of study patients with severe extremity bleeds in Iraq had systolic blood pressure > 90 mm Hg on admission. More than 90 % of all study patients had improving physiological indicators during the prehospital phase (Papers 1, 2 and 3). There are thus good reasons not to revise the protocol of moderate hypotensive fluid resuscitation.

### *Basic versus advanced life support measures*

Prehospital trauma care protocols suitable to low-resource scenarios with long prehospital transport times are under debate. Two different approaches are considered; speedy on-site response and transport to surgical center, "Scoop and Run"; versus taking the time at the scene to initiate primary treatment and temporarily

stabilize the patient using advanced measures if so indicated, before evacuation, “Stay and Play”. It may well be that the “scoop and run” approach saves lives in the urban setting. However, in trauma systems with out-of-hospital times of four hours, it is hardly relevant to argue that on-site ATLS causes significant delay of transfer. Furthermore, the dogma that on-scene procedures will necessarily increase the on-scene interval is simply not true.

Several studies aim to compare the efficacy of basic versus advanced prehospital trauma care.<sup>49, 50</sup> The validity of these studies is compromised due to lack of control for confounding variables and appropriate comparison groups. ATLS and BLS also entail different protocols in different countries, making comparisons between systems dubious. Neither of the studies include rural trauma where prehospital transit times are long. The question of resources and infrastructure is not considered; experiences from societies where the health infrastructure is weak or damaged by disasters and war were not included these studies.

### *Summary, study aim 3*

Trauma audit is the main tool to monitor and improve quality of trauma system performance. Developing a death risk predictor based on data from the actual study population was a prerequisite to implement suitable audit procedures in Iraq.

The audit documented that simple life support provided early is the most important measure for trauma survival. The rate of avoidable deaths was too high, and can probably be reduced by two interventions: better triage and on-site response in mass casualties, and implementation of forward damage control surgery.

## **5.4 Life support in burn casualties**

The overall mortality rate in burn patients in the actual intervention was 16%, which corresponds to in-hospital mortality rates in the range of 20% to 37 % reported by other studies from the area.<sup>148, 149, 150, 151</sup>

In the ten year-study sample, we found that there was significant reduction in overall mortality by year but during the third time cohort the mortality of burn casualties increased. This raises the question of the efficacy of prehospital life support in burn casualties. The study demonstrated that ISS and PSS1 are risk factors for burn death and explain 73% of the variation in burns fatality rates. However, we noticed that in-field response time and prehospital transit times were not significant risk factors for burn death. This indicates that the physiological derangements and response to treatment is different in burn casualties, a hypothesis supported also by the finding that the time line of death in burn cases is different from non-burn patients. Of the burn fatalities there were few out-of-hospital deaths compared to the group of non-burn fatalities (3/43 versus 72/134); in-hospital deaths made up 37/43 (86%) of all burn fatalities. Of the in-hospital burn fatalities, 86% occurred more than 48 hours after hospital admission compared to 30% in non-burn fatalities. The mortality pattern observed in the actual intervention corresponds to studies from other low-resource settings

reporting that most burn patient deaths, 67%, occurred during the first week, and 16 % during the second week post-burn; the main causes of death were septicemia and renal failure.<sup>152</sup>

*The pathophysiology of burns is unique.*

The local and the systematic inflammatory responses in burn complex. The body responds to cellular injury by activating protective mechanisms lead to a hyper-dynamic and hyper-metabolic state with massive release of cytokines and other inflammatory mediators. The mediator response is progressive, minor burns trigger moderate post-injury stress while burns of more than 25% of TBSA may have a deleterious systematic effect in all organ systems distant from the burn area itself. The post-injury systemic response progresses with time, usually peaking five to seven days after burn injury.<sup>153</sup> The acute care of major burns is a challenge. During the first days after the injury, hypoperfusion due to leaking endothelial membranes of the small vessels and hypothermia due to loss of the skin membrane and protective vascular regulation are the main problems. Later during the first week a state of severe catabolism develops, often with gastrointestinal failure making nutrition difficult. The cytokine release also acts on the capillary wall and induces tissue edema, not only in the burn wound but also in unaffected tissues; edema means hypoperfusion and further triggering of the stress responses. The outcome of the massive and protracted trigger activity seen in major burns is a pronounced depression of the immune system that predisposes patients to subsequent sepsis and multiple organ failure, the major causes of morbidity and mortality in the burn patients.<sup>154, 155</sup>

