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Editorial

General (Dr.) Sylvain Ausset

Tomorrow's challenges in the light of lessons learned yesterday and today

This issue of the International Review of the Armed Forces Medical Services contains 8 articles transposing the oral interventions of the French delegation to the last congress of military medicine held in September 2022 in Brussels. They are written from a double perspective. The first is the feedback from the health service of an army that is described as an "army of employment" because it has been continuously engaged in successive conflicts for 30 years. The second is the timing of this congress which leads the authors to have conceived their point during the first 6 months of the Ukrainian conflict.

If these articles present three decades of combat-proven evolution of military medicine, at least of certain combat situations, in this case the so-called asymmetric conflicts, they also summarize the perspectives looming over us. These perspectives are, first of all, the return of confrontations between state powers and, secondly, the persistence of counter-terrorism, especially in remote areas of the planet. These two perspectives have in common the need for rusticity, as they constitute a major challenge to the logistics chain and evacuation routes.

In addition, they raise two questions which are both challenging for our institution. The first is to know if the recent achievements of military medicine are feasible in such contexts.

Whatever the answer to this first question, the next one is to know if progress is still possible and what are the ways to achieve it.

The basic question about the sustainability of progress in military medicine is the one raised in the two articles on "prolonged field care" when they confront the objectives of TCCC with the imperatives of counter-terrorism, which are the light footprint and the tyranny of distance. Eric Quemeneur identifies the educational challenges of teaching the concept, while Pierre Pasquier reviews the ways in which it can be improved. The latter are largely based on the resuscitation of the bleeding patients, as was already the case in the Afghan and Iraqi conflicts [1,2]including mortality, with a special focus on the incidence and causes of potentially preventable deaths among US combat fatalities, is central to identifying gaps in knowledge, training, equipment, and execution of battlefield trauma care. The impetus to produce this analysis was to develop a comprehensive perspective of battlefield death, concentrating on deaths that occurred in the pre-medical treatment facility (pre-MTF).

Nicolas Py presents in his article the results of the transfusion-based resuscitation of such casualties by the French army in the Sahara-Sahelian strip. Yann Daniel describes the solutions provided by the special forces in even more harsher environments. Thomas Colleonny gives an overview of the progress already undertaken in this field, namely pre-hospital transfusion. Christophe Martinaud presents the history and the future of transfusion therapy. Finally, Guillaume Boddaert provides an update on the ongoing challenge of life support for non-compressible hemorrhages.

We can see that all of this reflection is focused on bringing the maximum therapeutic intensity possible to the front, rendered compulsory by the interruption of logistical routes and the loss of control of air space. This strategy has a name, it is the "remote damage control resucitation" (RDCR) which consists in capitalizing on the achievements of the TCCC, by improving its performance by exporting to the forefront the lessons of "damage control resucitation" (DCR). This concept is explored and developed by a group of researchers and clinicians from several allied countries with different specialties [3]DCR employs a unique hypotensive-hemostatic resuscitation strategy that avoids traditional crystalloid intravenous fluids in favor of early blood component use in ratios mimicking whole blood. Although it is used in its rudiments by some health care systems, civilian or military, in austere environments [4–7]US Air Force paramedic-led PEDRO, and UK physician-led medical emergency response team (MERT, it remains a subject of research in which the French armed forces health service has a leading position with its anteriority in the medicalization of the front and its proficiency in the use of lyophilized plasma.

Despite these progresses and the adjustments made, we should not forget the fundamentals that we must preserve in the hope that we will never have to resort to them. In his article, Emmanuel Petit explains the role that medical support on submarines can play in maintaining the permanence of the nuclear dissuasion and the means to achieve this. Once again, this is an experience that few health services in the world have.

Each of these 8 articles are therefore valuable lessons in military medicine designed to contribute to its education and development. Thus, cadets of the Army Medical School, which I have the huge honor of leading, have been involved in their writing and are deservedly associated to the list of authors.

General (Dr.) Sylvain Ausset
Full Professor of the Val de Grâce
Commander of the Military Health Schools
Director of the Armed Forces Health School

Éditorial

General (Dr.) Sylvain Ausset

Les défis de demain à la lueur des leçons reçues hier et aujourd'hui

Ce numéro de la Revue Internationale des Services des Forces Armées comporte 8 articles transposant les interventions orales de la délégation française au dernier congrès de médecine militaire s'étant tenu en septembre 2022 à Bruxelles. Ils s'inscrivent donc dans une double perspective. La première est celle du retour d'expérience du service de santé d'une armée que l'on qualifie « d'armée d'emploi » car elle n'a cessé depuis 30 ans d'être engagée dans des conflits successifs. La seconde est celle de la date de ce congrès qui conduit les auteurs à avoir conçu leur propos pendant les 6 premiers mois du conflit ukrainien.

Si ces articles présentent donc bien trois décennies d'évolution à l'épreuve du feu de la médecine militaire, du moins de certains feux, en l'occurrence les conflits dits « asymétriques », ils en font la synthèse au regard des perspectives qui nous menacent. Ces perspectives sont d'une part le retour des affrontements entre états puissances et d'autre part la persistance de la lutte contre le terrorisme, notamment dans des endroits reculés de la planète. Ces deux perspectives ont en commun une exigence de rusticité tant elles font peser de menaces sur la chaîne logistique et les voies d'évacuations.

Elles posent de surcroit deux questions qui sont autant de défis à notre institution. La première est de savoir si les acquis récents de la médecine militaire sont applicables à de tels contextes.
Quelle que soit la réponse à cette première question, la suivante est de savoir si des progrès sont encore possibles et quelles en sont les voies.

Le questionnement de base sur la pérennité des progrès de la médecine militaire est celui des deux articles à propos du « prolonged field care » quand ils confrontent les objectifs du TCCC aux impératifs de la lutte anti-terroriste qui sont la faible empreinte au sol et la tyrannie des distance. Eric Quemeneur recense les défis pédagogiques de l'apprentissage du concept, tandis que Pierre Pasquier en balaie les voies de progrès. Ces dernières résident en grande partie dans la réanimation des blessés hémorragiques, comme c'était déjà le cas dans les conflits afghan et irakien [1,2]. Nicolas Py présente dans son article le bilan de la réanimation transfusionnelle de tels blessés par l'armée française dans le contexte de la bande saharo-sahelienne. Yann Daniel expose les solutions apportées par les forces spéciales dans des contextes encore plus rustiques. Thomas Colleonny dresse la perspective des voies de progrès déjà engagées dans ce domaine, à savoir la transfusion pre-hospitalière. Christophe Martinaud quant à lui présente l'historique et l'avenir de la thérapeutique transfusionnelle. Enfin Guillaume Boddaert fait le point sur ce défi permanent qu'est le maintien en vie des hémorragies non compressibles.

On voit que toute cette réflexion porte sur l'apport le plus à l'avant possible d'une intensité thérapeutique maximale rendue nécessaire par l'interruption des voies de communication et la perte de maitrise de l'espace aérien. Cette stratégie a un nom, c'est le « remote damage control resucitation » (RDCR) qui consiste à capitaliser les acquis du TCCC, en en améliorant la performance par l'export à l'avant les leçons du « damage control resucitation » (DCR). Ce concept est exploré et porté par un groupe de chercheurs et de cliniciens de plusieurs pays alliés issus de spécialités variées [3]. Quoi qu'employé dans ses rudiments par certains systèmes de soins, civils ou militaires, en milieu austère [4–7], il demeure un sujet de recherche dans lequel le service de santé des armées français possède une longueur d'avance avec son antériorité dans la médicalisation de l'avant et sa maîtrise de l'utilisation du plasma lyophilisé.

Ces avancées et adaptations ne doivent pas nous faire oublier des fondamentaux qu'il nous faut maintenir en espérant ne jamais devoir y recourir et Emmanuel Petit nous expose dans son article le rôle que peut avoir le soutien médical embarqué dans des sous-marins dans le maintien de la permanence de la dissuasion nucléaire et les moyens pour y parvenir. Il s'agit, là encore, d'une expérience que peu de services de santé au monde possèdent.

Chacun de ces 8 articles sont donc autant de leçons de médecine militaire qui serviront de base à son enseignement et son progrès. Des officiers élèves de l'école de santé des armées, que j'ai l'immense honneur de commander, ont donc concouru à leur rédaction et sont fort justement associés à la liste des auteurs.

Médecin général Sylvain Ausset
Professeur agrégé du Val de Grâce
Commandant des Ecoles militaires de santé
Directeur de l'école de santé des Armées

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Presented at the ICMM World Congress in September 2022 in Brussels

Prolonged Casualty Care, during Serval and Barkhane operations: capability gaps and training issues. What are the challenges of Prolonged Casualty Care on the battlefield, based on the experience of the French medical service in the Sahel?

« Prolonged Casualty Care » pendant les operations Serval et Barkhane: écarts de capacité et problèmes d'entrainement. Quels sont les défis du "Prolonged Casualty Care" sur le terrain, basé sur l'expérience du service de santé Français au Sahel ?

K. Oladeji[1], E. Réginot[1], P. Pasquier[2]. FRANCE

Abstract

From 2013 to 2022, the French military medical service supported the French armed forces during the Serval and Barkhane operation in the Sahel over a 5 million square kilometer area. A low concentration of MEDEVAC helicopters and remote surgical medical treatment facilities required the French medical service to do more than Tactical Combat Casualty Care in the field and practice Prolonged Casualty Care. Several studies have highlighted important aspects of the prehospital care performed by the French military medical teams during operations in the Sahel, with room for continuous improvements: better tourniquet management with reassessment in the field and a greater availability of blood products. Interestingly, medical teams expressed a desire for more dedicated training in Prolonged Casualty Care. The use of new technologies, including telemedicine, could be widespread in the future to better conduct challenging medical procedures in real time. In any case Prolonged Casualty Care, defined in minimal, better, and best options can be provided whether in ruck, truck, house or plane, with limited resources and a hostile environment.

Key words: Prolonged Casualty Care, Prolonged Field Care

Résumé

De 2013 à 2022, le service de santé des armées Français a accompagné les forces armées Françaises dans le Sahel pendant les opérations Serval et Barkhane avec un terrain s'étendant sur plus de 5 millions de kilomètres carrés. Le faible nombre d'hélicoptères MEDEVAC et l'éloignement des infrastructures médico-chirurgicales ont poussé le service de santé français à aller plus loin que le « Tactical Combat Casualty Care » en pratiquant le « Prolonged Casualty Care ». Plusieurs études ont souligné certains aspects importants de la prise en charge pré-hospitalière effectuée par le service de santé des armées français pendant les opérations au Sahel, avec des améliorations toujours possibles : une meilleure utilisation des garrots avec une réévaluation plus précoce sur le terrain et une plus grande disponibilité des produits sanguins. Afin de progresser, les équipes médicales ont exprimé le désir d'avoir une formation plus poussée sur le thème du « Prolonged Casualty Care ». L'utilisation des nouvelles technologies, comme la télémédecine, pourrait à l'avenir se répandre et faciliter en temps réel la réalisation de procédures médicales parfois difficiles. En tout état de cause, le « Prolonged Casualty Care » dans ses diverses options qu'elles soient minimales, bonnes ou meilleures peut être pratiqué que ce soit dans la brousse, dans un véhicule, dans une maison ou dans un avion avec des ressources limitées et dans un environnement hostile.

Mots clés : Réanimation de l'avant, Soins Critiques Prolongés

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Introduction

Over the last twenty years, through the medical experience in Middle East and Sahel conflicts, it has been well established that to save more lives of combat casualties on the battlefield, the priority was to perform damage control resuscitation and surgery as soon as possible [1]. Getting to a medical treatment facility with resuscitation and surgical capabilities in less than an hour was associated with a significant re-

duction in mortality and morbidity [2][3]. But this *golden hour* principle was established for kinetic asymmetric and unconventional conflicts with guarantees of air superiority and rapid evacuation time [4]. Some may argue that that this doctrine is hardly applicable in new or future conflicts in which such conditions are not guaranteed. Furthermore, the *golden hour* works in synergy with Tactical Combat Casualty Care (TCCC). TCCC is a set of best pre-hospital military lifesaving interventions used to stabilize the patient while waiting for a Tactical or Medical Evacuation. It may include for example the use of tactical tourniquet and forward transfusion. the combined use of tactical tourniquet, forward transfusion and the *golden hour* is associated with a threefold increase in survival [5]. Therefore, the North Atlantic Treaty Organization (NATO)'s guideline for special operation forces medical support has integrated both the TCCC and the *golden hour* [6]. But what if the golden hour principle cannot be met because of the loss of superiority over the enemy, especially air superiority, which facilitates medical evacuations in less than an hour. This is the case, for example, for special operations forces, which operate in all regions of the world and on a wide variety of missions, in particularly hostile environments, far from a security zone controlled by the allies [7]. In these operations, the extraction of casualties is therefore complex, requires more time, and TCCC will not be enough to manage combat casualties for a prolonged period [8]. Facing this challenge, the application of Prolonged Casualty Care could be an auspicious solution. Prolonged Casualty Care is defined as "*Field medical care, applied beyond 'doctrinal planning time-lines' by a Special Operations Combat Medic or higher, in order to decrease patient mortality and morbidity. Utilizes limited resources, and is sustained until the patient arrives at an appropriate level of care*" [9]. To put it in other words, Prolonged Casualty Care is just like "*holding a patient sicker than you can care for, for longer than you want with fewer resources than you need, in a place you do not want to be*" [10]. Thus, Prolonged Casualty Care does not replace TCCC, but it is a continuation of it [11]. Prolonged Casualty Care comes together with TCCC and Damaged Control procedures. It implies that Prolonged Casualty Care is also conducted during medical evacuations, until the combat casualties have reached a medical treatment facility with a higher level of care. Some authors have described also the

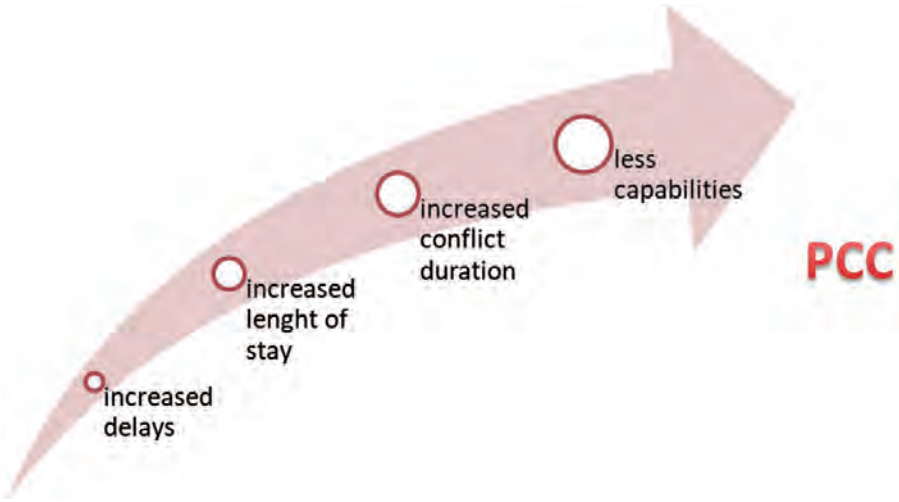

Figure 1: Modification of the casualties' care due to conflicts evolution

Prolonged Field Care. Prolonged Casualty Care and Prolonged Field Care define the same process, but Prolonged Field Care was originally for the Army. To include the Navy, who is not on the field, it was decided to switch from Prolonged Field Care to Prolonged Casualty Care. [12] This narrative review aims to measure the challenges of Prolonged Casualty Care on the battlefield, based on the experience of the French medical service in the Sahel.

