MMSL Military Medical Science Letters

Mil. Med. Sci. Lett. (Voj. Zdrav. Listy) 2011, vol. 80(4), p. 150-158
ISSN 0372-7025
DOI: 10.31482/mmsl.2011.021

CASE REPORT

MULTIPLE MECHANICAL AND THERMAL BLAST INJURY IN CIVILIAN INDUSTRIAL SETTING – POSSIBLE PARALLEL TO THE BATTLEFIELD BLAST SYNDROME TYPE INJURIES

Leo Klein[1,2] ✉, Eduard Havel[2], Karel Smejkal[1,2], Jaroslav Cerman[2], Frantisek Hosek[2], Miloslav Hronek[3,4]

[1] Chair of Field Surgery, Faculty of Military Health Sciences, University of Defence, Hradec Králové, Czech Republic
[2] Dept. of Surgery, Medical Faculty and Teaching Hospital, Charles University, Hradec Králové, Czech Republic
[3] Dept. of Biological and Medical Sciences, Faculty of Pharmacy, Charles University, Hradec Králové, Czech Republic
[4] Dept. of Research and Development, Teaching Hospital Hradec Králové, Czech Republic

Received 19th October 2011.
Revised 24th November 2011.
Published 9th December 2011.

Summary

A 43-year-old man, injured during a factory explosion on January 4, 2010, was transported to the nearest hospital. Volume resuscitation started, subclavian vein cannulation, chest tube, and covering of burns were performed. The intubated and ventilated patient was transferred by helicopter to our hospital. The leading diagnoses were: haemorrhagic – traumatic and burns shock, haemoperitoneum, pneumothorax, subtotal amputation of the left distal crus/feet, burns over 40 % of the body surface, right calcaneus fracture etc. Preliminary circulatory stabilisation with discontinuation of norepinephrine infusion was achieved within 10 hours, by excessive positive fluid balance, which took three days (22, 10 and 9 litres). Preliminary blood lactate 7 mmol/l was normalised within 24 hours. Blood albumin level 15 g/l was tolerated without any artificial replacement. The second hit appeared on day 10, in a form of septic shock caused by *Aspergillus fumigatus* infection from the lacerated left lower limb. High-volume continuous haemodiafiltration because of hyperpyrexia was used, after the exarticulation in the left knee-joint. An excessive proteolysis (urea loss more than 1000 mmol/day) persisted 1.5 months, with energy expenditure over 2600 kcal/day. The patient underwent multiple surgical interventions. Metabolic support using combined parenteral and enteral nutrition was performed during the first month, enteral nutrition combined with food were consequently given for more than 3 months. The patient was hospitalised until April 26, 2010. These types of traumas are fully comparable with military battlefield environment injuries. Principles of war surgery (life and limb saving, damage control surgery) should be applied also in civilian environment, particularly in disaster situations.

Key words: Blast injury; combination of mechanical trauma and burns; field surgery, triage; interdisciplinary approach; nutritional support; mycotic (Aspergillus) infection

✉ University of Defence, Faculty of Military Health Sciences, Chair of Field Surgery, Třebešská 1575, 500 01 Hradec Králové, Czech Republic
klein@fnhk.cz
+420 495834959
+420 495832026

INTRODUCTION

Blast injury is one of the most important sources of casualties in military combat operations and, at the same time, a typical clinical syndrome of field surgery within the area of military medicine. The spectrum of blast injuries and their con-

sequences is very broad. In today´s world, however, not only military environment deals with this considerable multi-disciplinary problem. Expansion of terrorist attacks worldwide, industrial and other man-made disasters may cause, among others, blast injuries with all their clinical aspects. In this report we refer about a case of combination of mechanical and burns injuries in a young healthy man, as a consequence of the disastrous explosion within the civilian rural industrial setting.

CASE REPORT

On Monday, January 4, 2010 (the very first working day of the year) at 05.30 hours, a massive explosion in an industrial company, located in a mountain village occurred. A few of giant steam containers, as well as the steam pipeline-system exploded due to technical winter-time-related problems, after Christmas and New Year holidays. Victims of this limited industrial disaster (due to time-coincidence and other positive circumstances only few people were present before regular working hours at 06,00 and 07,00 started) were as follows: 1 dead on the spot, 1 dead after transportation to hospital, 3 severely injured (polytrauma), 13 minor injuries.