*Severe injuries from self-inflicted burns in women*

In the actual study population we found that the female burn victims had a significantly higher mortality rate than male, 22.5% versus 8% (95% CI diff: 6.5 – 23). As many as 35% of the burn casualties died from thermal inhalation injury. We found that rising incidence of self-inflicted burns in young women in certain feudal districts after the 2003 invasion account for increasing mortality rates for burns observed in the third time cohort. Self-inflicted burns are usually more extensive than accidental burns.

**Figure 19**



(Figure legend) Self-inflicted burn in a young woman, Iraq 2008.

Anecdotal evidence by family members and survivors of self-inflicted burns confirm that the young female victims had poured kerosene over themselves and ignited the burn themselves. Such burns often affect the head and neck and causes airway injury. In the actual study the mean burn wound area in self-inflicted burns was 74% of TBSA, and the mortality rate as high as 88%.

The intentional self-harm burns accounted 22% of all burn admissions in the actual study which is higher than rates reported from other countries of the region: Pakistan 2%, Turkey 5%, Iran 9% to 15%, while studies from high income countries report smaller rates of self-harm burn such as 1% in USA, and 3% to 5% in UK.<sup>156, 157, 158, 159</sup> The reason for this high rate of self-harm burn in female is likely related to situation of women in Kurdish society, especially in rural areas where tribal traditions still are strong. Several events of domestic violence and honor crimes have been reported by the trauma system paramedics in certain districts in the study area where tribal rules of conduct are still in rule. After the 2003 invasion the rural areas of Iraq faced a transition from relative isolation towards an open market economy and political modernization characterized by agitation for Western style democracy, gender equality and women rights. Being concerned about the high death tolls in self-inflicted burns, the author in 2009 conducted a rapid survey in the districts of high incidence rates of self-inflicted burns, gathering information from burn accident survivors, school teachers, police officers, tribal and religious leaders. The survey indicated that many male family heads from the local communities found it hard to cope with the cultural transition, and young females found themselves in a squeeze between Women Rights propaganda and old conducts of behavior. MKM strongly believes that the contradiction must be solved, but this can only happen by genuine local dialogue and not by pressure from outsiders. Therefore a committee was established of influential local persons to start educating the tribal leaders, male villagers and students through schools and mosques – and at the same time starting small vocational centers for young women where they can socialize, earn a modest income, and set the foundation for an independent job career. The results of the initiative are pending.

#### *The severity calculator does not fit in severe burns*

The death risk predictor developed from the study sample identified ten unexpected burn fatalities, burn patients with physiological severity score, PSS, at first in-field encounter > 6, and a probability of survival > 75%. A retrospective survey of the unexpected fatalities showed that all ten cases were late deaths due to post-burn sepsis and/or organ failure. However, we should note that the patients had improving PSS score during the prehospital phase, yet they died. The finding indicates that there are uncontrolled explanatory variables in action, triggers of post-injury physiological derangement in burns different from non-burn trauma. One might well hypothesize that chemical tracers of immune system failure, interleukins and serum lactate, would give better accuracy in death risk prediction if included in the severity calculator.

The specific features of the pathophysiology of burns make survival and the probability of unexpected deaths depend to a large extent on post injury surgical care rather than prehospital life support. There are good reasons to believe that the quality of the hospital treatment of burns during the study period was below standard, which is another variable explaining raising mortality rates in severe burns during the third time cohort. Until 2005 there were no specialized burn units in the study area. In 2005 a burn unit was established

at Suleimaniah Teaching Hospital, and as late as 2010 a burn unit was established also in the war zones of Central Iraq, at Baquba University Hospital in Central Iraq.

Still we should not claim that prehospital care for burn patients has no affect on morbidity and mortality. In particular, for inhalation burns, early in-field airway management is urgent. Also adequate fluid resuscitation is essential, which requires active prehospital treatment where the out-of-hospital times are high. Burn wounds are painful, and analgesia has high priority in the prehospital phase to prevent excessive physiological stress (prehospital management of burns).