Experience of the French military medical service in Serval and Barkhane operations

In the medical doctrine of the French armed forces, a medical team is deployed as close as possible to the point of injury. This has many several benefits. First, it means that many high-level medical procedures can be performed at an early stage [13]. Then, the physician can get a clear and direct view of the situation and organize either tactical or medical evacuation. Finally, the physician has sufficient perspective and medical background to provide adequate medical procedures, depending on the type of casualty, the level of resources he has on the field and the time before evacuating the casualty. In this context, the French military medical service operated during the Serval and Barkhane operation in the Sahel since 2013 and 2014 respectively. The French armed forces were deployed in a 5 millions square kilometer area, more than one half the area of the United States over five countries (Mauritania, Mali, Burkina Faso, Niger, and Chad). The French military medical service supported armed forces with a low concentration of helicopters and remote access to surgical capabilities [14]. Medical evacuations in such large areas were associated with major logistical and human challenges.

Increased evacuation time

A retrospective study from Carfantan C *et al* from 2013 to 2016 analyzed 533 medical evacuations from the point of injury to a Role 2 [15]. It found out that the median time from the point of injury to a Role 2 for ALPHA patients (the most severe ones) was 145 minutes;interquartile range (IQR) :100 - 251.

Another retrospective study by Travers *et al* analyzed five years of prehospital data from the French military operation in the Sahel [14]. In this study, the median time from the point of injury to a Role 2 for 46 ALPHA combat casualties was 130 minutes (IQR 70 - 252). 57% of the medical evacuations were exceeding 120 minutes and 26% were exceeding 240 minutes. The authors of these two studies concluded that, ALPHA patients time frame was longer than the *golden hour* recommended by the North Atlantic Treaty Organization. Finally, it means that, in the Sahel the French military medical teams had to conduct Prolonged Casualty Care.

Use of tactical tourniquet and forward transfusion

Among the medical procedures that the French military medical service performed for Prolonged Casualty Care, those concerning the management of hemorrhage are probably the most important since, this is the first cause of preventable death in military setting [16]. And as part of the TCCC, the use of tactical tourniquet and the forward transfusion are two life-saving interventions that significantly reduced the mortality rate by tackling hemorrhage [5].

Table 1: The 10 essentials Prolonged Casualty Care from Ball et al [9]

	1. Monitoring	2. Resuscitate	3. Ventilate and oxygenate	4. Control the Airway	5. Sedation and Analgesia	6. Physical Exam and diagnostics	7. Nursing and Hygeine	8. Surgical Interventions	9. Telemedical Consult	10. Package and Prepare for flight
Minimum	BP Cuff, Stethescope, Pulse Ox, Foley	Fresh whole Blood kit	Bag-Valve-Mask with PEEP Valve	Awake Ketamine Cric	Opiate Analgesics titrated through IV	Physical Exam whitout advanced	Clean, warm, dry, padded, catheterized	Chest tube, cric	Make comms, present patients and key witals	Be familiar with stressors of flight
Better	Capnometry	2-3 cases of LR for Burn Resus	O2 concentrator	Long duration sedation	Sedation wih Ketamine and option of midazolam	Ultrasound and point of care labs	Elevate head of red bed debride washout NG/OG	Fasciotomy debridement, amputation	Add labs and ultrasound video	Trained in critical care transport
Best	Vital Signs monitor	PRBS, FPF, Type specific donors	Portable Ventilator	Proficient un Rapid Sequence Intubation	Educated and praticed in multi drug sedation	Experienced and trained in above	Experienced in all nursing care concerns	Trained and experience in above	Real time video conference	Experienced in critical care transport
Ruck	Pulse Ox, head Lamp	1 FWB Kit per man, 2 250cc bag NS	BVM with PEEP valve	Cric Kit LMA/SGA, lidocaine and ketamine IM	Fentanyl TML, Perc PO, Ketamine IM/IV	Urinalysis test strips, fluorescein strips	Compact foley kit, Sterile kerlix, litter padding	Cric 10g Needle D Scalpel	Cell Phone and call sheet	Have checklist available
Truck	BP Cuff, Stethescope, Capnometry, Small monitor	Casre LR, Additional FWB Kits, 3% Saline	SAVent or SAVE 2	RSI, LMA/SGA, Cric kit ketamine bag IV	Ketamine IV with midazolam	Blood tubes to drop off labs on the way	Padded, litter, NG	Sterile chest Tube Kit with drapes	Celle Phone and call sheet, sat phone, radio	Checklist plus flight evac kit
House	Add defibrillation	2 additional cases LR, Cases NS, Additional 3% Saline	Impact Vent and O2 bottle	All from above Add Benzo if not available for truck	Same as above	Blood tubes to run labs to local clinic	Real matress with head elevated nursing care kit sleeping Bag	Sterile surgical Kit with drapes, Gowns and srub soap	Secure comms, email	Extensive evac kit
Plane	Take all of above	All of above	Impact vent on O2	All above calculate for flight and double	All above calculate for flight and double		Padded Litter, Sleeping Bag	10g needle D Chest tube kit Cric kit	Through aircraft	From above

In the study by Travers *et al*, 183 combat casualties. ¾ of the casualties were caused by an explosion. From the 183 casualties, 6% were killed in action, 4% died of wound. The tactical tourniquet was used for 18 combat casualties. In some cases, due to the ineffectiveness of the first one placed, another tourniquet was positioned higher than the first one. Travers *et al* found out that the median time for tourniquet application was 90 minutes (from 62 to 262 minutes) before withdrawal at the Role 2. In association with extented medical evacuation times, a tourniquet was applied for more than 120 minutes in six combat casualties. Complications possibly related to ischemia (rhabdomyolysis and compartment syndrome) were described for four casualties with a tourniquet application time longer than 120 minutes, and none when the tourniquet had been loosened in less than 120 minutes. Regarding forward transfusion, lyophilized plasma was transfused in nine casualties and red blood cells were transfused in four casualties before arriving at a Role 2. Transfusion was initiated a total of three times in the field, two times during helicopter medical evacuation, and five times during forward MEDEVAC. The failure to reconstitute lyophilized plasma was described in one case. No transfusion complications have been reported.

What can be learned from this French experience?

Regarding the results of the two studies, it is clear that NATO standards concerning forward MEDEVAC in less than 60 minutes could not be met. Moreover, it highlights some major issues due to these extended delays. So, the application of a tourniquet for more than two hours is associated with higher rates of complications [14]. Among these complications, the most feared is limb ischemia [17]. Current French and international guidelines recommend reassessing tourniquets as soon as the tactical situation allows it, and whenever possible to convert it to a simple local hemostatic packing [18]. The only contraindications to conversion are for patients with hemorrhagic shock, to avoid worsening shock in the case of rebleeding, traumatic amputated limbs, or, for some, a delay of over 6 hours following injury. The second crucial aspect of a Prolonged Casualty Care is the availability of blood product on the field. Indeed, whole blood and red blood cells storage is difficult. But the French military blood institute proposed the French lyophilized plasma, particularly suitable for remote and austere settings, as it can be stored at ambient temperature for 2 years (even in hot environments), then reconstituted in less than 6 minutes, while being universal for all blood groups [19]. Moreover only 62% of the casualties were transported to a Role 1 before the Role 2 which means that in 38% cases the medical team at the point of injury had to deal with the casualty with the minimal equipment they had [12]. And this justifies ongoing works on future medical vehicles, the miniaturization of devices for monitoring or oxygen therapy, or pharmaceutical storage, including blood products, in extremely hot or cold environments. But having a better equipment also implies having people well trained to operate it. This is a key element for Prolonged Casualty Care.

The next steps for a good practice of Prolonged Casualty Care

Ball *et al* described 10 essential capacities for the good practice of Prolonged Casualty Care (see Table 1) [9]. Among those capabilities, some encompass basic medical skills received, at a minimum, in initial training but others require more experience and more skills. For example using ultra sounds for a diagnosis or performing advanced chirurgical interventions. From Travers *et al* study, the medical personnel reported that they wished they had more training for Prolonged Casualty Care. This means that more needs to be done for the medical team's preparation. The medical team doing Prolonged Casualty Care is wide ranging, from the first aid buddies to the surgical team in

a Role 2. Therefore, the training and preparation to Prolonged Casualty Care involve not only the physician but every level of care. For example, Travers *et al* reported that 80% of the prehospital care was done by a physician due to difficulties to access the point of injury. It implies that 20% of the prehospital care was performed by either a nurse, or even a first aid buddies trained to *Sauvetage au combat* [20]. This data highlights the importance of involving everyone for Prolonged Casualty Care training courses. Finally, one key aspect of Prolonged Casualty Care is the communication, in particular mentoring from medical experts [9]. That can be done with telemedicine [21]. The minimum is to call with our phone, but it could be better with the exchange of photos and videos, or it would be best to have real time audio and video feed to allow a remote diagnostic or guidance through a medical procedure.

Conclusion

The way war is fought is evolving and so must the medical practices on the battlefield. Prolonged Casualty Care will not change the essential which is TCCC but now, more needs to be done. Indeed, military medical teams deployed in combat zones may have to deal with combat casualties on the battlefield longer. They will need to care for these casualties until these last ones reach a Role 2 and/or a medical treatment facility in a safer place, while ensuring that they are still able to receive more victims. This new temporality shows the limits of the current *golden hour* concept and the necessity to develop adapted protocols, including the management of tactical tourniquet for longer times and an easier access to blood transfusion. Despite this, some injuries like non-compressible torso hemorrhage will still require early specialized management, that would imply deployment of surgical teams closer to the frontline [22]. Finally, Prolonged Casualty Care is all about time and capabilities. If TCCC is acquired for most military medical services, French military medical teams need more dedicated trainings for Prolonged Casualty Care. To move forward, innovative collaborations with countries that have already developed capabilities in unconventional warfare such as the US, or Lithuania are possible [7] [23]. Training for Prolonged Casualty Care should be a point of major focus, with focus on adaptive solutions, in order to always do what is best. Military medical teams need to be ready to operate in every situations, whether on ruck, truck, house or plane, with limited resources and a hostile environment.

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Conflicts of Interest:

The authors declare that they have no conflicts of interest. The opinions or assertions expressed herein are the private views of the authors and are not to be considered as reflecting the official views of the French Military Medical Service.

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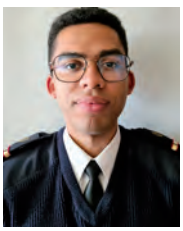

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Transfusion chain during Barkhane operation: organization and lessons learned

Chaine transfusionnelle pendant l'opération Barkhane : organisation et retour d'expérience

L. Ganaye[1], A. Carbonaro[1], N.PY [2]. FRANCE

Abstract

From the perspective of a major combat operation, or counter-terrorism operations with a small footprint on the ground, modern conflicts put a strain on the logistics chain. One of the most sensitive and critical is the supply of blood products. Various solutions are possible to provide our casualties with the right blood products at the right time, from fractionated bank products to "buddy transfusion". The recent experience of the French army in the Sahara-Sahelian strip shows that none of them should be ruled out beforehand and all of them require anticipation and training.

Keywords: Blood Transfusion, Blood Product, Military Medicine

Résumé

Les conflits modernes mettent à rude épreuve la chaîne logistique, qu'il s'agisse d'une opération majeure de combat ou d'opérations de lutte contre le terrorisme avec peu d'implications sur le terrain. L'approvisionnement en produits sanguins représente l'un des aspects les plus sensibles et primordiaux de cette chaine logistique. Différentes solutions sont envisageables pour fournir aux victimes les bons produits sanguins au bon moment, depuis les produits fractionnés issus de banques de sang jusqu'à la "transfusion entre camarades" sur le terrain. L'expérience récente de l'Armée française dans la bande saharo-sahélienne montre qu'aucune de ces solutions n'est à exclure a priori et que toutes nécessitent une certaine anticipation et formation.

Mots clés : Transfusion Sanguine, Produits Sanguins, Médecine Militaire.

Introduction

For years and especially since the first international conflicts, it has been evident that survival of the hemorrhagic injured soldiers is inevitably compromised without transfusion. Since the WWI, fresh whole blood transfusions have been used to treat the military trauma patients.

Two factors of the transfusion therapy are essential to improve the survival of the trauma patient: the timing and the quality of this transfusion.

First, to restore blood pressure and subsequent complications as well as the clotting capacity, the time to first transfusion must be as short as possible. During the conflict in Afghanistan, the 24h mortality of the US military trauma patients who received a first transfusion within the first 15 min after the injury was lower (HR 0.17 [95% CI, 0.04-0.73], p=0.02) than those who could not be transfused or could be transfused only within more than 15 minutes.(1)

Second, the blood loss and the traumatic coagulopathy require a transfusion, which composition is close to that of whole blood. Indeed, in a study of Roquet et al, the 30-day survival rate of the trauma patients was higher (HR, 0.74; 95% CI, 0.58- 0.94; p=0.01) when the transfusion ratio was greater than 1 plasma for 1.5 RBCs transfused.(2,3)

Blood products in Barkhane operation_

The French Military Medical Service (FMMS) provides four categories of blood products in the field. (4)

The different products available during Operation Barkhane were Red Blood Cell units (RBCs), French Lyophilized Plasma (FLYP), cold-stored low-titer group O WB (CS-LTOWB) and warm fresh whole blood (wFWB).

The RBCs that are obtained from blood collections in France, are 280 mL bags composed of approximately 60% erythrocytes. It can be stored 42 days at a temperature between 2 and 6°C and are supplied from France every 30 days. Transfusion must be performed according to ABO compatibility. The FLYP, prepared by plasmapheresis of about ten human blood by the French Military Blood Institute (FMBI) packaged in a 210 mL glass vial with a shelf life of 2 or 3 years at room temperature.(5) The FLYP provides only coagulation factors. There are significant logistical advantages to using FLYP: storage at room temperature and no requirement for thawing time permits usage at pre-hospital stages and in austere conditions, with only 3 to 5 minutes to be reconstituted. Moreover, FLYP is compatible with all blood type, make it easy to use. Finally, two types of whole blood are available: the warm Fresh Whole Blood (wFWB) and the cold-stored low titer group O whole blood (CS-LTOWB). The main advantage of the whole blood transfusion is to provide to the military trauma patient all

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the constituent of the blood: red blood cells, plasma and platelet. The whole blood transfusion is the only source of platelet transfusion before the repatriation to the France.

The wFWB is fresh blood collected by the medical team directly in the field from pre-screened donors, in a 500mL bag. The main limitations of the wFWB are a collection time of around one hour for a trained medical team, a theorical infectious risk (HIV, HCV, malaria). It can be stored at room temperature for 6 hours before used then at 2-6°C for 48 hours.

The CS-LTOWB is prepared by the FMBI from whole blood collected from group O donors who have low titer of anti-A and anti-B antibodies. The group O whole blood is then filtered for leukoreduction without altering the number of platelets or their hemostatic quality. [5] The low titer of anti A and B antibodies allow its universal transfusion compatibility. It can be stored in a cooler between 2 and 6°C for 21 days which requires a supply from France more frequently than RBC, every 14 days. The CS-LTOWB was made available for the first time in the field in 2021.(6)

Transfusion chain organization

The FMMS's policy concerning the management of the hemorrhagic war wounded is based on the Damage control resuscitation strategy (DCR).

The DCR starts from the point of injury by controlling massive bleeding, applying hemostatic strategies of the Tactical Combat Casualty Care with pressure dressing, tourniquet, pelvic binder or hemostatic gauze, as close to combat as possible. The DCR continues with the fastest possible transport to ROLE 1.

