Emerging Technological Advances in tactical Casualty Care

Technical Evaluation Report

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ABSTRACT

We have gained a vast amount of knowledge from the operations of the last decade. Although the development of body armour dramatically has reduced the injuries to the torso, improvements in casualty care management has contributed to the reduction in fatalities. In a military setting, extremity injuries now dominate. The Survival from battlefield injury has increased to 90%. The majority of deaths occur before reaching a medical treatment facility. In accordance, most of the research and new technologies address the acute management of the casualties.

As the most important timeline for survival is the time elapsing from injury to surgery, thus most research aims at closing this gap. To effectively close the gap three strategies need to be implemented:

1. Accurate diagnostics to identify the patients most at risk and make adequate triage for transport and treatment. Several new tools are promising.

2. Delay deterioration of the patient's vital functions by optimal emergency care. Both transfusion practice, drug modulation of the inflammatory response and physiological measures are being explored

3. Reduce the time between injury and damage control surgery by logistic measures. This can be achieved by improving evacuation or moving damage control surgery forward.

There is an urgent need for standardized training of all staff managing casualties all the way from soldiers' pre deployment, to the medical staff handling the damage control resuscitation, to the surgeons. Trauma surgery requires a broad set of skills that are not learned in the civilian hospitals today. Standardized courses need to be mandatory for all surgeons prior to working in a medical treatment facility.

The title "Emerging Technological Advances in tactical Casualty Care"

Keywords:

War casualty management, haemorrhage management, damage control surgery, damage control resuscitation

INTRODUCTION

The aim of tactical casualty care is to provide continuous care from the point of injury to return to active duty or home. The international operations by NATO forces during the last two decades have provided new knowledge leading to improved soldier protection and improved management of the injured from the point of care to surgery. Several factors have contributed to this knowledge, but there is little doubt that the use of registries in systematic information gathering plays a major role, particularly the US Joint theatre Trauma registry and eventually the UK registry.

The expected standard of care in NATO is defined in the allied joint medical support doctrine of 1999: "Medical support to NATO forces must meet standards acceptable to all participating nations. Even in crisis or conflict, the aim is to provide a standard of medical care as close as possible to prevailing peacetime national medical standards, given the difficulties of doing so in an operational setting."

The algorithm for care of the traumatized patient implies the following prioritization:

- Measures to avoid acute or immediate death;
- Measures to avoid late death;
- Measures to minimize sequelae;
- Measures to optimize function.

All experience confirms that the main factor for survival after injury is the time elapsing before damage control Surgery. It is also well documented that adequate first aid may expand the timeline.

Thus the Comeds in 2012 issued the following doctrine on the timeline for life and limb salvage:

Enhanced First Aid

Immediate life saving measures applied by personnel trained in tactical combat casualty care. Bleeding and airway control for severely injured casualties to be achieved within 10 minutes of wounding.

Damage Control Resuscitation

Measures commenced by emergency medical personnel within 1 hour of wounding.

Damage Control Surgery

Depending on the specific and individual requirement , damage control surgery within 1 hour, but no later than 2 hours of wounding.

As the most important timeline for survival is the time elapsing from injury to surgery, thus most research aims at closing this gap. To effectively close the gap three strategies need to be implemented:

- Accurate diagnostics to identify the patients most at risk and make adequate triage for transport and treatment;
- Delay deterioration of the patient's vital functions by optimal emergency care;
- Reduce the time between injury and damage control surgery by logistic measures.

The symposium focused mainly on these three strategies for acute survival and to a lesser degree on complications and late deaths and sequelae. This included technologies and systems that may enhance first

aid, improve damage control resuscitation, improve evacuation and facilitate damage control surgery. Based on lessons learned there is an urgent need for more systematic gathering of information and training at all levels of the evacuation chain. Particularly as more technologies are available for optimizing treatment. All new technologies require dedicated user skills.

