Technical Evaluation Report

"Force Sustainment: Rehabilitation, Regeneration and Prosthetics for Re-Integration to Duty"

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ABSTRACT

The complexity and severity of injuries sustained by military personnel in current wars dictated the directions that military rehabilitation has taken over the last decade. The rehabilitation of the Operation Iraqi Freedom (OIF) and Operation Enduring Freedom (OEF) veterans presented a new and complicated set of challenges for allied nations health care providers. A large number of OIF and OEF soldiers returned home with amputations, spinal cord injuries, traumatic brain injury, and hearing and vision loss, among others, many of them causing lifelong impairments. The current symposium's presentations have been grouped into five sections: Novel Therapies (16%), Prosthetic Technologies (21%); Orthopedics and Related Research (23%); Rehabilitation and Reintegration (21%); and Auditory and Vestibular Rehabilitation (19%). By research topic, the presentations focused on technology-guided treatments (39%), rehabilitative utilization of virtual reality (22%), physical aids (17%), biological treatments (11%) and mental health (11%). The discussions have emphasized the ethical and moral obligation of health care providers to provide care beyond the traditional and thereby ensure optimal life-long function. This can be achieved with new technologies that are based on lessons learned from the past and focus on individual patient's need. Moreover, with changing dynamics of military engagements, a shift in military rehabilitation is needed: from an overwhelming focus on reconstructive/restorative rehabilitation moving toward pre-emptive and preventive rehabilitation paradigms that would decrease the soldiers' susceptibility toward injury/disease and increase their fitness and resilience.

1.0 PROGRAM SECTIONS

The presentations have been grouped into four sections: Novel Therapies (16%), Prosthetic Technologies (21%); Orthopedics and Related Research (23%); Rehabilitation and Reintegration (21%); and Auditory and Vestibular Rehabilitation (19%) (Figure 1).

1.1 Novel Therapies in Rehabilitation

Authors A. Fisher and L. Hebert demonstrated the advantages of virtual world and virtual reality (VR) technologies in rehabilitation. Fisher et al. presented the "Amputee Virtual Environment Support Space", which is being developed by the U.S. Telemedicine and Advanced Technology Research Center (TATRC) to provide a virtual support-environment for amputees with the main goal to facilitate peer support regardless of one's physical or geographic constraints. The authors discussed the benefits and limitations of this new technology, its capabilities and overall practicality for the delivery of care. Dr L. Hebert and his team used a different aspect of virtual reality technologies and demonstrated a proof of principle project for the development of a VR interactive avatar system. This system has a broad range of applications: from therapeutic purposes treating low-back pain and neurological deficits due to traumatic brain injury (TBI), among others, to optimizing the training and assessment in order to improve return to function of military personnel.

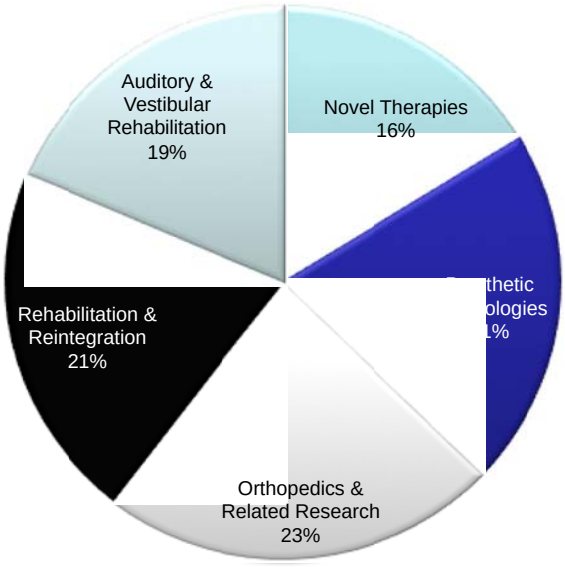

Figure 1. Distribution of the articles in the Symposium's sections.

Dr Thomas-Pohl's presentation highlighted the benefits of coupled fMRI and kinetic analysis of gait for accurate estimation of prosthetic gait, thus optimizing the rehabilitation of traumatic amputees. A broad range of novel therapeutic modalities including exoskeletal-assisted walking (A. Spungen), implementation of platelet- rich plasma and stem cells (V. Piccinni), and inhibition of reperfusion injury of microvascular tissue transplants (C. Villamaria & M. Davis) outlined potential technological solutions for treating devastating extremity injuries.