At ROLE 1, the medical care begins by injection of tranexamic acid, an antifibrinolytic drug, and by starting the transfusion strategy for the military trauma patient who required it, with FLYP or Cs-LTOWB transfusion in a first time and wFWB if necessary. When the patient is properly conditioned and a carrier is available, the military trauma patient is transported by forward MEDEVAC to ROLE 2, usually by air. During the forward MEDEVAC, the transfusion may be continued with RBC, CS-LTOWB or FLYP.
At ROLE 2, the damage control strategy includes a damage control surgery (DCS). The DCS consists of rapid surgery (ideally less than 60 minutes) aiming at stopping bleeding by strategies of suturing culprit arteries, arterial shunts, packing, or compression devices. This shortened surgery avoids the development of the lethal triad. At this stage, the transfusion is continued with RBC, FLYP, CS-LTOWB and wFWB is necessary.

The main goal is to stabilize the military trauma patient to allow the transport to France early. During the strategical evacuation (STRATEVAC) to France, the transfusion may be continued, if necessary, with RBC, FLYP and platelet concentrate (PC).
Finally, the ROLE 4 is the French military training hospital in France where the military trauma patient receives the definitive care.

The organization of the transfusion chain must therefore be modelled on this chain of survival while taking into consideration the logistical constraints to provide the patient and the medical team with the right products at the right time.
Thus, the transfusion chain must meet the following 4 rules:

- transfuse as quickly as possible ;
- transfuse blood first instead of crystalloids ;
- provide platelets during the transfusion protocol ;
- and, respect a ratio of products close to the composition of whole blood (ratio of 1:1:1 of RBCs, plasma and platelets or whole blood unit).

FLYP is therefore available to all medical teams from forward medical team to strategical evacuation medical team.

RBCs or CS-LTOWB are available where they can be stored according to their storage rules so at ROLE 2. But in some case, RBC and CS-LTOWB could be used at ROLE 1 and forward MEDEVAC thanks to the golden hour box, which is a cooler allowing 48 hours storage for 3 RBCs or 2 CS-LTOWB. In some special circumstances, these products are available in armored vehicles directly at the beginning of patient care.

During STRATEVAC, the possibility of bringing back blood products directly from the FMBI allows a "multi-component" transfusion notably with platelet concentrate and to continue the transfusion strategy as long as necessary. The CS-LTOWB, currently not much produced, is not used at this stage of the transfusion chain.

Since it requires an hour to be done, wFWB is mainly performed on stable phases without transport (ROLE 1 and ROLE 2).

Finally, for logistical reasons, platelet concentrates are not available on the field.

Feedback on transfusion consumption in Barkhane between 2013 and 2021

The FMMS's doctrine is based on using the transfusion in the following order of priority :

Priority 1= CS-LTOWB ;
Priority 2 = RBCs and FLYP in a 1:1 ratio ;
Priority 3 = RBCs or FLyP if only one is available ;
Priority 4 = crystalloids while waiting for FLYP.

During Barkhane operation, 45 french military trauma patients were transfused with at least one blood products. Twenty three

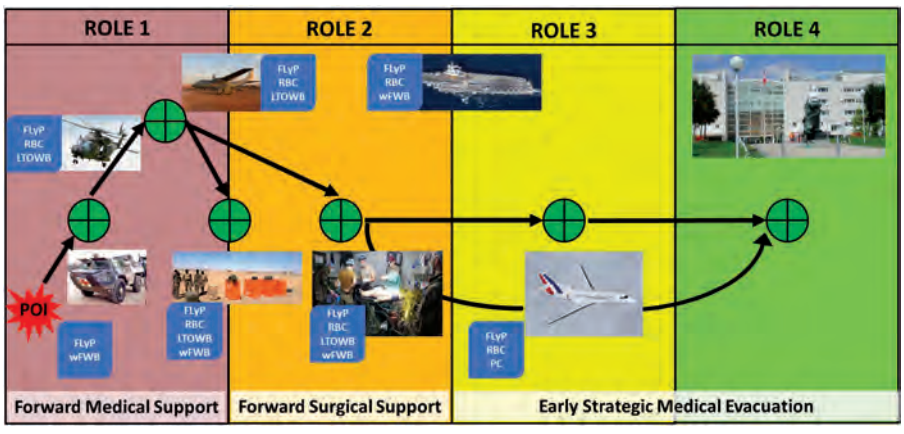

Figure 1: Medical blood supply in the French military medical service, organized according to the chain of survival of the war wounded, from point of injury to role 4 facility.
FLyP : French Lyophilized Plasma ; LTOWB : Low Titer group O Whole Blood ; PC : Platelet Concentrate ; POI : Point Of Injury ; RBC : Red Blood Cell units ; wFWB : warm Fresh Whole Blood.

patients (51%) received at least four RBC during the first day, defining a severe hemorrhage (SH).

At ROLE 1, 12 (27%) of the 45 injured patients who required a transfusion during Barkhane operation were transfused. Among these, four were defined retrospectively as severe hemorrhaged, whereas five were not transfused again after this stage. Totally, 17 blood products were transfused, mostly FLYP, while two patients with SH were transfused with FLYP and RBC.

During the forward MEDEVAC, fourteen patients (31%) were transfused. Of these patients, eight subsequently presented with non-SH and six with SH. Twenty-four blood products were transfused at this stage, divided into 15 to patient with SH and nine to patient without SH. The FLYP was the most blood products transfused with thirteen FLYP transfused, equally divided between patients with and without SH. Six RBCs and three wFWB were transfused to patients with SH. Only one CS-LTOWB transfusion, was transfused to a patient without SH.

Overall, 41 blood products were transfused before ROLE 2 arrivals with a significantly increase from 0.45 blood products per patients before 2017, to 1.28 since this year.

At ROLE 2, 38 patients (84%) were transfused with 310 blood products. A roughly equal proportion of RBCs, FLYP or wFWB were transfused to patients with SH. Patients with SH received a median of 10 blood products at ROLE 2, divided into 4 RBCs, 4 FLYP and 3 wFWB. In contrast, the patients without SH received median of 2 blood products mostly FLYP or RBC.

Therefore, the patient with SH, received from the ROLE 1 to the end of the ROLE 2 management a median Plasma:RBC ratio of 1.2 and Platelets:RBC 0.4.

During STRATEVAC, nine (24%) patients received a transfusion. Eight were patient with a SH and were transfused with 36 blood products whereas one patient without SH was transfused with one blood products. A similar proportion of RBCs and FLYP were transfused (16 RBCs and 14 FLYP). Interestingly, regarding platelet products, 2 wFWB and 2 PC were transfused.

In France at ROLE 4, 16 (42%) patients were transfused with 131 blood products until the 48th hours after the injury, 13 with SH and 3 without SH. In detail, patient with SH received a median of 6 blood products, with a median of 2 RBC and 2 plasma. At this stage, the plasma transfused is mostly fresh frozen plasma rather than FLYP.

Finally, between the 48th hours and the day 7, 400 blood products, mainly RBCs, then plasma and some mixed platelets were transfused, almost exclusively to patients with SH at baseline.

To summarize, 55% of blood products were used on the field, and 45% were needed throughout the first week, mainly by the patient with a severe hemorrhage.

Conclusion

The FMMS's doctrine is based on the damage control strategy. As soon as possible, the military trauma patient should receive medical support, starting from the POI with tactical combat casualty care, then from ROLE 1 and 2 with advanced medical and surgical support and throughout the different medical evacuation.

During all these steps, the FMMS provides a transfusion chain with different blood products adapted to the logistic and tactical constraints: RBC, FLYP, and two types of whole blood unit : CS-LTOWB and wFWB.

This feedback from the transfusion chain during Operation Barkhane demonstrates the ability of the FMMS to deploy a complete transfusion chain in a low-intensity conflict despite an extensive war zone.

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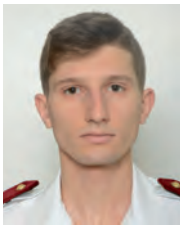

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Warm whole blood collection in role 1: preparation, training and safety management

Prélèvement de sang à chaud dans le rôle 1 : préparation, formation et gestion de la sécurité

L. Foglierini[1], V. Terrenoire[1], B. Gonod[1], Y. Daniel[2]. FRANCE

Abstract

Strong data supports the use of prehospital blood transfusion for the war wounded suffering from severe hemorrhage at an early stage. A walking blood bank program can be a solution to logistical constraints related to transfusion in an austere environment. Transfusion related safety issues, mainly transfusion-transmitted diseases and ABO mismatch are manageable on the field using adapted controls. Blood donation or "buddy transfusion" does not seem to affect the overall fighting capabilities of highly trained soldiers, nor seems to affect the quality of the blood, making forward transfusion feasible.

Keywords: Blood Transfusion, Blood Product, Military Medicine

Résumé

Il existe aujourd'hui des données solides en faveur de la transfusion des blessés de guerre hémorragiques dès la phase préhospitalière. La mise en place d'un programme de sang total chaud (« banque de sang sur pieds ») permet de palier aux contraintes logistiques liées à l'isolement géographique. Les risques doivent néanmoins être parfaitement contrôlés, notamment celui de la transmission d'un agent infectieux, et celui de l'incompatibilité ABO. L'application de protocoles rigoureux permet de maintenir dans ce contexte un niveau de sécurité transfusionnelle satisfaisant. La transfusion entre camarades (« Buddy Transfusion ») qui consiste à prélever du sang directement sur le champ de bataille, et de le transfuser immédiatement à un blessé, apparaît aussi comme une solution à l'avant : les qualités hémostatiques du sang ainsi prélevé ne semblent pas être altérées et les capacités du donneur à poursuivre le combat apparaissent conservées pour les personnels entrainés.

Mots clés : Transfusion Sanguine, Produits Sanguins, Médecine Militaire

Introduction

The French armed forces, like their NATO allies, have faced the challenges of modern warfare at the turn of the 21st century. Amid rapid change of doctrine regarding resuscitation and combat casualty care, the French Military Health Service has implemented prehospital blood transfusion, including a Walking Blood Bank program since 2006 [1].

Interest of prehospital blood transfusion for survival of the war wounded

Hemorrhage remains the leading preventable cause of death in combat-related injuries [2].

Early implementation of lifesaving medical treatment seems like an intuitive, straightforward approach to address this problem. Furthermore, trauma-related death has been shown in hospital studies to be most prevalent in the first hours following the injury [3].

Following this idea, prehospital blood transfusion has been performed on severe war wounded of western militaries during the middle eastern conflicts of the early 21st century [4]. Retrospective analysis of this emergency-related practice suggests that prehospital blood transfusion decreases mortality for the most severely wounded [5, 6]. Further analysis of medical support practices of this era highlights the importance of forward damage control resuscitation [7] and the interest of forward, physician-led medical teams [8] able to perform additional care.

Although these first analysis were encouraging, attempts of prehospital blood transfusion in a civilian setting did not find the same inspiring results. However scarce and heterogenous data suggested poor methodology quality of peacetime studies available at the time [10]. Randomized controlled trials funded by the United States Department of Defense showed that prehospital transfusion of blood products, compared to crystalloid-based resuscitation, had the greatest mortality benefit [11, 12].

European randomized trials found conflicting results, with no superiority of plasma over crystalloids for patients with hemorrhagic shock [13, 14]. However, these studies suggested that further research is needed to fully understand the challenges and mechanics behind prehospital blood transfusion.

Successes and failures regarding the assessment of prehospital blood transfusion suggest that early administration of blood products following the injury is a key factor to ensure lifesaving benefits to severely wounded patients [15].

Wartime prehospital blood transfusion in an austere environment poses the problem

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of logistic constraints. Blood products as seen in a civilian setting require strict storage conditions and which are not always available in military operations. Civilian blood products are generally divided into plasma, platelets and packed red cells adding the multiplicity of blood products to the logistical challenge. [9] Warm whole blood collected by forward medical teams is a way to address these constraints [17,18]. It also reduces waste of blood products by producing the right amount or by transporting the surplus with the victim for later use [19].

Principles of the Walking Blood Bank

Several countries have a Walking Blood Bank (WBB) program available. The majority are military programs, the Malian program is a civilian one, and Norway and the United States have both military and civilian programs. These programs follow civilian regulation for their country, when appliable. Specifications falling outside of this regulation framework are governed by military regulations. [15]

The French WBB program is a military program that comes in addition to a predefined dotation in packed red blood cells (PRC) depending on the size of the unit and minimum time for medical evacuation. The program is activated if the need for blood product overcomes the supply. The limit is theoretically fixed at more than 5 PRC in 3 hours or 10 PRC in 24 hours [16]. The use of fresh whole blood transfusion is limited to situations when reconstitution of whole blood (PRC, plasma, and platelets in 1:1:1 ratio) is not possible because of an insufficient supply, the need for massive transfusion or when platelets are not available. Platelets represent a logistical challenge due to their short shelf life (7 days from collection to infusion) and their storage conditions (22°C ± 2°C on oscillating table). Such platelets are rarely available on the field and may be the real reason to use WB during massive transfusion.

Transfusion related safety issues

The implementation of blood collection in the field requires procedures designed to control the main transfusion risks. These risks are mainly ABO error and transfusion-transmitted infections. Even on the battlefield, risks can be controlled thanks to a well-conducted a priori screening and a quick medical interview allowing to check for any new clinical elements before the whole blood (WB) donation.

Transfusion-transmitted diseases (TTDs)

According to French regulation for blood donation, TTDs risk is reduced by using a combination of a medical history interview focused on risky behavior, a physical examination, and a battery of serologic and nucleic acid tests. Volunteer blood donations undergo tests for human immunodeficiency virus (HIV), hepatitis B virus (HBV) and hepatitis C virus (HCV), human T-cell lymphotropic virus (HTLV) and syphilis processed by the French Military Blood Institute (FMBI).

On the battlefield or in a forward medical post, the absence of laboratory facilities makes it impossible to perform screening for TTDs. Pathogen-reduction techniques (chemical processing, ultraviolet light, leukoreduction filters, etc.) to reduce residual infections with virus, bacteria or parasite are not feasible in austere environment. Only rapid tests are available for HIV, HBV, and HCV (results available in 5 minutes, 30 minutes, and 40 minutes respectively).

TTDs risk is controlled by following strict protocols. Potential donors are prescreened by the general practitioner of their unit during a medical interview before deployment. The goal of this interview is to explain the purpose of a whole blood donation, identify risky behavior and obtain consent for donation. Potential donors are examined looking for sign of transmissible diseases or bad tolerance of blood subtraction. They are tested for TTDs accordingly to French regulation, Chagas disease and malaria are screened depending on individual risk factors. Once all risks have been excluded and tests results are negative, the volunteer is registered on the list of potential whole blood donors.

When the WBB program is activated, the volunteers needed for the donation undergo another interview with a physician to evaluate any further risk factors that may have occur since the medical screening (acute disease, medication intake, risky behavior). Rapid diagnostic tests for HBV, HCV and HIV are performed, and a blood sample is drawn, which will be sent to France, for a TTDs a posteriori analysis in a qualified laboratory [16].

Other countries than France allow the use of blood from donors that have not been screened before deployment. They use the combination of standardized questionnaire, different models of questionnaire have been developed by the military [20], with a medical examination and rapid diagnostic tests for HBV, HCV, and HIV to determine serological status. If no risk is found by the tests, the blood is infused. Samples are kept for later analysis according to standards [1].

ABO Mismatch

The same alternative exists for the determination of the blood group: to determine the donor's group and confirm the receiver's group at the time of transfusion, or to have determined both before. If the first attitude is feasible in a field hospital and allows an iso group transfusion, it is not feasible in the front line because grouping performed outside a laboratory, even if it is a field laboratory, exposes to an unacceptable error rate [21]. In the same way, the blood type on the dog tag is equally unreliable. Therefore, France decided, as many other countries, to control ABO mismatch by screening potential donors before deployment. The blood group and titers of anti-A and anti-B antibodies are determined.

Another way to ensure ABO compatibility is to select group O donors with a low titer of anti-A and anti-B antibodies to avoid the risk of hemolytic reactions mediated by these antibodies contained in the donor's serum and the receiver's red cells. Such low-titer O donors are considered "universal donors" for WB. Many armed forces identify these donors before the start of military operations [22].