Figure 1. View on the factory damaged area.

Within 16 minutes after the explosion report, the first ambulances of the Emergency Medical Service arrived. Triage of all injured was performed and first aid at the spot was rendered. Three severely injured persons were transported to the three nearest local hospitals within the region, 13 persons with minor injuries were given the primary care in place, and subsequently checked within the 3 local hospitals (outpatient departments), none of them had to be hospitalised.

The Patient´s History

A 43-year-old healthy man with negative medical history, worker in the factory, 88 kg, 180 cm, BMI 27.8, suffered multiple mechanical trauma and burns injury – scalds from the hot water-steam - in the moment of the explosion and subsequent damage of factory buildings. He was evacuated from the wreckage and rendered first aid by medical staff of the Emergency Medical Service (EMS). He was "labelled" Priority 1 and transported by the ambulance of the EMS to the local hospital 16 kilometers from the injury site.

Treatment

Prior to the Admission to the Trauma Centre

Clinical examination and basic diagnostic procedures including X-rays and sonography were performed. The volume resuscitation started after the right subclavian vein cannulation, drainage of the right hemithorax and covering of burned areas were performed. Left lower extremity was immobilised within a vacuum splint. The patient was intubated, artificially ventilated and then transferred by helicopter to our hospital (Emergency Department). The patient was admitted to our hospital at 08.30 hours, 3 hours after the injury.

Urgent Surgical Procedures

During the admission procedure, the leading diagnoses were: haemorrhagic – traumatic and burns shock, haemoperitoneum from the lacerated spleen, right-sided pneumothorax, subtotal amputation of the left distal crus/feet, 2nd degree burns covering 40 % of the TBSA (Total Body Surface Area), craniotrauma with brain commotion and subgaleal haematoma, right calcaneus fracture, multiple open soft tissue wounds.

Figure 2. Open left distal tibial fracture with bone loss and tibialis anterior artery disruption.

At 09.00 hours, the patient was in the operating theatre. Because of the spleen laceration (haemoperitoneum) splenectomy was performed. During the same surgery, reduction and external fixation of the left lower limb was done to stabilise segmental open tibial fracture. Debridement of soft tissue wounds was done, including extraction of one totally free fragment of the left tibia. Vascular surgeon revised the disruption of the left tibialis anterior artery, and after thrombectomy by Fogarthy catheter was done, he performed vascular end-to-end anastomosis. Burned areas (scalds caused by hot steam) were washed, cleaned and covered with tull-gras and gauze with iodisol 10% solution. The patient was at 11.00 hours, after two-hour-procedure, admitted to the ICU. All complex monitoring and care, artificial ventilation and fluid resuscitation continued. The patient was unstable and because of haemorrhagic secretion from the drain of the abdominal cavity (sign of continual bleeding) at 13.00 hours, the surgical revision of the abdomen was needed. The source of bleeding was found within the pancreatic cauda area and the bleeding was stopped surgically by pericenthesis.