The so-called "invisible wounds" of traumatic brain injury (TBI) with or without co-morbidities such as post-traumatic stress disorder (PTSD), major depression disorder (MDD), and anxiety disorders are another hallmark of the recent wars [1]. Dr G. Somma discussed the issue of treatment, rehabilitation and reintegration to duty of returning veterans with mental health impairments while showing a case of an Italian soldier who developed delusional and hallucinatory symptoms after being seriously injured by the explosion of a mortar bomb in Afghanistan.

1.2 Prosthetic Technologies

This section provided a state-of-the-art overview of current approaches to the rehabilitation of amputees including the existing surgical techniques for limb salvaging or stump preparation (R. Stiegelmar, D. Rogez), designing prosthetic sockets (L. Darmon) and bionic prosthetics (F. Dochez & A. Mistral), and addressing the complications of the stump-prosthetics interface (H. Bisseriex). The need of physiologically reliable functional feedback was shown by several presentations (B. Schnall, I. Murphy, J. Ghannadian). The capabilities of new technologies in maximizing the function of prosthetics have been highlighted by the presentations of Dr E. Lemaire and Dr J. Hebert.

1.3 Orthopedics and Related Research

Military orthopaedics requires a broad range of skills and capabilities as compared to requirements in civilian population. The symposium's presentations reflected such needs, and the presented articles outlined the principles of damage-control orthopaedics (S. Brill, A. Suda, M. Liccardo), deformity prevention (Achatz, Houston) and defect management /correction (M. Laviano, Teyhen, Palm, Robitaille), among others.

1.4 Rehabilitation and Reintegration

Over the past decade, great advances have been made in the surgical treatment and rehabilitation of patients with combat-related injuries, which led to increased number of soldiers who were capable of returning to duty. New and improved technology contributed to better pain management and facilitated rehabilitation practices, and the increased social awareness resulted in the development of community reintegration programs. The symposium's presentations provided an excellent overview of the currently existing approaches to soldiers' recovery, rehabilitation, and reintegration and challenges they encounter during their back-to-duty process (S. Mailloux, Dr M. Besemann, Dr R. Cooper, Dr S. Messinger, Dr L. deKruijff, Dr K. Siddharthan, Dr G. Ponomarenko, Dr H. Riesner, Drs J. Facione & D. Rogez, and Dr F. von Luebken).

1.5 Auditory and Vestibular Rehabilitation

Hearing loss is one of the most frequent sequelae of military service. It develops as a consequence of repeated exposures to noise or blasts and may lead to decline in job performance, social isolation and depression. Also, hearing loss might aggravate combat-related TBI and its co-morbidities. Dr R. Jacob outlined the challenges the rehabilitation of hearing loss in military personnel represent today, specifically addressing blast-induced hearing loss as one of the long-term consequences of blast exposure. Dr D. Brungart and Dr D. Berg emphasized the dire need for an international consensus about auditory fitness for duty standards and hearing screening for soldiers. Vertigo, tinnitus, and postural instability are among most important consequences of hearing loss, and if untreated they can lead to a high security risk, especially in technical jobs (work with aircraft, explosive devices weapon systems etc). New technologies for treating/alleviating these neurological deficits have been presented by Drs A, Nert, R. Jacob, and A. Job. Hearing rehabilitation is possible in most cases; even in deafness hearing can be functionally restored. Dr A. Knoeffler provided an overview of currently existing hearing aids used by aircrew members.

2.0 RESEARCH DIRECTIONS

When analysed based on the research topics, the symposium's presentations can be grouped into five major groups: technology-guided treatments (39%), rehabilitative utilization of virtual reality (22%), physical aids (17%), biological treatments (11%) and mental health (11%) (Figure 2). This structure showed that the majority of the articles focused on defining the problems in military rehabilitation and describing the *status quo* (57%), 32% of the presentations demonstrated improved procedures with currently existing technologies, and 11% presented novel ideas that could lead to a paradigm shift in military rehabilitation (Figures 3a and 3b).