In the French armed forces, for example, isogroup transfusions are preferred, but if no isogroup donor is present, a low-titer O donor will be chosen.

O low titers individuals

Using group O low titer is a possible mean of establishing a universal blood product in trauma scenario, as they show minimal risk of transfusion-associated graft-versus-host disease.

O individuals would require cheap, cost-effective titer screening program to mitigate adverse transfusion reactions, but no standardized method of titrations nor low titers definition exist, although current practices are safe. [23]

Administration of incompatible plasma from O whole blood fewer than 2 doses of whole blood units results in no evidence for hemolysis in the next 48h for the recipient patient. [23]

Cold-stored O low titer whole blood has been implemented by the French armed forces as a practical solution for use as a versatile, easy to use blood product for

trauma victims in a forward setting, most notably aboard medical evacuation helicopters [24].
Planification of transfusion and use of prepared blood products must not overshadow the possibility of immediate battlefield blood collection and transfusion, otherwise known as "buddy transfusion".

"Buddy transfusion" in wartime prehospital blood transfusion: overview

"Buddy transfusion", in a military context, refers to warm fresh whole blood collected on the battlefield from an uninjured soldier being directly infused to a war wounded. It offers many advantages on a logistical point of view, being always available even in hostile territory, and requiring virtually no cooling or storage. However, risk management must still be managed even in an austere environment [22] [25].
"Buddy transfusion" may raise the concern of its operational impact, with blood donation affecting the capabilities of the donor. A study led by the Norwegian Naval Special Operations Command suggests a 450-mL blood donation does not decrease physical capacity and shooting skills [26]. A randomized, controlled, double-blinded trial led by the same Norwegian service show no decrease in physical performance after a blood donation in severe fatigue conditions for special forces personnel [27]. Although these results concern a highly trained, highly motivated population, it shows the feasibility of "buddy transfusion" in the field [28] [29].

However, this physical straining raises question of the suitability of these soldiers' blood for transfusion. A level III cohort study from 2021 has shown no deleterious modifications of hemostatic properties in soldiers undergoing intense and prolonged physical activities, although the relatively small sample indicates further studies would be beneficial [28].

Management of potential blood donation symptoms

Vaso-vagal reactions (VVRs), ranging from pre-syncopal symptoms (e.g light-headedness) to syncope (transient loss of consciousness), may occur in blood donations [30]. It has significant implications in civilians blood donations centres [31] where safety measures and a safe environment is the norm.
Implementation of forward blood collection on the battlefield raises the question of dealing with VVRs in a more austere environment.
The World Health Organization (WHO) recommends pre-donation hydration and Applied Muscle Tension (AMT) to reduce the incidence of VVRs [32]. Applied Muscle Tension involves repeated contraction of leg, arm and/or abdomen muscles to increase blood pressure. Other interventions as well have been proposed: caffeine, distraction techniques, supportive care, and education [33].
A meta-analysis published 2015 had shown limited evidence and lacked strong support for pre-donation hydration and AMT during donation [34].
However, a large randomized controlled trial assessing hydration by water or isotonic drink and muscle tension exercices suggests that AMT reduces syncopal reactions during donation and isotonic drink reduces syncopal reaction during the 48 hours after phlebotomy [35].
Furthermore, one study has shown correlation between reduced VVRs and setting an estimated blood volume (EBV) threshold required for donation [36]. Another study has shown a correlation between donor age and rate of decrease of pre-syncopal reactions [37].

For all these reasons, in many blood donation protocols including "buddy transfusion" protocols, a donor must drink 500 mL of water during the donation.

Dealing with the needed volume of blood collection

If fresh whole blood transfusion is necessary on the battlefield, the volume collected in field situation can never be measured by specific equipment such as a scale. Different methods for simple and rapid control of the collection bag arose, as an incorrect amount of blood collected can expose the receiver to citrate toxicity in an underfilled bag, and coagulation and excessive blood loss from donor in an overfilled one. By comparing bag constriction with a length of material (the cord method) and clamping/folding the bag with a hemostat and gauze, a study showed similar results between the two methods. However, the cord method tended to be easier to achieve as means to do it are more widely spread among soldiers [38]. Regardless of the chosen method, it is important that staff in charge of blood collection be able to recognize underfilled or overfilled blood bags.

Dealing with hypocalcemia

Citrates added in blood and plasma transfusion bags bind to calcium. Study showed increased incidence of hypocalcemia in patients receiving citrated plasma versus normal saline, which resulted in higher mortality and increased probability of massive transfusion [39].
European guidelines on managemement of coagulopathy recommend a monitoring of calcemia. [40]
In the even where this monitoring is not feasible, it is recommended to administrate 1g of calcium in haemorrhagic shock during or immediately after transfusion of the first unit of blood product and with ongoing resuscitation after every 4 units of blood products [41].

Conclusion

Strong data supports the use of prehospital blood products for the war wounded. Walking blood bank programs and "buddy transfusion" can be a solution of enabling prehospital blood transfusion while not relying on heavy logistics. Management of transfusion related safety issues, the absence of documented loss of fighting capability among donors, and management of other problems surrounding the blood donation make this practice feasible in an austere or hostile environment.
Furthermore, the United States Army 75th Rangers regiment has reported a first documented case of a warm whole blood collection and transfusion in a hostile environment, which managed to stabilize a seriously injured casualty until his evacuation [22]. Although this practice may not be new, there is a lack of well documented and published cases, and further data could encourage the feasibility of forward transfusion.
However, complex maneuvers requiring specific knowledge and skills implies a training course with regular exercises, as blood transfusion adverse events can put the life of the receiver in danger. In difficult conditions, such events must be thoroughly studied and trained against to keep a beneficial outcome. Regulations regarding duration and frequency of training is variable from one country to another [1], but for all countries, training appears essential.

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23rd LoAC Course 2023

General Information

The 23rd ICMM Specialized Course for Military Medical Personnel on the Law of Armed Conflict (LoAC) will take place from 03 – 07 September 2023. As in the previous years, it will be organised by the Medical Services Directorate of the Swiss Armed Forces in Spiez, Switzerland. The LoAC course will be offered both as an on-site course in Spiez and as a separate online course as well.

For more information, please visit:
https://melac.ch/courses-workshops/loac-courses/loac-spiez-2023

Transfusion in the field: benefits and challenges

Transfusion sur le terrain : avantages et défis

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Abstract

In the aftermath of a step forward of a magnitude never seen in the history of military medicine, two questions stand out for military medicine.
The first is to know if there is still room for improvement and the second is to know if, at a moment when major engagements between powerful armies are looming, the human and logistical cost of further improvement or even just preservation of these improvements is feasible.
All the paths relevant to these two goals are centered on the management of hemorrhagic shock, which is by far the leading cause of the 25% of deaths that are still avoidable among the war wounded.

Keywords: Far Forward Medicine, Blood Transfusion, Blood Product, Military Medicine

Résumé

Au lendemain d'une avancée d'une ampleur inédite dans l'histoire de la médecine militaire, deux questions se posent : La première est de savoir si des améliorations sont encore possibles. La seconde est de savoir si, à un moment où des conflits de haute intensité entre armées conventionnelles semblent imminents, le coût humain et logistique d'une amélioration supplémentaire ou même d'une simple préservation de ces améliorations est réalisable.
Toutes les pistes relatives à ces deux objectifs sont centrées sur la prise en charge du choc hémorragique, qui est de loin la première cause des 25 % de décès encore évitables chez les blessés de guerre.

Mots clés : Médecine de l'avant, Transfusion Sanguine, Produits Sanguins, Médecine Militaire

Introduction

The history of military medicine is one of a race between medical progress and constant development of new weapons. The principles of PERCY and LARREY, still relevant to this day, allowed for saving half, or even two-thirds, of the wounded soldiers who came to them still alive. This figure decreased only slightly until World War I when, despite a phenomenal increase in the power of weapons and the firepower of armies, there was a drastic reduction in what can now be called intra-hospital mortality at the end of the conflict. This was not only due to the advent of field hospitals, but also to the use of mobile surgical structures set up near the front lines, equipped in 1918 with radiological and anaesthetic means.
For the first time in history, the proportion of of hospital deaths decreased significantly while the proportion of deaths on the battlefield or during evacuation increased. Previously, these two proportions were comparable or even equal. At the end of the conflict, their total would sometimes decrease to reach 20%. Most deaths would now occur on the battlefield or during evacuation [1].

Surgery, radiology, and field transfusions were the winning assets for saving the lives of our wounded – up until the end of the Second World War – at the cost of a logistical capacity whose neglect proved detrimental to all armies that had forgotten its value. Despite pre-hospital care – only at its infancy – with the use of dehydrated plasma, the major challenge at the time was still to control hospital mortality. For nations that succeeded, it appeared that the next challenge was to shorten the time it took to transport their wounded to a hospital.

Helicopters then fulfilled this role starting from the Korean War, while intra-hospital mortality continued to decrease to well below 5% [2].
This trend continued during the Vietnam War which still provided its own lot of lessons learned leading to the creation of trauma centres in the US. The latter would truly be assimilated after the dramatic events of Mogadiscio in 1993. These events were analysed in light of the data from the "Wound Data and Munition Effectiveness Team" [3]. This led to the doctrine of "TCCC," which is expressed in three objectives that are achieved in three phases through three targets [4]. The first objective is to save as many lives as possible during the operational phase as it is at this stage – and this cannot be stressed enough - that most deaths occur. The second is to prevent additional losses during the rescue phase. Indeed, a quarter of losses occur when trying to assist the wounded. The third objective - medical - is finally to ensure the success of the mission, which is essential for the proper progress of care.

To achieve these objectives, three targets are identified: deaths from haemorrhage, obstruction of the airways, and compressive pneumothorax, which respectively represent 91%, 8%, and 1% of preventable deaths. Finally, to take into account the tactical context, three phases are defined: care under fire, care at the casualty nest, and medical evacuation.

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This concept was implemented in the US Army's special forces in 1996 and in the entire army at the beginning of its engagement in the Middle East in 2003. In France, the same process led to the introduction of specific courses on the concept of combat rescue in 2007 thanks to the work of the Advisory Committee on Military Health led by Professor ESCARMENT at the Val-de-Grâce School (EVDG) [5].

The application of this doctrine was a success and, for the first time in history, the mortality rate of combat injuries in the US Army dropped below 10% after its implementation [6]. The result is even better in pioneering units such as the 75th Rangers, a large unit comprising most of the US Army's special forces, where the method is being implemented and where the number of avoidable deaths in combat dropped to zero, according to them [7]. For the French army, the mortality rate of injured soldiers in Afghanistan decreased from over 20% to just over 10% after the introduction of combat rescue.

In light of nearly 20 years of war against terrorism, assessment has been done and conclusions drawn: even though deaths by haemorrhage from extremities have significantly decreased, haemorrhage remains the main cause of preventable deaths in war injuries, mainly from trunk or junctional bleeding [8]. Reducing the duration of transport to a surgical facility has proven effective [6], but the "tyranny of distance" in recent conflicts limits its implementation. Prehospital transfusion has also shown effective, and it has been observed that its benefits add up to those of rapid evacuation [9].
During Operation Barkhane, the French army deployed over 5-million square kilometres in 5 countries. In the TRAVERS series, 183 soldiers were evacuated [10]. 32 tourniquets were applied to 19 (23%) wounded. 13 (16%) received prehospital transfusions (3 directly on the field, 7 during transfer to a role 2 facility). In another French retrospective series (VITALIS, with 28 patients), 7 (25%) wounded received tourniquets and prehospital transfusions. For two-thirds of them (15%), it was performed during transport after an average delay of 200 minutes. Prehospital transfusion thus became a front-line practice, including the use of tourniquets.
As this technique enters the standards of front-line medical care (US, UK, French army...), two questions arise: Can we do better? If the intervention is relevant, to what extent can human and logistical costs remain sustainable?

1. When do war casualties die?

In Vietnam, 65% of soldiers died within 5 minutes of being wounded [1]. Less than 10% of the injured survived for an hour. According to British data [11], three peaks of mortality for all causes were identified: within the first 10 minutes, one hour, and two hours after the injury. In Afghanistan, amongst 303 KIA (ISS at 75), 202 (67.7%) died within the "ten-minute platinum" period due to chest, head, or multiple injuries (more than three regions). Therefore, a third of them could expect to benefit from medical treatment on the field.

Eastbridge analysed 4696 autopsies of soldiers that had died in combat [8]. 4016 (87%) died before reaching a Role 2 facility (R2), including 976 (21%) of potentially avoidable deaths. Amongst the latter, 888 (90%) bled to death. TRAVERS and VITALIS also found a predominance of haemorrhagic injuries during the BARKHANE operation [10,12]. Life-saving interventions are therefore essential during the pre-hospital phase and should continue throughout the transfer to R2. Data from the Afghan theatre show that a delay of less than an hour during this phase is associated with a better outcome.

One of the main objectives of this transfusion is to prevent or treat acute traumatic coagulopathy (ATC). It can occur early after a haemorrhagic injury due to the loss of coagulation factors and their dilution from the infusion of resuscitation fluids. Reducing the time between the haemorrhagic injury and compensation for this loss is likely to increase the chances of survival. ATC occurs in 24-36% of cases before arrival at the hospital. It is a marker of the severity of the injury and is linked to mortality [13].

These data support NATO Policy 10-1-2 –*"all casualties should receive battlefield first aid within 10 minutes, advanced first aid within 1 hour, and surgery within 2 hours"* – with medical support structured around three phases:

- **Ten-minute platinum with survival techniques;**
- **Golden hour with pre-hospital medicalisation, including ATC management and actions against post-traumatic coagulopathy;**
- **Surgical intervention and early resuscitation upon arrival at an R2 facility**

2. What could work?

In the latest Tactical Casualties Combact Care (TCCC) guideline, management of massive haemorrhage is the first step following triage [14]. Once severe bleeding is brought under control, the guide states, "Perform an initial evaluation of haemorrhagic shock and consider immediate initiation of shock resuscitation." A retrospective British study in Afghanistan found a 50% reduction in mortality amongst severely injured patients with early use of blood products (transfusion, TXA) [15]. The "survivors" received more intensive therapy on the front lines, were evacuated more quickly, and received more blood products on the first day. In the KOTWAL series analysing 1692 records of injured US military personnel, access to early PHT, regardless of evacuation speed, reduced mortality by 38% in the critically ill patient population [9]. An analysis using a propensity score, and covering 502 injured Americans evacuated by helicopter in Afghanistan [16], found that only blood product transfusions initiated within fifteen minutes of the start of MEDEVAC transfer (median, 36 minutes after injury) were associated with a reduction in 24-hour mortality (HR, 0.17 [95% CI, 0.04-0.73], P=0.02). For those performed between 16-20 minutes, there was no longer a significant association with survival after 24 hours.

Therefore, pre-hospital transfusion is a suitable tool for managing haemorrhagic shock on the battlefield, on the frontline, and during transfer from an R1 to an R2 facility. Following the Paris attacks [17,18], a military-civilian doctrine related to the management of gunshot wounds was published in 2017. Concepts validated by military experience and expertise are being transposed, from triage to frontline transfusion. Outside of this concept of mass patient influx, is prehospital blood transfusion also applicable in an *en-route* strategy.

3. Data extracted from civilian studies

Two randomized American studies, sponsored by the United States Department of Defense (DOD), were published in 2018.

The COMBAT study, which involved 125 patients (ISS 22), discusses the contribution of plasma compared to the use of crystalloid solutions [19]. With a short evacuation time (<20min) in peri-urban areas, this single-center study was deemed futile and terminated, after an interim analysis concluded, mainly due to low mortality, that it was impossible to demonstrate a difference on this criterion between the two groups. This is especially true since, compared to military data, traumatic brain injuries predominated as causes of death. With a higher baseline mortality and a larger sample size, the PAMPER study included air evacuations with an average duration of 40 minutes [20], showing a one-third decrease in mortality with plasma-based transfusion representing a 10% out of the 30 % mortality rate in the control arm.