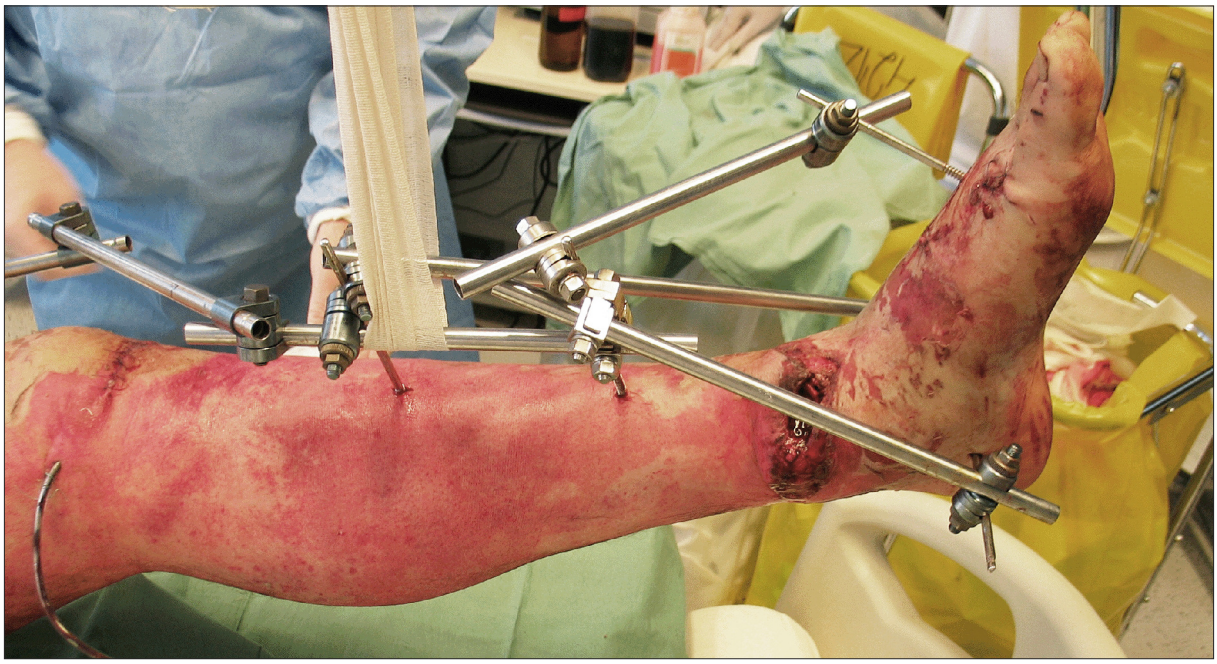

Figure. 3. Fixateur externe in scalded crus over the open fracture.

Another Surgical Procedures

Beside the almost daily dressing-changes on burned areas, the patient was operated on for additional injuries. On January 7, the minimal invasive osteosynthesis (MIO) of the right calcaneus fracture by closed reduction using a lag screw and Kirschner wires was performed. On January 8, the double level MIO of the left crus using lag screws and Kirschner wires was done. Repeated surgical debridement of the wounds was performed. Because of deterioration of the local status within the wound on the left crus and consequent general status aggravation, on January 14, (day 10 after the injury) the exarticulation in the left knee-joint-level had to be performed in order to solve this life-threatening complication. The cause of it was the presence of *Aspergillus fumigatus* infection within the wound. Superficial dermal burns healed spontaneously very well under the temporary skin substitute Askina Derm® and Askina Thinsite®. Full thickness burns appeared due to conversion on the upper right arm, axilla and right thorax wall region. On January 27 and 29, necrectomies of full thickness burns of the right upper arm, axilla, right thorax wall region and multiple necrotic skin focuses on the dorsal part of the right crus and on the stump of the left thigh were performed. On February 10, skin autotransplantation by 1:3 meshed grafts was performed. The grafts healed-in well within 10-12 days.

Figure. 4. Burns of the dorsal parts covered by temporary skin substitutes.