Thus the comments of the symposium follow the following content:

- Acute management;
- Late death and sequelae management;
- Lessons learned from recent scenarios;
- The need for training, coordination and information;
- Recommendations and conclusions.

1.0 ACUTE MANAGEMENT

In the Key note "Paradigm Shift in the Preparation for Deployment" Dr. Sylvain Ausset presented a global decrease in Case fatality rate (CFR), indicating an improvement of care and soldier protection. At the same time there is an increase in died of wound, indicating that more patients receive medical care before dying. Since 9/10 deaths occur before reaching the first medical treatment facility (MTF) improving the effectiveness of far forward casualty care is necessary to continue lowering the casualty fatality rate. The research axis should concentrate on hemorrhage control as the majority of the survivable patients die from hemorrhage. Secondly, it is necessary to increase the quality of care at all levels of the medical evacuation chain. To achieve this comprehensive system of Remote Damage control resuscitation including transfusion medicine and efficient team work is needed along with pre-deployment training of all soldiers is mandatory.

1.1 Accurate Diagnostics to Identify the Patients Most at Risk

Damage control resuscitation implies far forward identification of those casualties at risk of dying and effective targeted treatment. Five authors addressed the challenge of recognizing the degree of urgency when handling a severely injured patient. Young people have a formidable compensatory reserve that may disguise serious hypovolemia.

1.1.1 Haemodymanic Monitoring

The baroreflex cause vasoconstriction that may maintain blood pressure in a severely hypovolemic patient on the expense of blood flow to vital organs. Kirkman pointed out that there *may be considerable variation between individuals in the degree of vasoconstriction initiated by the response to haemorrhage, so that a patient with a higher blood pressure may have less blood flow to vital organs because of enhanced vasoconstriction. The main problem with using blood pressure as the sole assessment of cardiovascular status is that it does not reflect blood flow in a patient. Measuring Base excess or Lactate give good indication of tissue ischemia, but require blood sampling. Assessing flow, or oxygen delivery, to organs would represent a major advance in the assessment of casualties. However simple technologies to quickly assess the severity of hypovolemia and bleeding are lacking. Near infra-red spectroscopy (NIRS), may be adapted to a pre-hospital setting. Preliminary results suggest that non-invasive assessment of tissue oxygenation in skeletal muscle with NIRS can phase lead more established measures of shock (such as base deficit and blood lactate) by up to 30 min and has the advantage of providing a continuous measure without the need to sample blood.(3)*

Convertino and co-workers addressed the same challenge and presented a method to measure the individual's reserve to compensate for reduced circulating blood volume by measuring changes in the

features of the arterial waveform. The non-invasive technology called the compensatory reserve index (CRI) may prove to be a reliable tool for estimating the degree of hypovolemia (2)

1.1.2 Imaging as Decision Support

In a trauma care setting in the hospital FAST – a systematic ultrasonic imaging of the abdomen has become routine, however a 2 D ultrasound examination is very operator dependent and requires a skilled operator.

Three authors addressed the same 3 D solution PUDIS developed to meet the challenge of operator dependency. By moving the probe over the body a 3D scn is acquired. Enhanced ultrasound software is developed to detect accumulated blood within the characteristic body regions like Morrison's pouch. The system also has an option for telecommunication allowing decision support by remote analysis of the images. The staff of the role 2 facility may thus provide additional decision support to the medic performing the examination in the field. (8,9,10) This is an interesting approach that need further studies by third party users.

