Mechanism of injury and microbiological flora of the geographical location are essential for the prognosis in soldiers with serious warfare injuries

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ABSTRACT

INTRODUCTION: Denmark has been engaged in the Afghanistan war and as a result, Rigshospitalet has received a number of multi-traumatized Danish soldiers. Lesions sustained in armed conflict differ from their civilian counterparts and knowledge of the pathophysiology related to these types of lesions is essential when engaging in the intensive care of these patients.

MATERIAL AND METHODS: The study was conducted as a retrospective survey of Danish soldiers evacuated from Afghanistan to the Intensive Care Unit at Rigshospitalet in the 2002-2012 period. The following data were recorded: age, gender, hospitalization (days), mortality, organ involvement, respiratory therapy, dialysis, circulatory supportive care, antibiotic treatment and bacteriology. Furthermore, Acute Physiology and Chronic Health Evaluation, Simplified Acute Physiology Score and Sequential Organ Failure Assessment scores were calculated.

RESULTS: A total of twenty patients were identified and included in the study. All patients had sustained serious blast injuries as a result of explosion. Primarily the central nervous system, respiratory, musculoskeletal and abdominal systems were affected by the explosions. Eighteen patients survived to discharge and two patients died.

DISCUSSION: Explosion was the most frequent cause of injury in all cases and caused damage to several organ systems. Infections after combat injuries are a major problem because of the different microbiological profile.

CONCLUSION: The use of explosives has been and remains a substantial part of warfare, and this review has showed us that the knowledge of the mechanism of injury is indeed essential, and that intelligence on the microbiological flora of the geographical location of the conflict is essential.

FUNDING: not relevant.

TRIAL REGISTRATION: not relevant.

Over the past decades, Denmark has increasingly been involved in armed conflicts around the world. Recently, Denmark has been engaged in the Afghanistan war. This has resulted in a number of multi-traumatized Danish soldiers. Prior to repatriation, all soldiers received damage control surgery and upon stabilization they were evacuated for further treatment in Denmark. Upon repatriation Rigshospitalet has the responsibility for treatment of Danish personnel injured in combat. Lesions sustained in armed conflict differ from their civilian counterparts [1, 2]. In particular, penetrating and blunt injuries caused by explosion dominate the pattern of lesions. Specific knowledge of the pathophysiology related to these types of lesions is essential when delivering intensive care for these patients [3].

Central nervous system (CNS), thoracic, abdominal and extremity injuries are often observed in relation to explosions [3-6]. Compared with similar injuries sustained in the civilian setting, infections after combat injuries are a major problem due to their different microbiological profile [7]. Especially *Acinetobacter*, *Pseudomonas* and methicillin-resistant *Staphylococcus aureus* are often identified in the wounds of injured soldiers [8-12].

This retrospective study was undertaken to delineate the intensive therapy offered to Danish soldiers repatriated to Denmark after serious injury.

MATERIAL AND METHODS

The study was conducted as a retrospective survey of Danish soldiers evacuated from Afghanistan to the Intensive Care Unit (ICU) at Rigshospitalet in the 2002-2012 period. The ICU is divided into three sections; General Intensive Care (Section 4131), Thoracic ICU (Section 4141) and the Neurointensive Care Unit (Section 2093).

Patients were identified through the central registry of the ICU. The list hereby obtained was validated against the repatriation lists of the Danish Army Command.

The following data were recorded: age, gender, diagnosis group, hospitalization (year of admission and length of ICU stay), mortality, organ involvement, respiratory therapy, dialysis, circulatory supportive care, antibiotic treatment and bacteriology. Furthermore, Acute Physiology and Chronic Health Evaluation (APACHE), Simplified Acute Physiology Score (SAPS) and Sequential Organ Failure Assessment (SOFA) scores were calculated. Parametric variables following a Gaussian distribution are shown as mean ± standard deviation, and otherwise as median and range.

Trial registration: not relevant.

ORIGINAL ARTICLE

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Dan Med J 2013;60(9):A4704

TABLE 1

Patient characteristics: the number of repatriated soldiers according to calendar year of admission to the intensive care unit, and the corresponding scoring systems[a].

Repatriated soldiers, n	
2006	1
2007	1
2008	5
2009	6
2010	5
2011	2
Total	20
APACHE II score, mean ± SD (n = 20)	11.3 ± 5.1
SAPS score, mean ± SD (n = 20)	26.6 ± 12.9
SOFA score, mean ± SD (n = 20)	8.5 ± 3.3
Mortality, n/N	2/20
Lenght of stay ICU, days, median (range)	8.3 (1-28)

APACHE II = Acute Physiology and Chronic Health Evaluation. SAPS = Simplified Acute Physiology Score. SD = standard deviation. SOFA = Sequential Organ Failure Assessment.
a) APACHE score of 10-14 predicts a mortality of 15%, SAPS score of 29 predicts a mortality of 10%, SOFA score of 7-9 predicts a mortality of 15-20%.