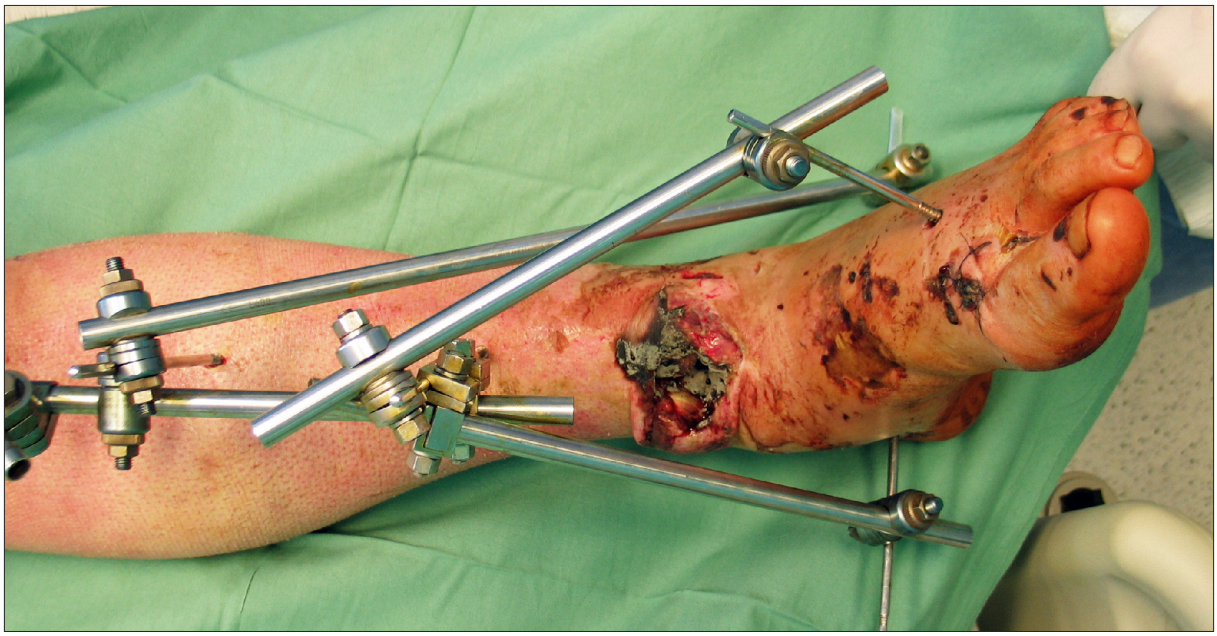

Figure. 5. Appearance of the local *Aspergillus fumigatus* infection.

Intensive Care Therapy

Fluid Resuscitation, Shock Therapy

The aim of the resuscitation phase after urgent abdominal operation was to achieve haemodynamic stabilization. Fluid resuscitation was performed dominantly by crystalloids in combination with starch solution, plasma and erythrocyte transfusions. Norepinephrin was dropped off within 10 hours, in spite of the tolerated severe positive fluid accumulation in the body. The positive fluid balance achieved during the 1st day was 22 litres, the 2nd day 10 litres and the 3rd day 9 litres. Maximal level of blood lactate was 7 mmol/litre and normalisation of the level was achieved within 24 hours after admission. The blood level of albumin on the 3rd day was 15 g/l dominantly due to enlargement of distributive space after reperfusion.

The early parenteral nutrition started the 2nd day already (150 g of glucose, 50 g of lipids and 140 g of aminoacids) and gastric stimulation by low-dose enteral feeding was also added. The first choice antibiotic therapy started by piperacilin + tazobactam administration. The parameters of arteficial ventilation in the pressure control regime (BIPAP) were set up as follows: PEEP 10, PIP up to 35. The body core temperature at the end of the acute abdominal surgery was 34.0 degree Celsius. During the first three days, it was difficult to keep normothermy without shewering. Room temperature had to be enhanced up to 29 degree Celsius by using additional sources of heating.

Second Hit Therapy

On the 10th day after admission, the second hit appeared in a form of septic shock. Acceptable haemodynamic stability was achieved within the following 8 hours, after correction of hyperpyrexia 42.8 degree Celsius by high volume CRRT (Continual Renal Replacement Therapy). Correction of oxygenation, which was worsening due to ARDS (Acute Respiratory Distress Syndrome), was achieved by enhancing ventilation parameters (PEEP 16, PIP 39, FiO2 0.6). Microscopic analysis of avital (necrotic) tissue sample from the wound of the left lower crus confirmed *Aspergillus fibres*. The low blood level of galaktomanan, however, has not confirmed the presence of systemic mycosis. *Serratia* species in blood culture was cultivated two days later. The wound over the distal tibia fracture itself was considered to be a source of the severe septic shock. In spite of successful first vascular reconstruction of tibialis anterior artery in that region during the emergency procedures, the appearance of a relatively small skin defect led us to the decision to perform amputation (exarticulation) in the left knee joint level with leaving the stump open. The next development of the general health status confirmed this decision was correct. An ischemic stroke in the right carotis interna artery region was a consequence of the mentioned severe septic shock. Sequelae of this ischemia, verifyed by the CT scan (malatia) were, however, minimalised by an intensive, prolonged physical therapy. This was confirmed during the follow-up examination after one year post injury. Systemic antimycotic therapy (voriconasol) was applied for 10 days. The local by *Aspergillus contaminated* small skin areas were debrided surgically during the following days. The patient was weaned from the ventilator on the 31st day and 2 weeks later, the tracheostomy cannula was extracted.