Three secondary and pre-planned analyses of combined data from the PAMPER and COMBAT studies broaden the reflection. Pusateri notes that the survival of haemorrhagic trauma patients is decisively but not independently conditioned by transport duration on one the hand and prehospital transfusion on the other [21]. As in the observational wartime data reported by Howard, prehospital transfusion (PHT) could thus buy time. In Iraq and Afghanistan, the time to reach the surgical unit with a dense network of surgical units and numerous dedicated helicopters had been reduced to one hour. In Sahel, on an extended operational theatre and with a low density of aerial means, this duration was of 145 minutes. It is easy to imagine that such delays could be observed in a high-intensity conflict [10,22]. Analysing the interactions between administered blood products, Guyette concludes that the PRBC-Plasma combination could be more effective than plasma alone [23]. Infusion of crystalloids alone was associated with increased mortality compared to any blood products. REITZ, on the other hand, finds a higher interest in PHT for blunt traumas [24].
In 2022, two European studies (PreHo-Plyo [25] and Rephill [26]) evaluated the contribution of PHT in a trauma context during peacetime. The outcome measures varied. They focused on correcting the INR for one and lactate clearance for the other. No statistically significant differences were found.

As disparate as their results may seem, these four reliable studies agree on three criteria as to indicate successful use:

- transport duration must be long enough to observe a benefit;
- transfusion chronology:
  - the procedure must be initiated as soon after injury as possible to break the chain of coagulopathy and shock. These time frames in the studies were as follows: Pamper <30 minutes, Combat 24 minutes, Rephill 56 minutes, Preho-plyo 51 minutes;
  - the procedure must be effectively carried out as expected. This was the case in the Pamper study for 90% of patients, in Combat 32%, Rephill 40%, and Preho-plyo 25%.
- The casualty must have sustained severe injuries in order to gain a benefit from PHT. But if too seriously injured, the casualty will stand very little chance of survival. Thus, the mortality rate in the control group of Pamper was of 33%, in Combat 10%, in Rephill 45%, and in Preho-plyo 15%).

These criteria are consistent with the results observed in Iraq, Afghanistan, and Sahel.

4. What are the risks?

According to estimates, the baseline mortality rate of the population of interest appear to range from 20 to 40% [27], and the expected benefit of prehospital transfusion places the known risks of transfusion accidents (AHTR, DHTR, FNHTR, TRALI) in a very particular perspective. The latter being 10 to 10^5 times less likely than the expected benefit of prehospital transfusion [28].

LABARTHE discusses the technical and legal aspects of prehospital transfusion [29]. The first constraint is to have an immunocompatible blood product regardless of the injured person's blood type, in order to avoid a major immediate incompatibility

	PAMPer	COMBAT	REPHILL	Preho-PLYo	TUCKER
Intervention	Up to 2 units of thawed plasma	Up to 2 units of plasma thawed on demand	Up to 2 units of packed red blood cells P RBC and 2 units Lyophilized plasma	Up to 4 units of lyophilized plasma	up to 2 RBC and 2 plasma or 2RBC and 2 lyophilized plasma
Comparator	0.9% saline and/or RBC	0.9% saline	0.9% saline	crystalloids	RBC or RCP or RBC+Plasma
Number of patients randomized to receive prehospital blood products	230	65	199	76	909
ISS [IQR]	22 (14-33)	27	36 (25-49)	29(12-48)	30 - 33
time form injury to hospital arrival (mins)	30	24	56	51	80 à 96
24-h mortality (%)	13,9	12	not reported	13,2	4130,00%
30-day mortality (%)	23,2	10	43	15	5000%
Receipt of full study dose of blood products in prehospital period (%)	90	32	45	15	10000%

RBC = Red Blood Cell
RCP = Red Cell and Plasma
ISS = Injury Severity Score

accident. The second difficulty is to simplify the choice of product. Indeed, each one has its own mode of preparation, storage, conservation, and transport. The third challenge is to ensure the safety of the transfusion. There is no derogation in France for the prehospital phase, which is subject to the same regulatory constraints as hospital transfusion. Prehospital transfusion is carried out in a specific context that combines vital emergency, high decision-making related stress, a race against time, and the optimization of chances of survival. In the fluctuating prehospital setting, logistics should not add a constraint. Too much variety in choice (grouping, product family) and a too lengthy process of preparation could lead to "logistical" and dispensing errors.

To further reduce the risk, simple actions exist (donor preselection, bedside control, group choice). The latter has little impact on the feasibility (simplicity, efficiency, logistical constraints) of transfusion. Neither VITALIS [12] nor TRAVERS [10], for French data, reports any complications following a prehospital transfusion.

5. Are these considerations not just the concerns of yesterday's war?

The modification of the caretaking conditions of the wounded – triggered by the renewed outbreaks of high-intensity conflicts – completely disrupts evacuation timing. The same concerns can apply to low-footprint counter-terrorism operations, which gave rise to the concept of "prolonged field care." The British research team of Porton Down has focused on building experimental models to explore this concept. Among the work of this team, we highlight that of Watts S and al, who, using swines as a model of haemorrhagic injury that closely resembles one of a severely injured and constantly fatal combat casualty in the absence of treatment, synthesizes its outcome [30]. In summary, in the context of delayed surgical haemostasis through an 8-hour medical evacuation, the use of blood products is the best possible option. Indeed, even if statistical significance was not achieved in the animal survival rate (9/9 with blood products and 7/9 with crystalloids), the hemodynamic and metabolic consequences of resuscitated shock were much less severe with blood products. In addition, resuscitation with crystalloids required three times the volume and more frequent therapeutic interventions. This argues for greater practicality in the use of blood products amidst human and logistical constraints in high-intensity conflicts.

To conclude

Despite significant progress in both civilian and military settings, there is still room for improvement, mainly with regard to death by haemorrhage. This type of avoidable mortality happens early on, and the pre-hospital phase represents a window of opportunity for which transfusion seems to be the most promising therapeutic intervention. The criteria for effectiveness are those that can lead to its implementation as quickly as possible. These conditions are simplicity and availability.

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Préparer la transfusion de l'avant de demain : ne pas réinventer la roue

Imagine tomorrow's forward transfusion: don't reinvent the wheel

A. Comin-Gokalsing[1], M. Lemonnier[1], C. Martinaud[2]. FRANCE

Résumé

Le changement de paradigme représenté par le « combat de haute intensité » impose une adaptation de la chaine de prise en charge des blessés. Considérant l'impact de la transfusion sanguine sur la morbi-mortalité de ces blessés, les modifications à apporter au soutien transfusionnel sont également de taille, afin de maintenir un standard de soins conforme aux recommandations internationales sur la prise en charge du choc hémorragique, s'appuyant notamment sur une disponibilité précoce en produits sanguins. La connaissance de l'histoire de la transfusion est une aide précieuse dans la mise à niveau de la capacité transfusionnelle. A travers trois thèmes, nous présenterons en quoi les données historiques peuvent être intégrées dans l'élaboration d'une future politique transfusionnelle de l'avant. Dans un premier temps, nous rappellerons la place centrale de l'immuno-hématologie et des différents produits sanguins, et dans quelle mesure ils peuvent participer de l'adaptation de la chaine transfusionnelle. Puis nous aborderons la question place des substituts aux produits sanguins, soulignant leur intérêt et leurs limites mais aussi les conditions de leur utilisation future. Enfin, nous verrons quelles données disponibles permettent de modéliser l'organisation du soutien transfusionnel de demain. Ensemble, nos données confortent l'importance d'une médecine transfusionnelle totalement transversale, du donneur au receveur, prenant en compte, dans une vision holistique, tous les éléments de cette chaine, au bénéfice des patients.

Mots clés : Transfusion Sanguine, Produits Sanguins, Médecine Militaire

Abstract

The paradigm shift represented by "high-intensity combat" requires adaptation of the injured patient care chain. Considering the impact of blood transfusion on the morbidity and mortality of these patients, significant modifications to transfusion support are also necessary to maintain a standard of care in line with international recommendations for the management of hemorrhagic shock, relying notably on early availability of blood products. Knowledge of the history of transfusion is a valuable aid in upgrading transfusion capacity. Through three themes, we will present how historical data can be integrated into the development of a future transfusion policy for the front line. First, we will recall the central role of immuno-hematology and various blood products, and to what extent they can contribute to the adaptation of the transfusion chain. Then, we will address the clinical relevance of blood products substitutes, highlighting their benefits and limitations, as well as the conditions for their future use. Finally, we will examine available data for modeling the organization of future transfusion support. Altogether, our data confirms the importance of a fully transversal transfusion medicine approach, from donor to recipient, considering, in a holistic view, all elements of this chain, for the benefit of patient.

Keywords: Blood Transfusion, Blood Product, Military Medicine.

Introduction

Aujourd'hui, nous assistons à un remodelage des armées françaises pour se préparer au « combat de haute intensité ». Alors que celles-ci n'ont pas été exposées à ce type de conflit depuis plusieurs décennies, le SSA ne fait pas exception quant à la nécessité de s'adapter à ce défi. En effet, que ce soit au Mali ou en Afghanistan, lorsqu'un soldat est gravement blessé sur le terrain, ce dernier se retrouve sur le sol français en 24h, pris alors en charge par les équipes des Hôpitaux d'Instruction des Armées concernés. Cependant, si la supériorité aérienne n'est plus assurée ou que les délais d'évacuation stratégique sont allongés, le parcours de soin doit alors être repensé dans son intégralité afin de garantir une prise en charge optimale. La prise en charge transfusionnelle des blessés de guerre est un élément clé de sa survie. Si l'organisation actuellement en place est parfaitement adaptée à un contexte dans lequel les évacuations tactiques et stratégiques permettent un respect des meilleures recommandations de prise en charge transfusionnelle, et dans lequel les afflux massifs sont rares, un allongement de ces temps et/ou une augmentation majeure du nombre de blessés obligerait à repenser cette organisation. Les enjeux de ce changement de paradigme sont majeurs compte-tenu de l'impact de la transfusion sur la morbi-mortalité du blessé de guerre. Pouvant paraître totalement inédites, une partie de situations engendrées par les

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conflits de haute intensité ont cependant déjà été rencontrées lors de conflits antérieurs, et si la médecine transfusionnelle est une discipline relativement récente, de nombreuses leçons peuvent être néanmoins tirées des données antérieures. Que ce soit sur le plan logistique, de la nature des produits sanguins ou même des pistes d'innovation qui ont été explorées, la connaissance de cette histoire de la médecine transfusionnelle est un atout majeur dans l'appréhension des situations futures. S'il faut préparer la guerre, pour avoir la paix, il faut connaitre le passé pour maitriser le futur. A travers trois exemples que sont les produits sanguins, les innovations en matière de substituts du sang et l'organisation de la transfusion de l'avant, nous montrerons comment les enseignements de l'histoire de la transfusion peuvent être mis à profit pour apporter une réponse à l'élaboration d'un soutien efficace, adapté aux nouvelles conditions d'emploi des forces armées.

1/ Ce que nous apprennent les produits sanguins du passé

A) L'importance de la sécurité immuno-hématologique

La sécurité transfusionnelle est intimement liée à la médecine transfusionnelle. En France, la tragédie du sang contaminé par le VIH demeure un rappel impérieux de sa nécessité et de la rigueur permanente qui doit être appliquée à la maîtrise des risques dans cette discipline. Aujourd'hui, l'aspect infectieux est très souvent l'élément le plus pris en compte, il ne doit cependant pas faire oublier l'importance capitale de la prise en compte du risque immuno-hématologique. Si le système ABO et ses règles de compatibilité sont enseignées très tôt à tous les professionnels de santé, cela témoigne de sa place fondamentale et rappelle que c'est sa découverte et sa prise en compte qui ont permis les premiers succès de la transfusion. Il est vrai que la découverte, en 1628, du système circulatoire par William Harvey a été très rapidement suivie de la première transfusion sanguine, de sang animal, chez l'homme le 15 juin 1667 par Jean-Baptiste Denis [1, 2]. Néanmoins, les succès ne furent qu'aléatoires et condamnèrent pour un temps la pratique de la transfusion. Lorsqu'en 1900 le viennois Karl Landsteiner, découvre lors du mélange de sérum de ses collaborateurs que dans certains cas les globules s'agglutinent, il émet l'hypothèse que les sérums pouvant agglutiner les globules possèdent une substance appelée agglutinine et défini trois catégories d'individus : c'est la naissance du système ABO. Avant la très large utilisation du sang au cours du premier conflit mondial, par exemple par Emile Jeanbrau, médecin-major à l'hôpital de Biarritz, qui mettra sa méthode au point lors de sa mobilisation et transfusera de nombreux blessés, un Américain, en 1913 publiera la première série de patients traités sans incident transfusionnel, et ce, grâce à l'introduction de la détermination du groupe sanguin ABO des unités transfusées [3]. C'est la naissance de la qualification biologique des dons, élément central de la chaine transfusionnelle, dont la liste des analyses ne va cesser de croître au fil des décennies : de la syphilis aux arboviroses…

Cette inflation, justifiée, ne doit pas faire oublier l'essentiel : l'accident ABO tue et aucune dérogation ne doit être autorisée aux règles de cette compatibilité. La mise à disposition de quantité importantes de produits sanguins, la projection toujours plus près des blessés, la collecte en situation dégradée ou bien encore l'échange de produits sanguins ne doivent jamais faire oublier cette notion essentielle dont l'importance doit toujours être rappelée et mise en perspective avec le niveau de gravité des autres risques. Ainsi, la détermination du groupe sanguin du receveur est-elle une préoccupation qui doit être constante lorsque de nouvelles stratégies transfusionnelles sont imaginées.

B) Les plasmas lyophilisés

Le plasma lyophilisé est un produit sanguin qui illustre bien l'intérêt de procédés anciens dans la prise en charge moderne du choc hémorragique. Il s'agit, en France, d'une spécificité militaire remontant à la seconde guerre mondiale. Mis au point par Strumia dans l'entre-deux guerre, les armées américaines l'utiliseront largement à la fin de la seconde guerre mondiale, en particulier en Afrique du Nord où exerce le futur médecin général Jean Juillard [4]. De retour à Paris, il participera à la mise au point de la lyophilisation au sein du Service de Réanimation et de Transfusion des Armées, futur Centre de Transfusion Sanguine des Armées, en compagnie du vétérinaire Hénaff. La préparation du plasma lyophilisé est demeurée, en France, une spécificité des Armées, qui n'ont quasiment jamais cessé de le préparer, au gré des conflits, adaptant ses caractéristiques aux contraintes réglementaires nationales et aux besoins des armées. Préparé, principalement, à partir d'un mélange de plasma d'aphérèse de groupe A, B et AB, sécurisés par un procédé physico-chimique d'atténuation des pathogènes (l'amotosalen, composé chimique intercalant des acides nucléiques, y formant des liaisons covalentes sous l'action des UV-A), il se présente sous la forme d'un lyophilisat permettant après reconstitution par 200 ou 250 mL d'eau pour préparation injectable d'obtenir environ 215 ou 265 mL de plasma thérapeutique. La lyophilisation, étape spécifique de la préparation de ce plasma, est obtenu par un processus de cryodessication (élimination de l'eau sans passage par l'état liquide), d'où l'appellation de plasma cryodesséché. Il se conserve entre 2 et 25°C et se reconstitue en moins de 6 min. Universel pour le groupe sanguin, il se comporte comme un plasma AB [5]. Produit sanguin hautement symbolique de la prise en charge militaire des blessés de guerre, le plasma lyophilisé à vu sa place dans la prise en charge du choc hémorragique et traumatique renforcée par les études les plus récentes, démontrant le bénéfice en termes de survie d'une transfusion précoce lorsque les délais de prise en charge pré-chirurgicaux sont supérieurs à 20 min [6].