TABLE 2

Injuries by organ systems (N = 20).

CNS, n/N	4/20
Circulatory system, n/N	
Inotropes	8/20
Blood transfusion	2/20
Respiratory system	
Mechanical ventilation, n/N	17/20
Ventilatory support, days, median (range)	5.1 (0-25)
PaO_2/FiO_2, kPa, mean ± SD	28.3 ± 12.4
ARDS, n	
Mild: PaO_2/FiO_2: 26.7-40.0 kPa	5
Moderate: PaO_2/FiO_2: 13.4-26.7 kPa	11
Severe: PaO_2/FiO_2: < 13.4 kPa	1
Gastrointestinal system	
Surgery, n/N	12/20
Renal system	
Max. creatinin, µmol/l, mean ± SD	96 ± 32.3
Clearance, ml/min., mean ± SD	80.4 ± 14.1
Extremities	
Amputation, n/N	9/20
Amputations, n	18
Max. myoglobin, µg/l, median (range)	4,199 (150-35,300)
Microbiology	
Change in antibiotics, n/N	18/20

ARDS = acute respitatory distress syndrome (Berlin definition) [13]. CNS = central nervous system. SD = standard deviation.

RESULTS

A total of twenty patients were identified and included in the study. The average age at admission was 23.8 ± 2.4 years. Selected patient characteristics are described in **Table 1** and **Table 2**. Patients were on average admitted to the ICU 2 ± 1 days after sustaining injury. All patients were men and had sustained serious blast injuries as a result of explosion. Four patients had also sustained penetrating wounds secondary to the blast injury.

CNS: Four patients had injury to the CNS; one patient with a subdural haematoma localized to the frontal region, one patient had a frontoparietal skull fracture, one patient a penetrating trauma to the eye, and one patient a penetrating lesion to the spinal cord.

Cardiac

Nine patients were in hypovolaemic shock upon arrival and were in need of support from inotropic drugs, primarily in the form of norepinephrine infusion. Benign supraventricular arrhythmias were observed in a large number of the patients. In one incident, regional myocardial dyskinesia was observed through echocardiography. No patients developed myocardial infarction or necrosis.

Respiratory

A total of 17 patients were intubated at the time of arrival. The duration of mechanical ventilation was 5.1 days (0-25 days), and the PaO_2/FiO_2-ratio = 29 ± 12 kPa was calculated to evaluate the degree of respiratory dysfunction.

Six patients had chest tubes inserted in order to treat pneumo-/haemothorax.

Abdominal

Second-look surgery was performed in 12 patients after arrival. Three patients had sustained injuries from penetrating trauma secondary to explosion. The injuries involved lesions to the liver, the spleen, the pancreas and the kidney.

Renal

Eight patients had mild renal failure. Two patients had a reduction in glomerular filtration rate of more than 25%. Dialysis treatment was, however, not required.

Extremities

A total of 19 patients had injuries to the extremities due to explosion. Nine patients had amputations of the extremities performed with a total of 18 amputations.

Due to infection, 15 patients needed one or more surgical revisions of lacerated areas.

Microbiology

Microorganisms of particular interest: *Enterobacter* species (seven patients), *Acinetobacter baumanii* (four patients), and *Clostridium difficile* (four patients).

The most commonly used antibiotic treatment dur-

ing hospitalization was triple-drug therapy in the form of meroponem, ciprofloxacin and metronidazole. After culture and determination of resistance pattern, antibiotics were changed to a combination of meropenem, polymyxin E and metronidazole in 18 patients.

Eighteen of the 20 patients survived. Two patients died, of which one patient had a penetrating trauma to the spinal cord and sustained severe damage to the brainstem and one patient was severely injured from a blast trauma and died subsequently of multiorgan failure.

DISCUSSION

Denmark's increased involvement in international conflicts has caused the number of multi-traumatized Danish soldiers to rise. It is pivotal that relevant clinical experience is reported given the differences between the multi-traumatized soldier and the "civilian" intensive care patient, in particular the mechanism of injury, the pattern of organ injuries and the microbiological profile, and given the inherent difficulty in performing clinical trials proper in this group of patients [1, 2].

Explosion was the cause of injury in all cases, and it caused damage to several organ systems. Primarily the respiratory, musculoskeletal and abdominal systems were affected by the explosions. The use of explosives has been and remains a substantial part of warfare, and explosives are also used in terrorist actions. While being engaged in armed conflicts, the likelihood of being confronted with this type of lesion is therefore increased. The pathophysiology of the explosions is related to its phases; explosion pressure, penetrating projectiles and possible inhalation of toxic gasses [3-5, 14].