### **5.5 Turning the tide – sustainability of the intervention**

In paper 1 we report that the retention rate of trained paramedics during the ten-year intervention was high, 75%. Also the cost-efficacy was acceptable, total prehospital treatment costs/case including data gathering and quality control was below US\$ 200. These are definitely factors, which enhance possibilities of viable system effects. However, the question of sustainability is more complex: The intervention was launched at a time when the health system was in a process of deterioration. To get to a stage of building a survivable EMS service, first the negative tide had to be turned.

#### *First – turning the tide*

Short of medicine, technical resources and support from the authorities, one should expect and understand that health staff loses professional motivation and neglects standards for quality of care. The aim of the Village University training was to establish a core group with capacity of giving good-quality trauma care and thus save lives and limbs that otherwise be lost. The hypothesis of the instructors was that commitment comes with professional skills, confidence and social reputation. The core group of paramedics trained during the first time cohort thus acted as models for other medical staff in the target area. This took a lot of effort – tight supervision and quality control, rehearsal courses and trauma case audits. Continuous field visits to medics and first responders, encouraging, giving feedback and acknowledgements made a psychological shift among the care providers themselves. Within three years it had the effect that requests were coming from other sectors of the health system and also from village leaders: “This is a new approach. This is useful. Also we want to get this program.” The tide was about to turn, not on a wide scale but in the catchment areas in Northern Iraq.

A prerequisite for low turnover of paramedics is a careful and wise selection of trainees. The candidates for the Village University courses were chosen by the local villagers with real-life knowledge of the danger and burden of land mines. The trauma system coordinator (MKM) himself was spending days and weeks in the target areas to get at a genuine dialogue to ensure a good selection process. This was a structural effort, which signified the importance of proper trauma care and gave a solid reputation to the chain-of-survival program.

### *Then – building sustainable structures*

US\$200, including systematic quality control, should be a feasible price for most low-income communities, and definitely for a country being drowned in foreign investments of dollars. However, the main obstacles to change and sustainability are not financial as much as cultural restraints. By tradition in the Middle East, social and political structures are centralistic and the medical doctor has high social status. The hospitals are thus under the rule of senior doctors; especially in the field of surgery the indications, timing and methods of operations are in the hand of the local “lords of surgery”. The health education system of Iraq suffered from embargo, war and brain drain, see chapter 1.3, and the level of professional skill and confidence among the newly graduated doctors was low. The actual intervention deliberately set the prehospital paramedic in focus as the key lifesaver in trauma. This approach was new to the seniors of the hospitals and was met with distrust, and most junior doctors had no choice but to obey. In order to change attitudes from the bottom-up, the Village University has since 2010 also conducted ATLS courses for newly graduated doctors. The design and results of the actual intervention has been published scientifically in journals and at conferences. This active marketing has had an impact on the national scale in Iraq; a two-tier dispatch system is now under implementation in the major cities in North Iraq, and there are requests from the Ministry of Health in Baghdad to implement the actual chain-of-survival model also in Central and South Iraq.

Atrocities of war are still going on in Iraq, ten years after the US led invasion. Insecurity and sectarian division makes it less likely that the humanitarian capital fleeing the country during the last decades will ever return. The triple challenges to Iraq are to restore a heavily damaged infrastructure, rebuild administrative and support systems, as well as replace lost human capital. For the health system, the last contest perhaps remains the greatest challenge. Therefore it is essential – also for reasons of sustainability – to re-establish scientific capacity and research activity in the medical faculties of Iraq. Such capacity will constitute a long-term capital for the country as long as the build-up is genuinely local and not a colonial copy-paste of private Western university satellites.

### *The capital of the intervention: Dedicated paramedics and good teachers*

The backbone of the trauma system and a condition sine qua non for long-term performance is experienced and dedicated paramedics – as care providers, as organizers of the on-site response under harsh conditions, and as teachers initiating “transfer of learning”. However, this capital is not easily gained and requires good teachers as well.<sup>110</sup> We should lend an ear to paramedics as they evaluate the Village University experience:

“Before this course I was afraid to approach the trauma patients. I was always tried to not be the first one to approach to patient. Now I like to manage any trauma patient, I want to be the first one to approach him and support him” (Emergency room paramedic)