1.1.3 Decision Support

Elharar Bio-nexus Medical Platform is an End-To-End telemedicine solution, from point of injury, throughout the various evacuation phases, interfacing with all higher echelons all the way to the hospital. Bio-nexus based on a mobile environment (smartphones and tablets), for managing military & civilian medical events and crews including all other first responders entities. The system may record all information from the battlefield to the hospital and is an example of systems both for gathering information in the first phase and providing decision support to the first responders. There is little doubt that this type of systems will have to explored and implemented in the future. (18)

1. 2 Delay Deterioration of the Patient's Vital Functions

As most avoidable deaths are caused by bleeding, haemorrhage control is an essential part of Damage control resuscitation. The terminal stage of uncontrolled bleeding is often termed the triade of death which comprise the three elements: Coagulopathy, Hypothermia, Acidosis. Acidosis develops as the patient loose the oxygen transportation capacity by loss of red blood cells and reduction in cardiac output due to hypovolemia. Acidosis impairs the coagulation system. Hypothermia will occur when the patient lies still and is wet. Open wounds cause temperature loss due to evaporation. Loss of blood volume impairs the temperature regulation. Already at a core temperature of 36^{o} Centigrade, the coagulation is impaired. Coagulopathy may be triggered by the inflammatory response to tissue damage and tissue ischemia. Acidosis and temperature loss makes the coagulopathy worse.

Haemorrhage control and maintenance of optimal oxygen transport are thus fundamental elements to delay the development of the triade of death to increase the patients chance to reach to damage control surgery in time.

1.2.1 Haemodynamic Intervention

Hypovolemia will reduce the central venous pressure of the patient. The filling of the central veins, the so-called pre-load is fundamental for Cardiac output. Convertine and c workers presented their studies where they by introducing an inspiratory resistance in the patient's breathing mask; they achieved a negative intrathoracic pressure, leading to increased central venous filling in hypovolemic patients. In their studies cardiac output increased without any significant increase in blood pressure I. Some concern was expressed as to creating a respiratory resistance in patients with possible inadequate oxygen delivery. It is thus a trade-off between adequate circulation and adequate oxygenation. *This is an innovative therapy that leverages the body's own physiology by enhancing blood circulation, improving cardiac output and lowering intracranial pressure (ICP) noninvasively*. Clinical studies are needed (22)

1.2.3 Inflammatory Response Intervention

Three papers presented possible pharmacological modulation of the inflammatory response to injury and ischemia.

The complement system plays a key role both in the acute situations and in the development of ARDS and multiple organ failure. C1 inhibitor plays a regulatory role both in the Kallikrein Kinin, the fibrinolysis and the coagulation cascades in addition to being and important inhibitor of the classical pathway of complement activation. In an animal trial Dalle Luca and co-workers showed that administration of C1 inhibitor 30 minutes after start of uncontrolled bleeding increased survival. The animals receiving C1 inh and Lactated Ringer also had less bleeding. Studies in man in a clinical setting are needed to establish the clinical potential of this treatment.

Kao and co-workers presented another study targeting the inflammatory response in mice by c-peptide. Administration of c-peptide before red blood cells transfusion attenuated the haemorrhagic shock-induced increased gut permeability and bacteria translocation as well as circulating HMGB1 diminished the acute lung injury and pulmonary protein leakage. Compared to the sham mice, the mice with hemorrhagic shock incurred increased gut permeability and bacteria translocation to circulation; increased circulating HMGB1 and acute lung injury as indicated by increased lung MPO activity and pulmonary protein leakage. (4)

Watts presented the role of different transfusion strategies on haemorrhage and inflammation A one to one transfusion of packed red blood cells and plasma is performed in most bleeding patients in hospital. For prolonged evacuation times this regimen may be applied pre hospital. This is necessary to reduce the inflammatory response to prolonged hypotensive resuscitation. Approaches to Sustaining Critically Injured Casualties During Protracted Evacuation. She also discussed the potential for using haemoglobin based oxygen carrying solutions (HBOC) as an alternative to the use of packed red cells for pre-hospital resuscitation. Potentially beneficial effects of HBOCs have been identified, which are of significant interest since some of these solutions do not require refrigeration for transport, thus conferring significant logistical advantage. There is important preliminary evidence in the published literature to suggest that early (pre-hospital) administration of erythropoietin (EPO) or pre-treatment with statins could attenuate the inflammatory response and secondary organ damage, which in turn would reduce patient morbidity and time required in resource intensive facilities such as intensive care and/or extends the window for effective pre-hospital resuscitation. This interesting topic needs further studies. (15)