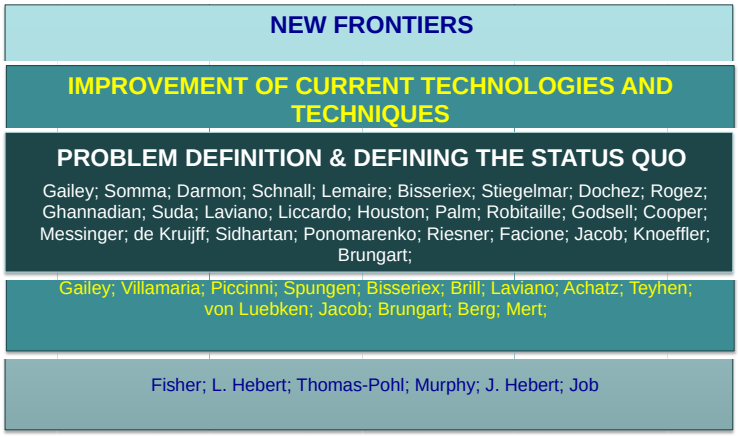

Figure 3a. Distribution of the presentations based on their research focus

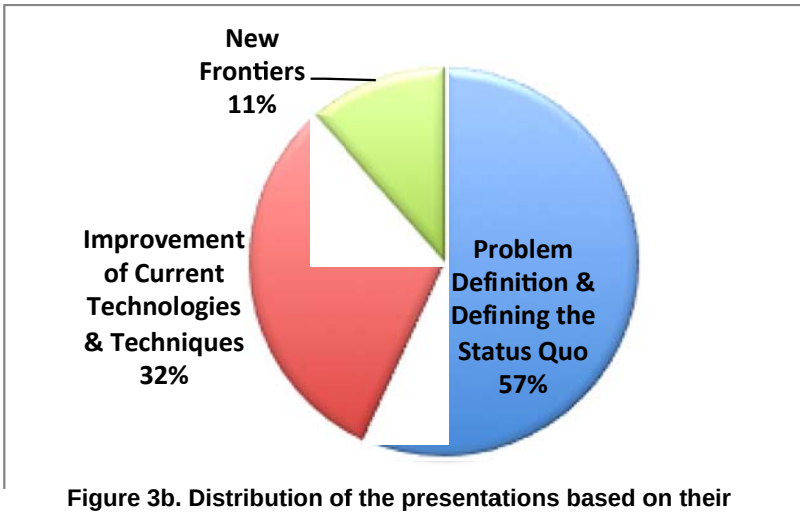

Figure 3b. Distribution of the presentations based on their research focus

3.0 FUTURE DEVELOPMENT OF MILITARY REHABILITATION

3.1 Factors Decisive for Future Development

The progressively increasing medical costs of the OIF / OEF could be explained by significant differences between the recent wars and previous conflicts [2]. Namely, many veterans survive injuries that would have killed them in past wars, due to improved properties of the interceptive body armour and enhanced capabilities of the medical evacuation and in-theatre medical care. Furthermore, the extensive use of the explosive weaponry including improvised explosive devices (IEDs) has caused complex injuries that involve multiple organs and organ systems (multiple amputations; brain injury; mental health impairments; auditory and visual deficits) that require decades of costly rehabilitation. If we project the current requirements for rehabilitation for the next 20 years, in 2033, today's veterans will be middle-aged, with health issues like those seen in aging Vietnam veterans, complicated by comorbidities of PTSD, TBI, and polytrauma [2].

The structure of the presented articles showed a heavy emphasis on reconstructive/restorative rehabilitation (Figure 4) of lower and upper extremity amputations caused mainly by secondary blast effects (i.e., shrapnel and/or particles generated by explosion and propelled by the released kinetic energy), but without addressing the systemic effects of blast or cranio-facial injuries that frequently occur parallel. As Capt. S. Mailloux underlined in his presentation about the requirements and limitations of rehabilitation the soldiers currently receive, “the mental aspect is usually what makes or breaks a soldier in rehabilitation, not the technical aspect”. However, none of the presentations showed combined rehabilitation approaches addressing both physical and psychological injuries.

3.2 Broadening the Scope of Restorative / Reconstructive Rehabilitation

Due to the complexity of injuries in military personnel, patient-focused, customized rehabilitative programs are needed that would take into account multi-system injuries and dysfunction amplified by mental health impairments. Elements of targeted physiotherapy should be combined with occupational therapy based on every individual patient’s needs, and the patient’s full engagement should be ensured.

Synthesizing the lessons learned from the past on rehabilitative techniques utilized for amputees, an internationally coordinated consensus should be developed that would guide the choice of surgical procedures, prosthetics, and functional training programs for soldiers with amputations. Furthermore, research programs on new materials, batteries with longer life, and accessories for prosthetics should be encouraged. Bearing in mind the progressively increasing utilization of implantable sensors in rehabilitation, more research is needed to clarify the mechanisms of interaction between biomechanical factors such as motion and pressure (i.e., micromotion and micropressure) and tissue surrounding the sensor, which lead to increased interfacial stresses, changed tissue physiology and, in turn, diminished sensor performance [3 4]. To improve the quality of life of veterans with long-term functional deficits, research on the applications of wearable technology is desired that would identify key enabling technologies (i.e. sensor technology, communication technology, and data analysis techniques) for monitoring veterans with chronic conditions in the home and community settings [5 6].