Les enjeux actuels se concentrent autours des capacités des rares centres dans le monde capables (et autorisés) de le préparer (actuellement le Centre de Transfusion Sanguine des Armées français, la Croix-Rouge allemande, l'institut Sud-Africain de la Transfusion et le groupe pharmaceutique Octapharma). Ces relatives contraintes imposent une gestion au plus juste des stocks et des indications. A ce titre, la péremption actuelle est un élément critique : produit sanguin de l'urgence vitale immédiate en milieu isolé, l'organisation de la rotation des stocks est une difficulté parfois majeure. L'augmentation de sa durée de conservation ne doit pas être un sujet interdit. Les données historiques du CTSA rappellent que dans les années 1960, il était possible de le conserver jusqu'à 7 ans ! L'utilisation d'un flacon en verre, qui peut être considéré comme un point faible, malgré les très rares cas rapportés de casse, n'est pas le fait d'une absence d'innovation : de nombreux essais ont été réalisés afin d'y substituer des contenant en plastique de tout genre. Toutes ces tentatives se sont révélées infructueuses, objectivant une forte altération des caractéristiques du plasma par rapport au flaconnage de verre. Aujourd'hui encore, le développement

d'un plasma lyophilisé en poches plastiques est un objectif poursuivi par de nombreuses équipes ou industriels. Force est de constater qu'aucune n'est encore autorisée, quand les 4 produits disponibles sont conservés en flacon de verre…
Bien entendu, ce produit sanguin peut être amélioré. Plusieurs pistes peuvent être explorées. L'ajout de composants plaquettaires en lyophilisant des plasmas riches en plaquettes pourrait améliorer l'hémostase primaire au cours du choc hémorragique, l'apport précoce ce concentrés plaquettaire étant associé à une réduction de la mortalité, et les thrombosomes (concentré de plaquettes lyophilisés, en cours de développement) ayant démontré des effets prometteurs dans les modèles pré-cliniques [7]. Une autre possibilité pourrait être d'ajouter à ce plasma avant lyophilisation des produits de sécrétions de cellules stromales mésenchymateuses. Ces cellules multipotentes possèdent des capacités d'immunomodulation et de protection cellulaire vis-à-vis du stress oxydatif (deux composants impliqués dans la morbidité du choc hémorragique) qui peuvent être médiées par leurs produits de sécrétion, ou microvésicules, qui sont lyophisables [8].

C) Le sang total

Le sang total est un produit sanguin labile autorisé en France, conservé 21 jours entre +2 et +4°C, exclusivement de groupe O, issus de donneurs sans anti-A ou anti-B hémolysant. La maxime « Le tout est plus que la somme de ses parties », attribuée à Aristote, est particulièrement applicable au sang total. En effet, malgré l'évolution des techniques de préparation des produits sanguins et dans une logique quasi pharmacologique de ne transfuser qu'une partie des dons (attitude renforcée par l'importance du risque infectieux transfusionnel, dont la catastrophe du VIH dans les années 1980 a fait un enjeu non négociable, et qui incite à ne pas transfuser plus que ce qui est requis), de nombreuses données rappellent une évidence : les hémorragies massives requièrent des transfusions équilibrées de globules rouges, de plaquettes et de plasma. Plusieurs éléments doivent être rappelés, qui soutiennent le recours au sang total dans ces situations. La transfusion de sang total a permis d'assurer le soutien transfusionnel des blessés de guerre au cours de nombreux conflits, même après la mise au point des techniques de séparation. Au Vietnam, par exemple, au maximum d'intensité de cette guerre, plusieurs dizaines de milliers d'unités ont été transfusées par mois, et entre 1967 et 1969 environ 364,900 unités ont été transfusées [9]. D'autres exemples pourraient être citées comme la guerre des six jours ou l'opération américaine en Afghanistan. L'utilisation du sang total permet d'apporter des globules rouges, du plasma et des plaquettes dans des proportions se rapprochant de la physiologie, tout en limitant fortement la transfusion de solutions de conservation. A titre d'exemple, un lot de transfusion massive composé de 6 concentrés de globules rouges (CGR), 6 plasmas et 1 concentré plaquettaire apporte 1055 mL de ces solutions quand l'équivalent en sang total apporte 378 mL Le corolaire de ce fait est que la manipulation, dans cet exemple, de 6 produits sanguins est plus commode que la gestion de 13.
Il faut également préciser que les constituants du sang total possèdent des propriétés non inférieures à l'équivalent fractionné. Ainsi, les globules rouges conservés jusqu'à 21 jours possèdent des qualités de transport de l'oxygène diminuées mais proches d'un CGR de même durée de conservation, tandis que les éléments plus classiquement évalués, et seuls contrôles de qualité actuellement obligatoires, que sont l'hémolyse et la quantité d'hémoglobine libre, sont strictement comparables [10]. L'étude des micro-érythrocytes de stockage (MES), paramètre basé sur une technologie innovante, permet d'évaluer in vitro le potentiel de recirculation des érythrocytes : sur une durée de 21 jours, le pourcentage de ces MES augmente mais reste lui aussi comparable à celui observé dans des CGR de la même durée de conservation, et inférieur à celui observé dans des CGR conservés 35 ou 42 jours [11]. Pour ce qui est des qualités du plasma, il est vrai que la conservation d'un plasma pendant 21 jours entre 2 et 6°C peut questionner sur ses qualités. Il faut néanmoins prendre en compte deux éléments. Premièrement, le plasma contenu dans le sang total est un plasma qui n'a jamais été congelé, contrairement au plasma frais congelé et décongelé. Il n'a pas non plus subi de procédé d'atténuation des pathogènes, qui peut être à l'origine d'altération de ses protéines, et certainement d'un certain degré de dilution. Rappelons que si le plasma « jamais congelé » est un produit qui n'est pas disponible en France, il est autorisé et utilisé aux USA avec une durée de conservation de 14 jours. Deuxièmement, les paramètres utilisés pour attester de la qualité d'un plasma thérapeutique sont aujourd'hui limité à sa composante « coagulation ». Les tests se résument à l'évaluation, plus ou moins exhaustive, de la quantité des facteurs de la coagulation ainsi qu'à des tests mis au point à l'origine pour évaluer le risque hémorragique des malades et non pas la capacité d'un plasma à produire un réseau fibrino-plaquettaire efficace ! Lorsque l'on s'intéresse à des évaluations plus globales à l'aide de la visco-élastométrie ou de la génération de thrombine, les différences sont en faveur de capacités hémostatiques conservées. Enfin, rappelons que la fonction hémostatique du plasma n'est pas la seule qui pourrait être utile au cours de la prise en charge du choc hémorragique : les effets sur l'endothélopathie ou sur l'immunomodulation sont également à prendre en compte, sans être pour le moment évaluées [12]. Quant à la composante plaquettaire, la conservation des plaquettes à « froid » pendant 21 jours, est évidemment un challenge.
Globalement, les études ont montré qu'elles conservent un potentiel à former des caillots efficaces. Cet aspect fait l'objet d'une présentation spécifique un peu plus loin dans ce manuscrit. Enfin, les résultats actuellement disponibles dans la littérature, principalement depuis son inscription en 2018 par la AABB (American Association of Blood Banking), ne montrent pas de surmortalité chez les malades traités par du sang total, et pourraient même être en faveur de son utilisation chez les plus graves [13, 14]. Aujourd'hui, l'utilisation du sang total dans la prise en charge des hémorragies massives d'origine traumatique est une réalité militaire pour plusieurs pays, notamment en Afrique subsaharienne mais aussi pour un certain nombre de trauma centers américains [15, 16]. En Europe, plusieurs essais cliniques sont en cours pour déterminer sa place [17]. Données d'autant plus importantes que son bénéfice hors des situations de choc hémorragiques traumatiques n'a pas été démontré et qu'une étude récente rapporte des effets indésirables graves chez le receveur, ce qui souligne l'importance de limiter son indication aux situations validées [18].

D) Les concentrés plaquettaires conservées au froid

Les concentrés plaquettaires conservés au froid constituent un dernier exemple de ce que la connaissance de l'histoire des produits sanguins peut apporter à l'élaboration des futures stratégies transfusion-

nelles. Aujourd'hui, les concentrés plaquettaires sont conservés à 22°C en agitation constante pour une durée allant de 5 à 7 jours, selon qu'ils ont bénéficié d'un procédé d'inactivation des pathogènes ou non. Ces contraintes sont quasi-incompatibles avec une utilisation en contexte opérationnel, encore plus si la zone de guerre est très éloignée du site de préparation du produit. Ce fait doit amener à se poser la question des raisons qui imposent ces contraintes. Il faut revenir à la fin des années 60 pour apporter une réponse à cette question. A l'époque, les plaquettes sont conservées à +4°C afin de limiter le risque d'infection transmis par leur transfusion, les bactéries se développant particulièrement bien à température ambiante dans ce produit sanguin. Néanmoins, l'essor de l'hématologie et des greffes de cellules souches en particulier, est alors à l'origine d'une demande toujours plus importante d'unités plaquettaires. La disponibilité du produit étant limitée, la question de la durée de vie des plaquettes après transfusion devient capitale. En effet, comme aujourd'hui encore, la première des indications de transfusions plaquettaires est la prophylaxie du saignement. Dans ce contexte, leur durée de recirculation après transfusion est le paramètre le plus important. Les études de Murphy ont alors clairement montré que la conservation à +22°C en agitation constante est associée à un doublement de cette durée [19]. Mais les capacités hémostatiques ne sont pas meilleures ! Une démonstration particulièrement parlante a été apportée par Valeri, transfusant des CP « froids » ou « chauds » à des volontaires sous aspirine, mettant en évidence un temps de saignement significativement plus court chez les volontaires transfusés en plaquettes froides [20]. Un éditorial de Kattlove dans le New England Journal of Medicine proposera, sans succès, à l'issue de cette période de remise en question, que « les plaquettes froides soient transfusées en situation hémorragique et les chaudes pour la prophylaxie » [21]. « One size does not fit all ! »

Depuis, l'intérêt pour les plaquettes froides a été remis à l'actualité et les armées américaines ont réintroduit ce produit, avec une durée de péremption à 14 jours, apportant de la flexibilité à son utilisation en missions extérieures. Une autorisation d'utilisation exceptionnelle a été accordée par la FDA et un essai clinique est en cours aux USA [22]. En dehors des Etats-Unis, l'utilisation de ces plaquettes est également envisagée, que ce soit par pour les hémorragies chirurgicales dans les hôpitaux éloignées des sites de préparations ou bien encore pour la gestion des stocks en période de pandémie, à Sars-CoV-2 par exemple, afin d'optimiser les dons rendus plus difficiles [23].

2/ Substituts des produits sanguins : apprendre des erreurs du passé

Si nous venons de montrer qu'il peut être judicieux de regarder en arrière afin d'explorer des idées émanant de travaux plus anciens, il faut également être capable de se souvenir des verrous identifiés, pour ne pas répéter les tentatives infructueuses du passé. Cette méthode peut s'appliquer au domaine de la recherche de substitut aux produits sanguins. Domaine de l'innovation aussi vaste qu'ancien puisque dès le XVIIème siècle, des potions à base de lait ou de bière ont été imaginées pour remplacer le sang dont les premières transfusions infructueuses avaient souligné les difficultés d'utilisation. En effet, si la perspective d'utilisation de substituts de l'hémoglobine semble prometteuse de prime abord, plusieurs études ont cependant montré leur application difficile en transfusion d'urgence, d'autant plus dans le cadre militaire. Parmi toutes les pistes explorées, rappelons les expériences des perfluorocarbone et celle des substituts de l'hémoglobine, qui présentent, malgré tout, aujourd'hui encore des pistes non dépourvues d'intérêt.

A) Les perfluorocarbones

Les perfluorocarbones (PFC) sont des composés halogénés gazeux de la famille des fluorocarbures. Ils ont la particularité de dissoudre de grandes quantités de gaz comme l'O2 ou le CO2, et ce jusqu'aux deux tiers de leur volume. Transportant l'oxygène dans l'émulsion qu'ils forment, ils permettent d'oxygéner les tissus, limitant les dommages tissulaires et les dysfonctions d'organes liés à l'hypoxie [24]. Les PFC étant bien plus polarisés que l'eau ou bien encore que les molécules d'hémoglobine, ils fixent mieux les molécules d'oxygène (le coefficient de fixation à l'oxygène étant proportionnel à la proportion d'oxygène apportée). De plus, si le fonctionnement de l'hémoglobine est très sensible aux modifications extérieures (pH, température, …), ces derniers paramètres n'ont que très peu d'effet sur les PFC, ce qui pourrait en faire un atout redoutable, notamment en milieu hostile. Actuellement utilisés en ophtalmologie comme remplaçant temporaire de l'humeur vitrée dans les chirurgies de détachement rétinien, leurs applications tendent à se diversifier avec une utilisation potentielle comme substituts de l'hémoglobine. Plusieurs problématiques demeurent. Dans un premier temps, les émulsions des PFC sont non miscible dans le sang et instables car les PFC sont sujets à la coagulation, la maturation d'Ostwald, la floculation ainsi qu'à la sédimentation, ce qui impose leur transfusion dans une solution émulsifiante. Les PFC nécessitent également une pression partielle en oxygène la plus haute possible afin de pouvoir fixer les molécules d'O2, ce qui n'est pas le cas des molécules d'hémoglobine. Ces composés posent également un problème assez récurrent puisque malgré leur capacité à transporter l'oxygène, ils provoquent une obligatoire hémodilution [25]. De plus, même si les effets secondaires des PFC lors des chirurgies rétiniennes ont été de multiples fois démontrées, ces derniers sont beaucoup plus controversés dès qu'il s'agit de les utiliser en tant que substituts sanguins. Les effets sont mal définis dans la littérature actuelle mais ces derniers sont des perturbateurs endocriniens et ont un retentissement néfaste sur le système nerveux, des cas de comas ont notamment été décrits [26].

Quelques produits ont déjà été largement étudiés depuis les années 1980. Le Fluosol-DA-20® (Fluosol, Alpha Therapeutics, Los Angeles, CA, USA), a été le premier et le seul substitut sanguin transportant de l'oxygène à avoir reçu l'approbation de la FDA en 1989, avant d'être retiré du marché en 1994, en raison des contraintes d'utilisation et des effets secondaires notables. Oxygent® (Alliance Pharmaceutical Corporation, San Diego, CA, USA) a été approuvé pour les essais de phase II en Europe et aux Etats-Unis [27]. D'abord prometteur pour réduire le besoin de don de sang au cours des chirurgies à haut risque hémorragique, les essais de phase III ont été arrêtés dans la mesure où les patients recevant Oxygent® présentaient un risque plus élevé d'accident vasculaire cérébral par rapport aux témoins recevant du sang de donneur. Perftec®, une émulsion de PFC approuvée pour un usage humain en Russie depuis 1996, et depuis 2005 au Mexique comme substitut sanguin ou encore Oxycyte® (Synthetic Blood International, Costa Mesa, CA, USA) ont montré des capacités de transport d'oxygène supérieure à celle de l'hémoglobine et font l'objet d'essais dans plusieurs

pays dans la prise en charge des lésions cérébrales traumatiques, des crises drépanocytaires ainsi que des infarctus (voir les études sur le site https://clinicaltrials.gov). Des études menées sur l'animal suggèrent que le PFC maintiendrait un métabolisme aérobique plus efficace qu'une solution saline dans le cadre des infarctus cérébraux, suggestion appuyée par images IRM montrant une diminution de la zone ombre ainsi qu'une diminution de la zone de lésion [28].