1.2.3 Devices for Haemorrhage Control

Blin presented a new hemostatic device consisting of a depression chamber and a central pillar, both made of silicone and attached to a vacuum suction. By establishing a negative pressure in the chamber, a strong compression of the wound was achieved. The device was tested in patients combining it with hemostatic gauze. This may be an interesting device for achieving bleeding control in injuries to the great vessels the heart and parenchymal organs.(21)

Dubick gave an overview of ongoing research on the vast number of devices now available of haemorrhage control:

- Haemostatic dressings. There are several products on the marked;
- Limb Tourniquets There are several models, but high failure rate;
- Tourniquets for junctional wounds has been a problem new devices are promising;
- iTC clamp;
- Tamponade sponges these are systems to be applied inside the wound;

- Chitosan spray promising;
- Air wrap promising;
- Ultra Clot Plug promising in animal trials;
- Rescue foam under research in intracavital bleeding animals.

Dubick emphasised that training is required for proper use of all devices (23)

Sheppard presented a study on the effect of Infusible Platelet-Derived Hemostatic Agents (hPDHA) on Severe Intra-Abdominal Hemorrhage with in a Non-Human Primate (Macaca Mulatta) Model. Theoretically this may be a way to go, but unfortunately they found no significant reduction in blood loss in the animals receiving hPDHA compared to controls. There were no thrombotic or coagulation adverse events. Further studies are required to establish the relevance of this treatment. (24)

1.2.4 Anaesthesia and Analgesia

So far there are no really effective analgesics available for use by the first responder. At the treatment facilities, morphine is the most used analgesic. Ritter presented studies on the effect of sublingually administered Fentanyl. Fentanyl applied sublingually is rapidly absorbed and give excellent pain killing effect. Sublingual Fentanyl could safely be administered by soldiers in the field. However, it is a narcotic drug and may be abused. Further studies are needed to see the practical use of this approach (12)

Gibbons further emphasized the limitations of Morphin and pointed out that 85% of wounded still experience pain after Morphine. 61% of the injured in operation enduring freedom did not receive analgesia. Fentanyl and Ketamine need to be considered as alternatives to Morphine. Ketamine cause hallucinations and need to be combined with other drugs. Morfin is still the most used analgesic drug, but intramuscular low dose ketamine has better hemodynamic effect and excellent pain relief. (13)

General anesthesia is a dynamic balance between hypnosis, analgesia and muscle relaxation. Currently, several prototypes for the automated titration of propofol are available. Automation is achieved by monitoring the cortical activity combined with automated infusion pumps. Further studies are needed to see if this is a way to go in damage control resuscitation. At the moment these systems need to be tested in a controlled surgical environment. (14)

1.3 Reduce the Time between Injury and Damage Control Surgery

Most of current military operations engage Special Forces. Intelligence from human is indispensable to guide airstrike. These operations run in an austere environment with isolation of forces and are highly dangerous. Jault presented the experiences with a far forward surgical team consisting of 4 persons equipped with ultrasound and a minilab and facilities to perform damage control surgery. They managed to perform damage control surgery far forward to on average 1.7 hrs from injury. But they had limited equipment and needed to be evacuated after a few hours, thus the capacity was 1-3 wounded before evacuation. Cost effectiveness study for this approach is needed and there are unsolved security issues. (16)