Metabolic Support and Nutrition

The predominantly parenteral nutrition with combination of gastric feeding was performed during the first month, after the starter-regime used from the 5th day. This nutrition contained 160 g of aminoacids, 300 g of glucose and 100 g of fat enriched with omega-3 fatty acids. The significant meal intake was from the 30th day, but the enteral feeding by fine nasojejunal tube continued up to the next 90 days. The measurement of energy expenditure was performed by using indirect calorimetry several times, starting from the 33rd day. The REE (Resting Energy Expenditure) up to 2700 kcal/day continued for more than two months – till the 68th day (Table 1).

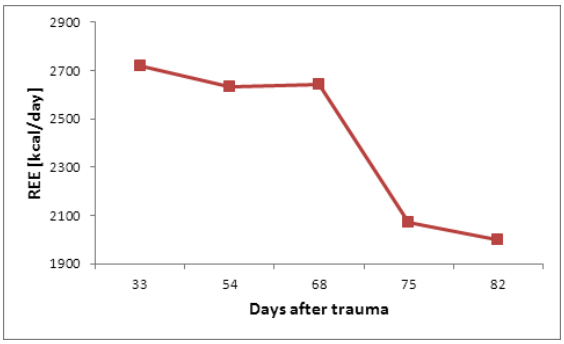

Table 1. Resting Energy Expenditure development.

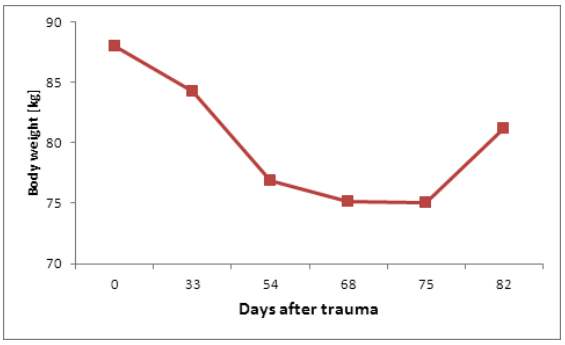

Table 2. Changes of the body weight.

The body weight changes are documented graphically in Table 2. The urine nitrogen output persisted in higher values up to 3 months. The values were in correlation with protein catabolism about 180 g of aminoacids per day. Because of presence of the prolonged catabolic status, the beta blocker drug was administered from the 3rd month (metoprolol 50 mg/day).

Therapeutic Results

After almost four months of hospitalization, this critically injured patient was transferred to a specialized rehabilitation centre to continue in occupational and physical therapy, which had already started at our department. This is a standard part of the complex and continuous care in such combined injuries. All burned areas, including grafted ones and the left femur stump, healed well; the patient started to gain his body weight. The 80th day after injury he achieved 82 kilograms (original weight was 88 kg). As sequelae of the injury and its treatment, only sensomotoric neuromyopathy of critically ill without lateralization persisted. But there was obvious clear progressive tendency towards improvement. One year after the injury, the patient started verticalization using the left crus prosthesis, as we could see during his follow-up visit. Psychologically, he was in a very good condition, thanks to the psychological support of all medical personnel, and his family members especially.

Figure. 6. Dermal burns of the trunk healed.

Figure 7. Left femur stump healed after skin grafting.