De nombreux autres produits ont été étudiés ou sont en cours d'essai. Ils conservent néanmoins des contraintes communes : des doses cumulées limitées, la nécessité de recourir à des solutions émulsifiantes à l'origine de contraintes d'utilisation (il faut réaliser cette émulsification extemporanément) et d'une hémodilution importante, et le recours à de hautes concentrations d'oxygène, ce qui limite aussi les situations au cours desquelles les PFC peuvent être utilisés. La levée de ces verrous est un préalable indispensable avant d'envisager leur utilisation en situation de guerre où leur place pourrait se situer comme celle d'une thérapeutique de « bridge » en attendant un produit sanguin ou pour les économiser grâce à leurs capacités de limiter les dommages tissulaires au cours des situations hypoxiques courtes et réversibles.

B) Les substituts de l'hémoglobine : Hemoglobin-Based Oxygen Carriers (HBOC)

La volonté de trouver un substitut à l'hémoglobine remonte à presque un siècle, avec le Dr. Amberson qui, en 1933, objective que l'hémoglobine bovine est capable de transporter l'oxygène dans des modèles animaux [29]. Le rêve serait de pouvoir créer une molécule agissant comme l'hémoglobine sans les problèmes immunologiques ou d'infections est un enjeu de santé et industriel majeur. Les HBOC incarnent cet espoir. Une molécule d'hémoglobine d'origine variée, souvent animale (bovine), couplée/modifiée avec une autre molécule permettant d'utiliser ces molécules d'hémoglobine hors de la cellule du globule rouge afin de faciliter le transport d'oxygène. Ces molécules transporteuses sont nombreuses, des plus simples aux structures les plus complexes : polymérisation avec du glutaraldehyde, « cross-linking », conjugaison à une enzyme antioxydante, ou encore encapsulation mimant les membranes naturelles et permettant une meilleure acceptation par le corps [30].

Plusieurs HBOC ont été mis au point, évalués dans le cadre d'essais cliniques et parfois commercialisés. On peut citer HemAssist® (Baxter Healthcare, Boulder, CO, USA) développé 1949 à 1999, Optro® (Somatogen Inc. in San Diego, CA, USA - Eli Lilyin Indianapolis, IN, USA) également arrêté en 1999, Hemolink® (Hemosol, Inc., Toronto, Canada) et Polyheme® (Northfield Laboratories, Chicago, IL, USA) tous deux retirés en 2009. Les causes de ses échecs sont variées mais l'exemple de PolyHeme® (Northfield Laboratories, Chicago, IL, USA) illustre bien les difficultés auxquelles ces substituts ont eu à faire face. Plusieurs études ont été menées pour tester son intérêt dans la prise en charge des hémorragies, deux ont été stoppées pour cause de réactions allergiques excessives mettant en jeu le pronostic vital et les autres l'ont comparées à des concentrés de globules rouges, mettant en évidence un effet sur la mortalité mais en association avec des effets secondaires qui l'ont condamné. Une méta-analyse des essais testant les HBOC parue en 2008 mettra un frein durable à leur évaluation en démontrant leur infériorité sur la survie de ces malades hémorragiques [31]. Il faut ici souligner, que dans une perspective de blessé de guerre, le meilleur comparatif n'est surement pas un produit sanguin, puisque les HBOC serviraient d'alternative en leur absence. C'est donc bien la tolérance qui doit être améliorée. Celle-ci a été depuis évaluée assez largement par Hemopure® (HbO2 Therapeutics LLC, Waltham, MA, USA) et a conduit à son utilisation en Afrique du Sud et dans le cas des refus de transfusion aux USA, avec une excellente tolérance à de grande quantité d'unités transfusées [32].

Ainsi, les HBOC présentent de nombreux avantages potentiels : facilement disponibles et non affectés par les conditions de stockage, ils pourraient donc être utilisés en situations d'urgence afin de pallier l'hypoxie tissulaire le temps que les globules rouges se régénèrent ou bien qu'une réelle transfusion puisse être réalisée. Cependant, les molécules d'hémoglobine seules présentent une certaine toxicité sur le long terme qui compromet leur utilisation. De plus, nous avons pu voir que la plupart des HBOC avaient été comparés en termes d'efficacité à la transfusion de globules rouges. La base de notre étude étant une pénurie potentielle de PSL à venir lors d'un combat de haute intensité. Il faudrait alors comparer l'utilisation des HBOC non plus à des transfusions de PSL mais à ce qu'il serait encore disponible sur le terrain. Ces nouvelles perspectives, qui peuvent sembler prometteuses, ne sont donc pas adaptées au contexte dans lequel nous travaillons, mais peuvent cependant se retrouver au cœur d'une prise en charge moins urgente sur le territoire métropolitain lorsque l'utilisation de PSL est impossible.

3/ Perspectives organisationnelles : des organismes de réanimation et de transfusion à l'élément mobile de transfusion des armées

Si le combat de haute intensité venait à nous faire repenser les paradigmes de prise en charge de nos blessés et donc la chaîne de transfusion, deux éléments seraient alors impératifs à prendre en compte dans le calcul des volumes à mettre à disposition. Deux éléments sont primordiaux : le nombre de blessés, notamment la cinétique de ceux à prendre en charge en choc hémorragique, et leur délai d'évacuation afin de prendre en compte la transfusion initiale mais aussi, éventuellement, au cours de la première semaine.

A) Quantité de PSL par individu

La détermination des volumes de produits sanguins à transfuser par blessé en situation de haute intensité est une donnée fondamentale. Les données du SSA au cours des opérations en territoire sahélo-saharien ont montré qu'en moyenne, un blessé hémorragique nécessite 3 CGR, 4 PFC, 1.8g de fibrinogène et une unité de sang total frais collecté sur place, au cours de sa prise en charge intra-théatre [33]. En étendant la durée prise en compte à la première semaine, on constate que cette quantité augmente, pour atteindre, parmi ces blessés hémorragiques, une médiane de 27 produits sanguins sur la première semaine (interquartile : 12 – 65), dont 17 au cours des 2 premiers jours (interquartile : 10 – 28), correspondant, en médiane, à 8 CGR – 7 Plasmas – 3 sang total, sur les 2 premiers jours [34]. Ces données sont en cohérence avec les données rapportées au cours des guerres de Corée, du Vietnam, d'Afghanistan ou lors des attaques terroristes, même si la plupart de celles-ci se concentrent sur les 24 premières heures [35].

B) Nombre d'individus à prendre en charge

Il paraît nécessaire de souligner que malgré une estimation théorique fine des quantités de PSL utilisées jusqu'à présent, la mo-

délisation des besoins sur le long terme est, elle, plus délicate. L'élément à déterminer est le nombre de blessés hémorragiques par unité de temps. Ce nombre de blessés dépend du nombre de militaires déployés et de l'intensité des combats. Cette intensité va alors déterminer la proportion attendue de blessés dont ceux en choc hémorragiques. En haute intensité, si on prend comme hypothèse de travail un nombre de 100 blessés par jour, on peut estimer entre 15 et 20 le nombre de blessés en choc hémorragique et ainsi déterminer la quantité et la qualité des produits sanguins à mettre à disposition. Ce calcul, à faire pour tous les niveaux d'intensité, devra ensuite être adapté aux temps de déploiement et à leur durée ! Il est également nécessaire de prendre en compte les autres composantes de la chaîne de prise en charge des blessés : l'objectif de tout soutien est bien évidemment de dimensionner sa capacité aux besoins, mais le scénario d'un conflit au cours duquel les capacités du SSA sont dépassées et se retrouvent inférieures au nombre de blessés ne peut pas être écarté. Ainsi, les capacités maximales de prise en charge sont déterminées par l'élément le plus faible de la chaîne de prise en charge : c'est alors le nombre de blessés pris en charge qui doit constituer la donnée dimensionnante du soutien transfusionnel, et non le nombre de blessés total. Ainsi, un travail de modélisation devient nécessaire pour déterminer les besoins nécessaires en temps réel sur un théâtre d'opération. Ceci implique deux composantes : tout d'abord, une collaboration étroite entre les services de santé et les acteurs militaires présents sur le terrain mais également une flexibilité de l'offre de soin proposée par le SSA. Cela commence déjà à été le cas, notamment avec le développement de l'ARCS (Antenne de réanimation et de chirurgie de sauvetage), l'idée est alors d'« amener le CTSA à l'avant ». Cette idée avait déjà été évoquée par Jean Julliard en Afrique du Nord, ainsi que par les Américains au Vietnam, qui, ne pouvant plus se reposer sur une chaine logistique aérienne, souhaitaient pouvoir collecter, préparer, contrôler, stocker et délivrer les produits sanguins nécessaires. Une des perspectives alors envisageables serait un élément mobile de transfusion : ce projet est en cours de réalisation par certaines forces armées. Ainsi, même si les défis à relever semblent colossaux, les alliances politico-militaires peuvent permettre d'unir les moyens ainsi que les expériences et procédures de chacun afin de pouvoir assurer un soutien adapté aux besoins grandissant, tout en respectant les principes fondamentaux de la sécurité transfusionnelle. De tels modules doivent être développés en collaboration avec les autres nations disposant de centres de transfusion. Cependant, le cahier des charges est exigeant puisque ce dernier doit être facilement déployable, doit pouvoir couvrir les besoins des blessés en opération tout en assurant la sécurité transfusionnelle de ces derniers. Effectivement, nous savons bien que la prise en charge dans l'urgence, d'autant plus dans un environnement hostile, expose à une adaptation des protocoles en place en fonction des possibilités offertes par le terrain. Les protocoles établis doivent donc être d'une rigueur exemplaire afin de réduire au maximum les risques d'accident transfusionnel par la suite.

Conclusion

La médecine transfusionnelle est une discipline complète qui ne peut se résumer à la préparation des produits ou au raisonnement biologique pur. La connaissance transfusionnelle actuelle est le fruit de longs siècles de recherche et d'essais, ayant permis d'accumuler une grande quantité de données. Elle permet une prise en charge efficace d'un blessé guerre en choc hémorragique par l'organisation d'un soutien transfusionnelle. Cependant, les modalités des conflits à venir nous impose de repenser ses modalités de mise en œuvre. Les données historiques concernant les besoins transfusionnels au cours des conflits de haute intensité, les solutions alternatives et innovantes sont nombreuses, il est plus que jamais nécessaire de s'y replonger afin de pouvoir innover sans dépenser les ressources disponibles en retombant dans les erreurs du passé : "I never lose. I either win or learn" (Nelson Mandela).

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Aspirant Médecin du Service de Santé des Armées, Agathe COMIN-GOKALSING a intégré les Ecoles Militaires de Santé de Lyon Bron en 2017. C'est lors de son cursus d'étudiante en médecine qu'elle découvre la recherche via un master de niveau 1 dans ce domaine, grâce auquel elle a pu effectuer un stage à l'Institut de Recherche Biomédicale des Armées. Désormais en cinquième année de médecine, au sein de la promotion Médecin Colonel Henri FRUCHAUD ; Agathe COMIN-GOKALSING a souhaité participer à la rédaction de cet article qui s'inscrit dans une certaine continuité.

ASPIRANT MÉDECIN Maya LEMONNIER

Incorporée à l'Ecole de santé des armées en 2018, l'AM LEMONNIER Maya est actuellement en 5ème année de médecine au sein de la promotion Médecin Colonel FRUCHAUD. Se dirigeant tout d'abord vers un cursus de médecine générale, elle réalise les différents stages de son cursus universitaire entre les hôpitaux civils de Lyon et hôpitaux militaires français.

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Field management of Non-Compressible Torso Haemorrhage Perspectives, researches and hopes

Gestion sur le terrain des hémorragies non compressibles : perspectives, recherches et espoirs

G. Boddaert[1,2], C. Baltazard[1], R. Foillard[3], AL. Ravaine[3], H. DE.Lesquen[2] . FRANCE

Abstract

Background: Warfare injuries to the trunk, namely the thorax and the abdomen, are relatively rare. However, Non-Compressible Torso Hemorrhage (NCTH) account for almost half of potentially survivable bleeding casualties.
Methods: This narrative review of the literature describes the tools available to manage NCTH on the field. Authors did not perform a systematic review or meta-analysis.
Results: Four points 4 points are declined. First, we describe our medical support and the far forward damage control surgery concept. Second, we address mechanical tools and especially Resuscitative Endovascular Occlusion of the Aorta (REBOA). Third, we deal with chemical agents which are of two types: local and systemic. Finally, we give a word about are blood derived products.
Conclusion: There are few devices available in clinical practice and relevant data are scarce. As of today, there is no ideal haemostatic device/agent and combination is often mandatory.

Keywords: Military Medicine, Preventable Death, Haemorrhage, Bleeding, Torso

Résumé

Contexte : En contexte de guerre, les lésions du tronc, à savoir du thorax ou de l'abdomen, sont rares. Néanmoins, les hémorragies non compressibles du tronc représentent environ la moitié des blessés hémorragiques potentiellement sauvables.
Méthode : Cette revue narrative de la littérature décrit les outils disponibles pour la prise en charge des hémorragies non compressibles du tronc. Les auteurs n'ont pas effectué une revue systématique ni une méta-analyse.
Résultats : Quatre points sont déclinés. En premier lieu nous décrivons notre modèle de soutien médical et abordons le concept de chirurgie de l'extrême avant. En second lieu, nous exposons les différents moyens mécaniques et insistons, en particulier, sur l'endoclampage aortique. En troisième lieu, nous traitons des agents chimiques qui sont de 2 types : locaux et systémique. Enfin, nous évoquons les produits dérivés du sang.
Conclusion : Les dispositifs et agents disponibles en pratique cliniques sont peu nombreux et leur niveau de preuve scientifique modéré. A ce jour, il n'existe pas de dispositif ou d'agent hémostatique idéal une combinaison de ces derniers est souvent nécessaire.

Mots-clés : Médecine Militaire, Morts évitables, Hémorragie, Saignement, Tronc

Injuries to the trunk, namely the thorax and the abdomen, are relatively rare. In recent conflicts, they account 7.5% for the thorax and 6.9% for the abdomen(1).

In the literature, a distinction is made between non survivable and potentially survivable death. Potentially survivable death account for 25% of combat related death. Bleeding is the main cause and accounts for 90% of those potentially survivable death(2). Non-Compressible Torso Hemorrhage (NCTH) is the main cause of death and account for 48% of Hemorrhages(3). If we have a look at where and when combat casualties die, we observe that the curve has trimodal shape with the majority of deaths occurring the first hour before reaching the first surgical facility(4). This short communication focuses on the tools we have to manage NCTH on the field during this time.

NCTH were defined in 2012 by Morrison and Rasmussen. They proposed 2 criteria: firstly, a major injury to the lung, a solid organ, the pelvis or a major vessel, secondly, physiological derangements with a systolic blood pressure less than 90 mmHg, serum lactates more than 4 mmol/l and the need for immediate intervention(5).

Our talk is articulated in 4 points: the concept of medical support, the mechanical tools, the chemical agents and lastly the products derived from blood.

Concerning the French concept of medical support, care under fire is provided within the first ten minutes after injury. Forward medicalization is provided in the first thirty minutes. The casualty is then evacuated before the first hour to receive damage control surgery less than 2 hours after the injury. The idea is to bring the surgical team closer to the point of injury to provide far forward damage control surgery. Thus light forward surgical teams have been developed and can be deployed by helicopter to operate under a tent or in a building but are also able to perform in flight surgery (figure 1).