NATO MILMED COE has developed the NATO Patient Evacuation Course aiming to provide knowledge and exercise skills required to effectively work in a patient evacuation coordination cel and to enable participants to achieve situational awareness in a multinational operational environment. The course is NATO accredited (NATO Selected) since it is fulfilling a gap on the medical related training field. The organization of an effective evacuation is can be divided in Medevac,(planned with medical personnel), Casevac, unplanned no medical personnel, Stratevac (evacuation to final care often at home). The Patient evacuation Coordination Cell (PECC) manages the evacuation by Coordinating requests, Coordinating with all players internal, Coordinate with all players external, Keeping everybody aware and updated and tracking

the patient during evacuation. PECC is thus an important factor for the rapid evacuation to damage control surgery. (20)

2.0 AVOIDING LATE DEATH AND SEQUELAE MANAGEMENT

Infection

During the wars in Iraq and Afghanistan, one of the emergent signature injuries was polytrauma to the extremities as a result of exposure to blast. These wounds are complex. More than 80% are open consisting of penetrating soft tissue wounds as well as concomitant open fractures. Pre-hospital delivery of lifesaving interventions have resulted in unprecedented survival levels in combat casualties from these wars. This success in reducing mortality has resulted in challenges in morbidity for those that suffer extremity wounds. The extensive wounds may set the stage for complications due to wound infection. Tyner pointed out that 53 % of the wounds are penetrating, often severe, and contaminated. Antibiotics at point of injury minimize infection as the primary contamination is caused by the patient's normal bacterial flora. This contamination paves the way for secondary infection. In addition to antibiotic treatment, mechanical cleansing of the wound by Pulse lavage (low pressure) reduce amount of bacteria. After primary wound care, negative pressure wound therapy reduces contamination. Results are promising with negative pressure wound therapy combined with local antibiotics in sponge. This reduces the formation of biofilm. Biofilm formation caused by gram positive bacteria complicates treatment. New therapeutics for biofilm disruption were presented. Rapid medical evacuation is important for infection control. Further research is necessary to understand biofilm formation and how to manage.(26)

Prosthesis

Over 2000 United States war fighters have sustained severe limb loss in the conflicts in Iraq and Afghanistan. Although socket suspension of artificial limbs is successful in many situations of single limb loss or in patients with long residual limbs, socket fitting for the patient with high transfemoral and transhumeral amputations and multiple limb loss is neither commonly successful nor practical. Many remain wheelchair bound. The direct skeletal attachment of prosthetic limbs may obviate many of the problems associated with socket suspension in these patients. Several osseointegrated prosthesis systems have been tried before without major success. Bloebao presented a new system that may provide a better option to amputees. (27)

Urogenital injuries

Orman presented a study based on information in the Joint Theatre Trauma Registry, and comprised 1291 males and 16 females with urogenital injuries. They found a high prevalence of comorbid injuries particularly with h lower limb injury and amputation 77.8% had serious amputation (at or above knee).The study had led development of protective devices like pelvic under and over garment. These garment reduce the risk of GU injury by 25-44%

Apart from giving important information on genitourethral injuries the paper demonstrated the importance of possible use of a trauma registry. (28)

3.0 LESSONS LEARNED FROM RECENT SCENARIOS

Ethics

In the military medical setting with limited resources, the personnel can be confronted with complex medical decisions with ethical consequences. Particularly as all military facilities also treat civilians. Pouliquen gave

several examples on such issues. For example intensive care treatment of children with congenital disease where we have no possibility to follow up. He also pointed out the complete different scenario of being in a civilian hospital receiving injuries occasionally and a military \facility where trauma care is the main purpose. 19

Role 3

Barbier presented the experience at the or Role 3 Hospital at IA (Kabul International Airport) 2009-2013 when France had the responsibility

Forty-three per cent (n = 1875) of 4318 procedures involved orthopaedic surgery. Half of these were emergencies. Many were combined with other injuries. French military personnel represented 17% of the patients, local civilians 47% and children 17%. Half of the procedures involved the soft tissues, 20% were for bone fixation and 10% for surgery of the hand. The rate of amputation was 6%. The diversity of the surgical acts was high ranging from emergency surgery to surgical reconstruction. The hospital treated also civilians. 1/5 of the patients were children. The diversity of surgical acts confirms the challenge of training military orthopaedic surgeons within the context of the hyper specialization of the civilian sector. Specific training has been organized in France by the École du Val de Grâce. Specific continuing education is also necessary. (29)