DISCUSSION

Severely injured patients with monotrauma, multiple mechanical trauma and/or polytrauma of most different kind represent a routine influx of patients to our level I Trauma Centre serving for population of almost 1 million. The same clinical case in combination with burns injury, however, is quite rare pattern of injury in our conditions [6]. Blast injuries have been mostly related to warfare traumatology in military medicine. Industrial disasters, large traffic catastrophes etc. can be situations, causing many of these injuries. Not to speak about worldwide spreading terrorism, which became a part of the reality of the modern world [1] increasingly. Recently, blast injuries represent a multidimensional problem in both military and civilian practice. In our presented case, we demonstrate possible similarities from both mentioned sites. The mechanism of injury was an industrial explosion causing thermic and mechanical polytrauma. The wet environment caused by hot steam presence after explosion, together with massive debris contamination of wounds could have been a direct cause of subsequently developed mycotic infection by *Aspergillus fumigatus*. An open bone segmental fracture with artery disruption was the main cause of tissue ischemia. These all appeared in burned area. Lower extremities have been reported predominantly to be injured by military blast injuries, particularly due to explosions caused by AV (anti-vehicular mines) and/or IED (Improvised Explosive Device) [14]. Detonations occurring under the vehicle transmit high amplitude and short duration axial loads onto the foot-ankle-tibia region of the occupant causing injuries to the lower leg [8]. Our patient suffered almost identical injury, moreover segmental within two levels. Some protective measures have been introduced within the military. The use of body armor e.g. is allowing soldiers to survive blasts that would otherwise be fatal due to systemic damage [5]. Our patient (without any body protection) suffered head contusion, thorax contusion with pneumothorax on the right side, spleen laceration followed by haemoperitoneum which was an urgent indication for surgery. Because this patient was only one at the certain period of the day, and all specialists were available, maximal treatment was given (particularly artery anastomosis in distal tibial part after thrombectomy from both ends by Fogarthy catheter, after the fixateurs externe had been placed (in burned area). In military field conditions, this situation would be solved most probably by bellow knee amputation. The same would with high probability happen in civilian hospital under mass casualty situation [8]. Our decision was modified by availability of all personal, material and technical resources. Some authors refer about this kind of decision. The decision of whether to salvage or proceed with limb amputation is one of the most difficult in orthopaedic trauma [7]. There is general agreement in accepted rule for following wound management. Timely wound debridement and excision of contaminated or avascular tissue, along with prevention of sepsis, are crucial to managing extremity injury. In our patient the wound debridement was done repeatedly, including removal of avascular bone fragments, the systemic support at the ICU in a complex way was rendered. But still the *Aspergillus fumigatus* infection within the most critical wound appeared, on the 9th day post injury. The septic shock with hyperpyrexia, ARDS, required a radical decision which was made. The exarticulation in the knee level of the left lower extremity had to be done, as a life-saving procedure. In our conditions, infection caused by *Aspergillus* has been extremely rare. In recent publications one can find recommendations of substantial surgical debridement or amputations associated with aggressive antifungal therapy [9]. Early, repeated and

systematic mycological wound samples to guide and adapt surgical and antifungal management in these filamentous fungal infections, is also recommended [2,3,13]. An extricable part of the complex management of blast and other combined injuries is, beside fluid early replacement and aggressive resuscitation, the metabolic care [11,12]. Polytraumas and burn injuries are well known for their hypermetabolic status (their catabolic effect leading up to the "autocanibalism" state) [4,10]. However, the intensity and persistence of such an excessive protein catabolism in our patient we did not expect. Although the metabolic care in combination of parenteral and enteral nutrition was performed very carefully, the positive energy balance was achieved after 3 months post injury only, when metoprolol with the goal of decreasing the protein catabolism, was administered. The registered body weight change was influenced by intersticial fluid transfer substantially. This was due to its temporary accumulation, influenced by increased capillary permeability during sepsis and SIRS, and furthermore by the loss of the extremity. In spite of it, the patient loss about 10 kilograms of his body weight within three months period of time.

CONCLUSION

The treatment of this patient may serve as a unique example of great challenge in many aspects of work within our Department of Surgery (Level I Trauma Centre).

We considered it as the best "test" of our interdisciplinary team approach (traumatologists, intensivists, burn surgeons etc.) and, at the same time, its co-ordination and co-operation. Many specialists participated in the complex therapy. Even more so, because this type of multiple combined (blast) injuries are in civilian environment quite rare (less than 5 % of all burns injuries). The role and importance of nursing care, including physical therapists´ activities is extremely important as well.

At our Department, traditionally, the academic and clinical civilian and military medical personnel work together. This case, originally from the civilian industrial explosion, served as an example of possible pattern of "military" environment type of injury; predominantly from the point of view of the mechanism of injury and other circumstances – prehospital aid, transportation, massive contamination of wounds etc.

Also in these "civilian" injuries and hospitals, the principles of "war surgery" can and should be applied, in order to achieve the best possible results, with regard to morbidity and lethality, particularly under the mass casualty situations.

ACKNOWLEDGEMENTS

This work was supported by Ministry of Defence, Czech Republic, the Research Project MO0FVZ0000503.

The authors wish to thank to 1LT Ondřej Malý, MD., for technical assistance in preparations of the manuscript.

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