3.2 Broadening the Scope of Military Rehabilitation: Time for Paradigm Shift

Due to the fast-developing technology for reconstructive/restorative rehabilitation over the past decade, our societies reached the level of medical care that is capable of delivering effective measures and aids for veterans with service-related deficiencies. Nevertheless, our obligations toward our military personnel should be beyond traditional care paradigms. While continuing with the development and refinement of techniques for reconstructive/restorative rehabilitation, we should move from the traditional definition of rehabilitation medicine (i.e., "a treatment or treatments designed to restore some or all of the patient's physical, sensory, and mental capabilities that were lost due to injury, illness, or disease to as normal a condition as possible") toward new paradigms of pre-emptive and preventive rehabilitation.

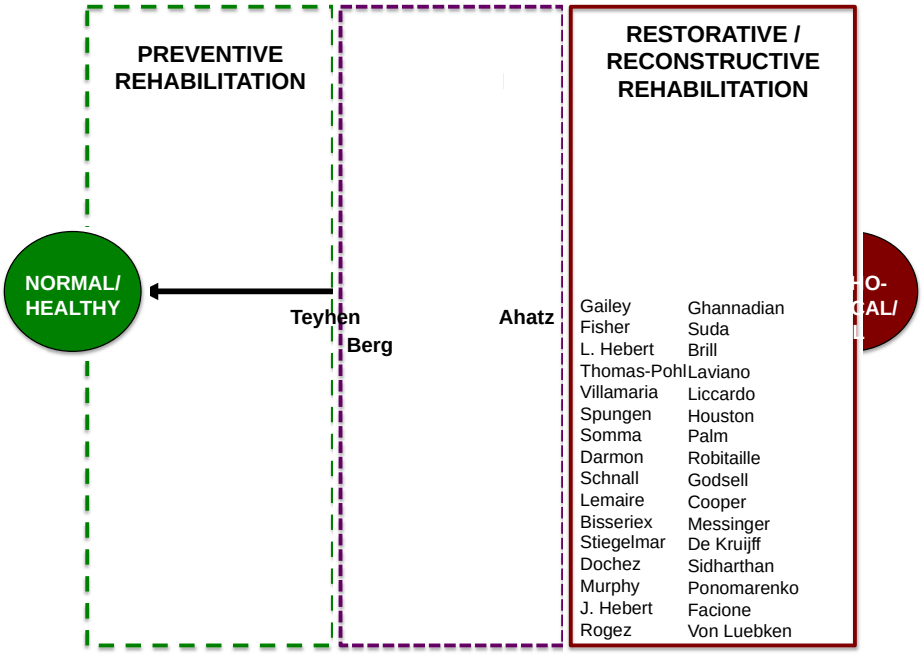

Figure 4. Health continuum in military rehabilitation: providing a roadmap for improved quality of life of individual soldiers and enhanced operational readiness for military. The authors' names denote the presented articles' rehabilitation categories.

Pre-emptive rehabilitation could be defined as a set of training or treatment programs that would stop the progress of dysfunctions and/or injuries before they fully develop (thus "pre-emption"), and fully restore all functions to normal conditions much faster than restorative rehabilitation would achieve. Preventive rehabilitation denotes a broad range of techniques and procedures that increase the individual's physical and mental resilience hence decrease his/her susceptibility toward injury, illness, or disease. The importance of preventive rehabilitation becomes obvious when bearing in mind the increasing age [7] and trend toward overweight, obesity and associated co-morbidities among military personnel today [8]. Furthermore, pre-emptive and preventive rehabilitation offer not only better quality of life for individual soldiers, but also enhanced operational readiness for military and reduced financial burden for societies.

Changing political priorities and international military tasks emphasize a need for establishing similarities and differences between deployment- and training-related rehabilitative requirements, and developing standardized customized protocols based on those similarities and differences. Moreover, research studies addressing the influence of resilience and injury susceptibility on injury response, outcome, and choice of rehabilitation method tailored for individual soldier should be encouraged; the obtained results would represent the building blocks of the 21st century military rehabilitation.

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