Open Fractures

Extremity injuries associated with natural disasters and combat are typically high-energy, often open injuries, and routinely represent only part of the scope of injury to a poly-traumatized patient. The principles and techniques of damage control orthopaedics and external fixation in the management of extremity trauma in the setting of combat- and natural disaster-related injuries was reviewed by Pasquier and co-workers They aimed at sequential treatment with Damage control consisting of haemorrhage control, Vascular injury repair and external fixation. Debridement was the most common procedure and external fixator application, delayed primary closure and flap coverage were used. (30)

Forward Surgical Team

Part of the operation Sangaris begun in December 2013 in the Central African Republic, the 14th Parachutist Forward Surgical Team was deployed to support French troops. Malgras presented the forward surgical team (FST, role 2 in the NATO classification) is a mobile surgical-medical treatment facility. During the first trimester of the operation Sangaris, 42 patients were treated at FST, of whom 29 underwent surgery. Almost 50% of patients operated on were French servicemen. All admissions were emergency admissions. Orthopaedic surgery represented two-thirds of surgical interventions executed, as a result of the high proportion of limb injuries. Fifty percent of injuries were specifically linked to combat. Surgery in a FST is primarily dedicated to the treatment of combat casualties with haemorrhagic injuries, but additionally plays a part in supporting general medical care of French troops. The facility provided Medical aid to the general civilian population because of the lack of civilian medical treatment facilities, even in the initial implementation of the military operation. (32)

ISAF

Under the lead of NATO MILMED COE. End of Oct 2014 the first ISAF Medical Support Lessons Identified /Lessons Learned workshop was held in Budapest, Hungary. The workshops gathered subject matter experts from across the alliance. The director of the Milmede coe Dr Stefan Kowits summed the most important lessons gathered from the workshops:

- Since Health Support Services have impacts on all levels of military missions, medical staff must be included during the preparation, including training and exercises, planning and execution of NATO

deployments and Medical Leadership must maintain a voice at all levels of NATO Command and Control;

- Continuous Improvement in Healthcare Support on Operations, combined with Evidence Based Medicine, can be better performed with the establishment of a NATO sponsored Case Registry entity;
- To ensure the best outcome for ill or injured service members, the continuous development and refinement of prehospital care standards and the analysis of patient transport (MEDEVAC) capabilities is critical;
- Continued emphasis on training deploying medical personnel and medical units;
- To ensure that Prehospital care achieves the same exceptional standards that hospital care has achieved, a formal Prehospital PI system needs to be developed and implemented;
- Prevention and Force Health Protection are basic capabilities and require a "Deployed Forces Health Protection Coordination Capability" as a technical and functional empowerment of a NCS;
- Commitment of the line commanders along with early identification and early treatment are the key to reduce the number of soldiers suffering mental health disorders. Using models presently employed by various Alliance members, we require a system of Embedded Behavioural/Mental Health Teams present during deployment, which are linked to care provided within the battalion and brigade of the home countries. (33)

4.0 THE NEED FOR TRAINING, COORDINATION AND INFORMATION

In her key note Shackleford addressed the problems of a compartmentalized medical system. The gap between in- and out-of-hospital care occurs because we train separately, we communicate only briefly at the time of handoff, and the pre-hospital providers rarely receive follow up on their care.

In order to bridge the gap, it is necessary to work together through improved communication, training, and data collection to define specific components of advanced trauma care that can be moved closer to the point of injury. It is necessary to train the participants the whole evacuation chain together. She also emphasised that the medical response must occur within the framework of the tactical mission. It is important to improve communication, training, and data collection to define specific components of advanced trauma care that can be moved closer to the point of injury.