Four patients had CNS damages, of which one patient had a penetrating spinal cord trauma and died after arrival to the ICU due to his injury.

The lungs are particularly vulnerable to explosions due to the large tissue-to-air surface. Lung tissue may thereby be consolidated, which may lead to acute respiratory distress syndrome (ARDS), pneumo/haemothorax or arterial air embolism [4, 5, 14-16]. Damage to the respiratory system as a result of explosions was significant among the patients. Eighteen patients required mechanical ventilation. Twelve patients were so severely injured that they met the criteria of moderate/severe ARDS, one patient had multiple pulmonary embolisms. Six patients were treated with a chest tube. Damage to the myocardium or rupture of the intrathoratical vessels is relatively rare and was not observed in the present cohort. Benign supraventricular tachycardias were observed, but did not require specific treatment.

The pressure wave from the explosion is transmitted from the air to the large surface area of tissue in the abdomen causing haemorrhage, shearing lesions and secondary perforations. Anatomically, the iliocoecal region and the colon are particularly vulnerable to the barophase of the explosion in the same way as the lungs. Intra-abdominal injuries were observed in more than half of the patients, especially perforating injuries and intra-abdominal bleeding which required surgical intervention. Injuries to the colon and spleen were initially stabilized by surgical intervention in Afghanistan and "second look" surgery was performed upon arrival at Rigshospitalet.

Hypermyoglobinaemia was observed in the majority of the patients and required forced diuresis to avoid development of renal failure. None of the patients needed dialysis.

War-related injuries are associated with a high risk of infection. The cause is multifactorial, e.g. the use of contaminated bombs, injury patterns with great skin and tissue lesions, damage frequency and severity, presence of fragments, prolonged timespan from the time of injury to the time of definitive treatment and the high risk of nosocomial infection [10]. Initially, mainly triple drug treatment with meropenem, ciprofloxacin and metronidazole was used. The antibiotics were changed in 18 patients. In multi-traumatized Danish soldiers from Afghanistan, it is particularly important to be aware of infection caused by *A. baumanii*, *Escherichia coli*, *Pseudomonas*, *Enterobacter* and *Bacillus cereus*. The frequent occurrence of multi-drug resistant organisms can complicate the treatment [7, 8, 12, 17]. Although most of the bacteria are well known from other armed conflicts, the infection caused by *A. baumanii* poses a new problem in Iraq and Afghanistan. Infection with this bacterium is particularly problematic in the healing process of the wound due to the resistance pattern and the for-

! ABBREVIATIONS

When evaluating the severity of organ failure, various scoring systems are being used in the ICU to assess the risk of morbidity and mortality. The following is a brief overview of the current systems used in intensive care units at Rigshospitalet:

APACHE II = Acute Physiology and Chronic Health Evaluation. This score is applied within 24 hours of admission of a patient to an intensive care unit. The APACHE II score is made of 12 physiological variables and two disease-related variables.

SAPS = Simplified Acute Physiology Score. Comparable to the APACHE score and measures the severity of disease for patients admitted to intensive care unit within the first 24 hours. The calculation of the SAPS score includes twelve physiological variables, age, admission type and concurrent chronic disease.

SOFA = Sequential Organ Failure Assessment. Unlike the APACHE and SAPS scoring systems the SOFA score is used to track a patient's status during the stay in an intensive care unit and focus is on organ dysfunction and morbidity, with less of an emphasis on mortality prediction. The score is based on six different scores, one each for the respiratory, cardiovascular, hepatic, coagulation, renal and neurological systems.

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mation of biofilm [8, 9]. Based on the microbiological findings demonstrated in the multi-traumatized soldiers of Afghanistan, the initial empirical antibiotic strategy since 2010 has changed into treating the infection with meropenem, polymyxin E and metronidazole.

Eighteen of the 20 patients survived and were transferred from the intensive care unit upon stabilization. Our retrospective review has identified the same spectrum of issues observed in British and American studies [1, 2]. Though multidisciplinary medical cooperation is always relevant and necessary in multi-traumatized patients, the experience gained on handling traumatized patients of war has contributed to the knowledge needed to ensure rapid, coordinated and proper treatment in this group of patients, and has showed us that knowledge of the mechanism of injury is, indeed, essential, and that intelligence on the microbiological flora of the geographical location of the conflict is essential. Cooperation between the armed forces and the civilian hospitals receiving injured soldiers with a view to gaining such intelligence will continue to be of essence in providing the best treatment to the wounded soldiers.

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ACCEPTED: 28 June 2013

CONFLICTS OF INTEREST: none. Disclosure forms provided by the authors are available with the full text of this article at www.danmedj.dk.

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