“ We got useful knowledge, by doing, not by listening. All I have learned in this course was important to my work. I have participated in many courses before, inside Iraq and outside the country. This was the only course I gained from, the only course that related to my work as medical assistant in the emergency room.” (Paramedic from district hospital)

“ I want to say that this is the first time in my life to see such way of training and teaching. It was an excellent strategy of teaching because you have learned me practically and also morally, how to deal with major injuries and how to act as a humanitarian doctor.” (Junior medical doctor from Suleimaniah)

“Before this course I was not able to give life support for trauma patients. But now I have self-confidence and practical skills to give first aid in any emergency cases, in a proper way, and scientifically. I want to thank my teacher; you made me to find my way as medical doctor. Even if I get post-graduate certifications, still I will consider myself as your student, because you was the first one to teach me scientifically and at the same time practically the “ABC” of emergencies.” (Graduate student from medical college)

“ The course was completely different from the way of teaching in medical college. It was efficient and successful teaching as we learned by doing. Teacher; I don’t feel you are my teacher; I feel like you have been my friend for a long time. I learned more from you here at the Village University than I learned during six years in the medical college.” (Graduate student from Medical College of Suleimaniah).

## 6. Conclusions

A three-tier chain-of-survival trauma system of trained lay first helpers, paramedics and emergency room staff reduced trauma mortality in the study area. The experience is relevant for countries where resources are lacking and out-of-hospital times are long.

Simple life supports measures provided by trained lay first responders improve probability for trauma survival. Forward networks of local paramedics with first helpers should be an integrated part of prehospital trauma systems.

Simple things done early remain the foundation for prehospital trauma care, also in severe injuries. Most airway problems can be managed safely by basic life support measures. Subfascial gauze packing with compressive referral for surgery takes hours.

A three-tier trauma system is able to respond to changing patterns of injury. Conditions for adaptability are careful monitoring of the epidemiology of trauma in the catchment area, close supervision of the trauma system paramedics, and constant teaching and support of the care providers.

Trauma epidemiology changes and any trauma system carry a potential for improvement. Trauma audit is therefore an ongoing process. The audit should scrutinize and take lessons from cases with unexpected outcomes. A death risk calculator should be developed based on the actual study population for accurate identification of such cases.

The audit of the actual trauma system revealed two main reasons of avoidable deaths: incorrect onsite triage and delayed surgery in cases with internal hemorrhage. In settings with mass casualties, especially in high-energy blast incidents, triage training should be an important part of paramedic and first helpers training. Where out-of-hospital times are long, damage control surgery at local hospital may be life saving.

Experienced paramedics constitute the backbone of a low-cost prehospital trauma system. The system seems to be sustainable if the paramedics are carefully selected from local health workers, if the training targets the real-life challenges paramedics face trauma care, and the trauma instructors constantly supervise and guide the paramedics.

The trauma system performed adequately on low costs with high retention of core care providers. By the end of the study period, the system is ready for expansion on a national scale. The ten-year history of the actual trauma system illustrates the usefulness of setting up pilot interventions; the pilot system outcome should be evaluated scientifically before the pilot is recommended for expansion.



## 7. Recommendations for further studies

The following recommendations are based on the findings and shortcomings of the actual studies.

1. The actual intervention is groundbreaking and represents a new and innovative approach to trauma teaching and trauma care. The lessons of the intervention should be documented and explained in protocols and teaching manuals to enhance the application of equivalent interventions in other low-resource societies.
2. The performance of the trauma system in mass casualties is inadequately documented. Further studies should be conducted of the response to and outcomes of mass casualty management, especially in high-energy blasts.
3. The documentation of chest injury management is insufficient for evidence-based evaluation of prehospital care. Future studies should be conducted to assess the benefit of forward thoracostomy drainage. If at all possible such studies should be conducted with controlled designs.
4. Survival prediction models are crucial for trauma audit. Further studies should be conducted to see if the actual probability model would be more accurate if pre-injury physiological capacity, body core temperature, and chemical indicators such as oxygen saturation and serum lactate were included in the model.
5. The rate of self-burns among young women is on the rise in the study area. The treatment of such burns is difficult and mortality rates range high. Immediate studies are required to clarify the epidemiology and get to a better understanding of the etiology in order to find ways of preventing the tragedies.

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# Paper 1



## Paper 2



## Paper 4





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