Shakleford pointed out that most achievements to improve survival are low tech. The high rate of procedure failures caused both by lack of training and the technology itself. Technology needs to be integrated with medical and tactical training. (KN2)

Training First Responders

To increase effectiveness, early diagnostics and resuscitation must start at the point of injury. Thus there is a need for training both of the first responders and all the actors in the evacuation chain.

Márta Eszterbauer from the MILMED COE presented some of the lessons learned from operation Iraqi freedom and Enduring freedom. As the leading causes for preventable deaths are haemorrhage and tension pneumothorax, first responders must be able to manage these conditions to improve survival. MILMED COE established a course in 2011 for First Responder Trainers with the aim of contributing to the standardization of teaching skills of national instructors and sharing the latest developments in teaching attributes and interoperability in the area of enhanced first aid. There is a problem during international operations that the training varies between nations and there is a need for a common curriculum.

Pasquier presented a system to train all soldiers in adequate first aid before deployment. They developed a 3D computer game that was offered to all soldiers. The system is currently under evaluation. This is an interesting way to increase the skill of all the soldiers to perform the correct first aid that may be lifesaving. They are developing special systems for soldiers, medics nurses and doctors.(17)

Training Surgeons for Combat Care

Bowyer addressed the training of surgeons for treating casualties of war and disaster. Existing national surgical curricula fall short of ensuring exposure to or competence with a substantial number of the surgical skills required to care for injured casualties. The collective expertise gained from recent conflicts must be captured, codified, and utilized to ensure future acquisition and sustainment of vital readiness skills.

Existing predeployment courses for surgeons and their teams suffer from lack of standardization and do not ensure that completion translates into competent practice. Advances in surgical simulation and virtual reality technologies offer the potential to revolutionize how we train and assess competency prior to deployment. By collaborating with all NATO nations and gathering information on the lessons learned from the JTTR, the authors aim at developing a standardized international comprehensive, consensus driven, validated, adaptable, distributable, multi-media curriculum for surgical, team, and leadership training that leverages best in class educational concepts and tools. Such a curriculum will enable development of evaluation tools and metrics that align curriculum and assessment, allowing for high-stakes determination of skills readiness, durability and decay.

5.0 CONCLUSIONS AND RECOMMENDATIONS

We have gained a vast amount of knowledge from the operations of the last decade. Although the development of body armour dramatically has reduced the injuries to the torso, improvements in casualty care management has contributed to the reduction in fatalities. In a military setting, extremity injuries now dominate. The Survival from battlefield injury has increased to 90%. The majority of deaths occur before reaching a medical treatment facility. In accordance, most of the research and new technologies address the acute management of the casualties:

- Surprisingly, there were no papers addressing management of hypothermia in bleeding patients. There is a need to address this topic.
- There is a need for more accurate diagnostics to identify the patients most at risk. Several new technologies are promising. Development of 3D ultrasound for use by an unskilled user is an interesting approach.
- Management of the inflammatory response to trauma and counteracting the development of coagulopathy is interesting, but need further research to be a clinical option.
- One way of reducing the time from injury to damage control surgery is to move the surgical team far forward. There are however, both security logistic challenges associated with this approach. Thus, the cost-effectiveness of this strategy needs to be explored.
- Majority of deaths occur before reaching MTF. Tre is thus a need to put efforts into improving pre hospital care, including care given by first responders.
- Infection may become a greater challenge in the future as bacteria globally get more resistant to antibiotics. Research into alternative management of infection and biofilm formation is mandatory.
- In all reports from the medical facilities, a large proportion of the patients were civilian, many were children. This implies ethical and practical challenges that should be addressed further.

Main recommendations are:

- There is an urgent need for standardized training of all staff managing casualties all the way from soldiers' pre deployment, to the medical staff handling the damage control resuscitation, to the surgeons. Trauma surgery requires a broad set of skills that are not learned in the civilian hospitals today. Standardized courses need to be mandatory for all surgeons prior to working in a medical treatment facility.
- Several lessons learned presented at the meeting derive from the Joint theatre trauma registry. The implementation of a NATO trauma registry system that allows research of all casualties in international operations is mandatory to increase the scientific base for effective casualty management.

PAPERS REVIEWED FOR THE EVALUATION IN CHRONOLOGICAL ORDER

Acute Management

KN1. Ausset S. Paradigm Shift in the Preparation for Deployment.

3. Kirkman E. Targeting resuscitation in the critically-injured Casualties

2. Convertino VA. Accurate Decision Support for Combat Casualties with Hemorrhage: It's Not About Monitoring, It's About Physiology!

8. Weber PK, Stergiopoulos S. Portable 3D/4D Ultrasound Diagnostic Imaging System (PUDIS).

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18. Elharar S. The BIO Nexus Medical Platform: A Full Dynamic, Interactive, Hands-Free Mobile EMR.

22. Convertino VA. Intrathoracic Pressure Regulation for Combat Casualty Care

1. Dalle Luca JJ. C1 inhibitor with minimal fluid resuscitation shows survival benefit and reduced indices of inflammation in swine subjected to trauma and uncontrolled haemorrhage.

4. Kao RLC. The Beneficial Effects of C-Peptide in a Mouse Model of Hemorrhagic Shock and Resuscitation.

15. Watts S. Approaches to sustaining critically injured casualties during protracted evacuation.

21. Blin D. New Devices to Control Severe Hemorrhages in War Surgery.

23. Dubick MA. Recent Technological Advances in Hemorrhage Control for Improved Survival from Combat Wounds.

24. Sheppard F. Control of Severe Intra-Abdominal Hemorrhage with Infusible Platelet-Derived Hemostatic Agents in a Non-Human Primate (Macaca Mulatta) Model.

12. Ritter D. Nasal Or Sublingual Fentanyl Application: A Convincing Way For Battlefield Analgesia? Seeking alternatives to Ketamin, NSAID or Morphin.

13. Gibbons RV. Prehospital Pain Medication Use by U.S. Forces in Afghanistan.

4. Liu N. Closed-loop Anesthesia and Sedation Based on Neuromonitoring: An Overview of Clinical Studies.

16. Jault P. French Vital-Surgery Module: a New Tool for Surgery Everywhere at Any Time.

20. Kiss J. PECC Procedures: Patient Evacuation With and Without Manned Vehicles.

Late Death and Sequelae Management

26. Tyner SD. Reduction of Extremity War Injury Infection from Iraq and Afghanistan.

27. Bloebaum RD. Percutaneous Osseointegrated Prosthesis Attachment for Warfighter Amputees.

28. Orman JA. Epidemiology of Genitourinary Injury and Extremity Trauma in OEF/OIF.

Lessons Learned From Recent Scenarios

19. Pouliquen G. Ethical Reflexions for a Military Intensivist on War Theatres.

29. Barbier O. French Surgical Experience in the Role 3 Medical Treatment Facility of KaIA (Kabul International Ariport, Afghanistan): the Place of Orthopaedic Surgery.

30. Pasquier P. Treatment of Open Fractures in Austere Setting.

32. Malgras B. Initial Deployment of the 14th Parachutist Forward Surgical Team at the Beginning of the Operation Sangaris in Central African Republic.

33. Kowitz S. Results of ISAF Lessons Identified Learned.

The Need for Training, Coordination and Information

KN2. Shackelford S, Bridging the Gap Between In and Out of Hospital Care: the Role and Limitations of Technology.

11. Eszterbauer M. First responder trainer symposium at MILMED COE.

17. Pasquier P. A Serious Game for Sauvetage Au Combat Training.

31. Bowyer MW, Elster EA.Development of a Standardized International Comprehensive Advanced Surgical Readiness Training Curriculum for Combat Casualty Care.