The second point concerns the mechanical tools. The first is the pelvic binder to close the pelvis and limit hemorrhage. We will

Figure 1: The French far forward surgery concept.

not insist but of note 50% of pelvic binder are applied incorrectly(6). The 2nd tool that is available is the Abdominal Aortic and Junctional Tourniquet (AAJT®, Speer Operational Technologies®, Greenville, SC, USA) which combined a large tourniquet and a pneumatic bag that allows abdominal aortic compression. A recent systematic review showed an occlusion rate of only 52% with as main obstacle, an intolerable pain. Nevertheless, the junctional application had proven to be effective in 100% of cases(7). The 3rd available tool is intra-aortic-occlusion balloon also named Resuscitative Endovascular Balloon Occlusion of the Aorta (REBOA). It is an alternative to thoracotomy and laparotomy for aortic cross clamping. This technique was described in the fifties by Colonel Carl Hughes(8). Three aortic occlusion zones are defined: Zone 1 is the descending thoracic aorta from the left subclavian artery to the diaphragmatic hiatus. Occlusion in this zone allows control of subdiaphragmatic hemorrhages. Zone 2 is the para-visceral aorta and is a no occlusion zone. Zone 3 is the infrarenal from the renal arteries to the aortic bifurcation. Occlusion in this zone allows control of pelvic and junctional hemorrhage to the groin(9). The main limitations of this technique are the vascular access and the occlusion time due to the visceral ischemia below. It is considered that zone 1 should not be occluded for more than 30 minutes and zone 3 for more than 90 minutes(10). Two main Balloons are available on the market. One Japanese (Rescue Balloon®, Tokaï Medical®, Kasugai, Japan) 7 Fr. compatible but requiring the use of a guidewire and with no possibility of monitoring blood pressure. The device we have chosen for the French army is the balloon developed by our North American colleagues (ER-REBOA®, Prytime Medical®, Boerne, TX, USA). It is also 7 Fr. compatible with an atraumatic tip, no need for guidewire and the possibility of monitoring blood pressure above.

The French Clinical Practice Guidelines (CPG) for REBOA used in the field define 3 criteria: a penetrating abdominal or pelvic lesion, a systolic blood pressure less than 70 mmHg and an intensive resuscitation including transfusion and norepinephrine at more than 3 mg/h. Concerning the neck, the thorax and the extremities we consider there are no indications for REBOA. In case of abdominal injury, REBOA is placed in zone 1. In case of pelvic or junctionnal injury, REBOA is placed in zone 3. To mitigate ischemic consequences, partial REBOA techniques have been described. The idea is to maintain proximal systolic blood pressure of more than 80 mmHg with a distal perfusion. Intermittent techniques have also been described. No formal protocol has been validated at the moment(11). Of note, a balloon dedicated to partial REBOA has been recently developed (p-REBOA PRO®, Prytime Medical®, Boerne, TX, USA). Few works report the use of REBOA in austere conditions. One paper written by our Belgian colleagues reports 3 patients who all survived(12). One paper written by our North American colleagues reports 20 patients, including 17 in zone 1, who also all survived(13).

Experimentally, insufflation of a pneumoperitoneum has been described in the 2000s with improved benefits on blood pressure and blood loss(14). Portable insufflators have been designed(15). This technique seems abandoned. The main limitations were the risk of tension pneumothorax in case of diaphragmatic injury and gas embolism in case of venous injury. An expanding polyurethane foam (RESQFOAM®, Arsenal Medical®, Waltham, MA, USA), developed by Arsenal Medical is largely reported. The concept is to inject through the umbilicus, with a kind of gun, a combination two fluids which when mixed create an expansive polyurethane foam that allows tamponade of the abdominal cavity. Results are encouraging despite ischemic compression injuries have been described on the bowel(16). A clinical trial, called REVIVE, is planned from April 2023(17). Another mechanical technique reported in experimental practice is insufflation of an intra-abdominal balloon. This balloon is also introduced through the umbilicus and then inflated allowing intra-abdominal tamponade and even an aortic occlusion if combined with an external compression(18)(19). In the same way, some authors have proposed the combination of an intra- gastric balloon with an abdominal tourniquet to occlude abdominal aorta. This has been described as GROA for Gastrooesophageal Resuscitative Occlusion of the Aorta. The results seem equivalent to those of the REBOA with no more gastric mucosa injury and the possibility to get rid of vascular access difficulties(20)(21).

The third point of our talk concerns chemical agents which are of two types: local and systemic. Regarding local chemical agents, a high-pressure fibrin sealant foam was proposed in the years 2000 by Kheirabadi et al. with encouraging results but without secondary developments(22). Another fibrin sealant with an expansion power of 4 hundred was proposed by Flaus et al. A clinical trial was to start in 2014 but without inclusions(23). Many other local chemical agents have been developed whether sponge-like, flowable material or self-assembling peptide, but they require an application on the bleeding site that is not suitable on the field(24).
Regarding systemic agents, the first is tranexamic acid with an efficiency well demonstrated by the study CRASH-II but also by the study MATTERS in the military setting(25)(26). From an experimental point of view, injectable, polymers have also been developed. These are polymers that create multiple bonds to fibrin, densify and stabilize the clot(27). The last category concerns nanoscale therapies with agents that are assimilate to synthetic platelets. Those agents are able to activate platelets, interact with GPIIbIIIa protein and promote aggregation at the bleeding site.
However, the main limit of these nano-therapies remains thrombotic complications

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especially in the lung and the liver(28)(29)(30).

Last but not least are blood derived products: fibrinogen, red blood cells, dried plasma, warm fresh whole blood, cold stores whole blood and dried platelets, still experimental. These are dealt in other talks and are not detailed here.

In conclusion, there are few devices available in clinical practice and relevant data are scarce. At the moment, there is no ideal hemostatic device/agent and combination is often mandatory. However, several therapies are promising but require more developments.

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Presented at the ICMM World Congress in September 2022 in Brussels

Prolonged field care: French SSBN medical training for the past 50 years

Médecine de l'avant sous les mers, cinquante ans de formation spécifique des Médecins embarqués sur sous-marins nucléaires lanceurs d'engins.

E.Petit[1] , S.Geromin[2], A.Picot[2], J.Sinquin[1]; F.Leclercq[3].FRANCE

Asbtract

The French nuclear deterrence mission must be permanent and effective and rely on both air and ocean components. To ensure the credibility and continuity of the mission, French SSBNs follow one another in mission without interruption. Their medical facilities are a field hospital with large capabilities but with a small optimized team: a general practitioner with skills in traumatology and surgery, a general practice nurse and a nurse anesthetist.
They have to face extreme isolation without any outside help to avoid communication and, by the way, indiscretion. This team is reinforced by stewardship crew members as lifeguards and stretcher-bearers and the deputy commander has surgical assistance skills.
This format requires a high level of specific training, both at the university and at the hospital, which represents a major challenge. The first level concerns environmental constraints (living in confined atmosphere, medical management of nuclear crisis, hyperbaric medicine) and the second is the acquisition of medical and surgical skills to get a large autonomy.
The whole crew is also trained to the combat rescue with adaptations to the industrial and nuclear environment of the SSBN. This adapted combat rescue has 3 levels of skills for combat or accident situations with many injured sailors. Objectives are to continue the conduct of the SSBN for the naval operations and to guarantee maximum survivability for the crew.
For 50 years, this medical model has been effective and prolonged field care is the usual medical practice on French SSBNs.
Keywords: French Submarines, SSBN Medical Team, Medical Team of Nuclear Deterrent Mission, Prolonged Underwater Care, Advanced Medical Care, Medical Autonomy, Isolated Medical Practice, Combat Rescue Adapted on Submarine, Hyperbare Medicine, Nuclear Medicine, Medical Training, Submarine Force Health Service, Naval Medicine

Résumé

La mission de dissuasion nucléaire française est basée sur sa crédibilité et sa permanence. Elle s'appuie à la fois sur les composantes aériennes et océaniques. Pour assurer la crédibilité et la continuité de la mission, les sous-marins nucléaires lanceur d'engins (SNLE) français se succèdent en mission sans interruption et sans moyen de communication extérieur.
Sur le plan du soutien sanitaire, le SNLE s'est doté d'un hôpital de campagne embarqué avec de grandes capacités et d'une équipe santé optimisée : un médecin militaire généraliste avec des compétences spécifiques, un infirmier généraliste et un infirmier anesthésiste. Ils doivent faire face à un isolement extrême sans aide extérieure pour éviter toute indiscrétion en communicant. Cette équipe est renforcée par les membres de l'équipe d'intendance en tant que sauveteurs-brancardiers, et par le commandant en second qui acquiert des compétences d'aide opératoire.
Ce format exige un niveau élevé de formation spécifique, tant à l'université qu'à l'hôpital, ce qui représente un défi majeur. Une première formation permet d'appréhender les contraintes environnementales spécifiques au sous-marin (atmosphère confinée, gestion du risque nucléaire, médecine hyperbare). Le second temps de formation permet d'acquérir des compétences médicales et chirurgicales nécessaires à une pratique en grande autonomie.
Pour faire face aux situations incidentelles critiques telles que l'incendie ou le combat maritime, l'équipage est également formé au sauvetage au combat adapté aux sous-marins. Ce sauvetage au combat présente trois niveaux de compétences permettant d'optimiser en situations de combat ou d'incident la prise en charge de victimes nombreuses. Les objectifs sont de poursuivre la conduite et la mission du SNLE, et de garantir une survie maximale de l'équipage.
Depuis 50 ans, ce modèle médical est efficace et la chaine de soin mis en place a permis de répondre aux différentes pathologies rencontrées sans rompre la discrétion opérationnelle malgré l'isolement extrême de la pratique médicale.
Mots clés : Sous-marins français, Équipe Médicale de SNLE, Service Médicale de la Mission de Dissuasion, Soins Continues en Sous-marin, Soins Médicaux Avancés, Autonomie Médicale, Pratique Médicale Isolée , Sauvetage au Combat adapté sur Sous-marin, Médecine Hyperbare, Médecine Nucléaire, Formation Médicale, Chefferie du Service de Santé de la Force Océanique Stratégique, Médecine Navale

PLAN

1. The nuclear deterrent mission
2. An isolated medical practice
3. Combat rescue adapted to submarines
4. Outcomes of a sector of excellence

I. THE NUCLEAR DETERRENT MISSION

Since 1960, France joined the circle of nuclear powers by restructuring its armed forces around nuclear weapons. Nuclear deterrence is the ultimate guarantee of national independence. It is the life insurance of the nation.

French nuclear doctrine is built on three pillars: strict sufficiency of nuclear weapons, credibility, and operational permanence. It is provided by two components: airborne and oceanic.

The oceanic component is based on SSBNs (Nuclear Missile Submarines). Since 1971, there has been permanently at least one French SSBN on patrol around the world

To be credible, SSBNs must not be detected. The discretion of the submarine is therefore essential. The SSBN at sea must be autonomous in dealing with issues and getting around technical problems without external help. Similarly, it must have the ability to deal with any health condition without breaking up discretion. Therefore, communication with the ground is impossible.

[1] Chefferie santé des forces sous-marines, Brest, France
[2] Ecole militaire de santé de Lyon Bron, Bron, France
[3] Division operation, Direction centrale du Service de santé des armées, Paris, France

II. AN ISOLATED MEDICAL PRACTICE

To perform an underwater isolated medical practice, highly advanced technical and human resources are needed.

Therefore, submarines carry an on-board hospital with all facilities for extended medical care. Any condition occurring on-board can be managed. Diagnosis equipment such as ultrasound, X-ray and medical biology is available. For surgical emergencies, an operating theater is ready with a full dotation of fourteen surgical sets. These instruments allow for a wide spectrum of surgeries from damage control surgery to dental care. Overall, more than a thousand pharmaceutical references are available on-board.

The medical team is composed of one physician, one anesthesia nurse and one qualified nurse.

Because of the lack of support services usually found in hospitals, the three members of the medical team must be trained in pharmacy management, laboratory analysis or handling of medical imagery systems. The rest of the crew is also trained in case of necessity: an officer receives an operational assistant training and quartermasters perform the role of first medical aid.

Another component of the efficiency of submarine prolonged field care is the enhanced submarine physician training.

The first step is the recruitment of physicians. A first experience of military medicine and emergency skills are required.

Throughout the selection process, a few candidates are selected to follow an intensive two-year training divided into two parts. A first 6-months course on submarine environment and a one year and half medical and surgical training.

Submarine environment course is attested by the "certificate of medicine applied to submarines". It is composed of a training module on the detailed technical operation of a nuclear-powered submarine. It is also made of a diving medicine module as well as a teaching on the industrial atmosphere of the submarine. This certificate gives the ability to embark on any French nuclear-powered submarine.

The second part of the training corresponds to the «certificate of medicine applied to nuclear-powered ballistic missile submarines». It starts with a three-months course on the crew exposure to nuclear risks. It provides an expertise in both radiation protection and the monitoring of workers exposed to nuclear risk.

Then follows a medical and surgical training in military hospitals. For a year and a half, the physician develops skills at performing general and specialized emergency surgeries. Abilities at dentistry, psychiatry, anesthesia, and intensive care are also developed. This medical training is carried out at the patient's bed throughout a strong companionship.

As a conclusion of this training, the physician serves as a Role-2 MTF surgical assistant in overseas operation.

Throughout their careers, submarine doctors never cease training as to provide optimal care in all situations. This skill maintaining program takes place both at hospital and in pre-hospital settings.

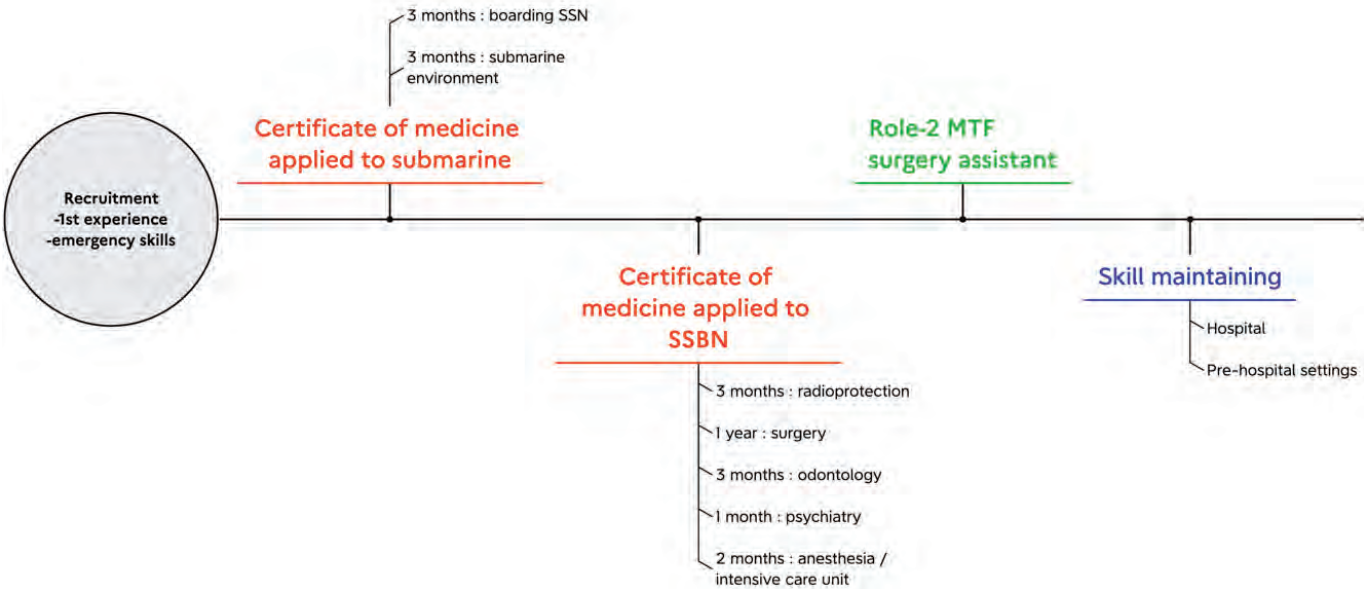

Figure 1: Training program of French submarine physicians

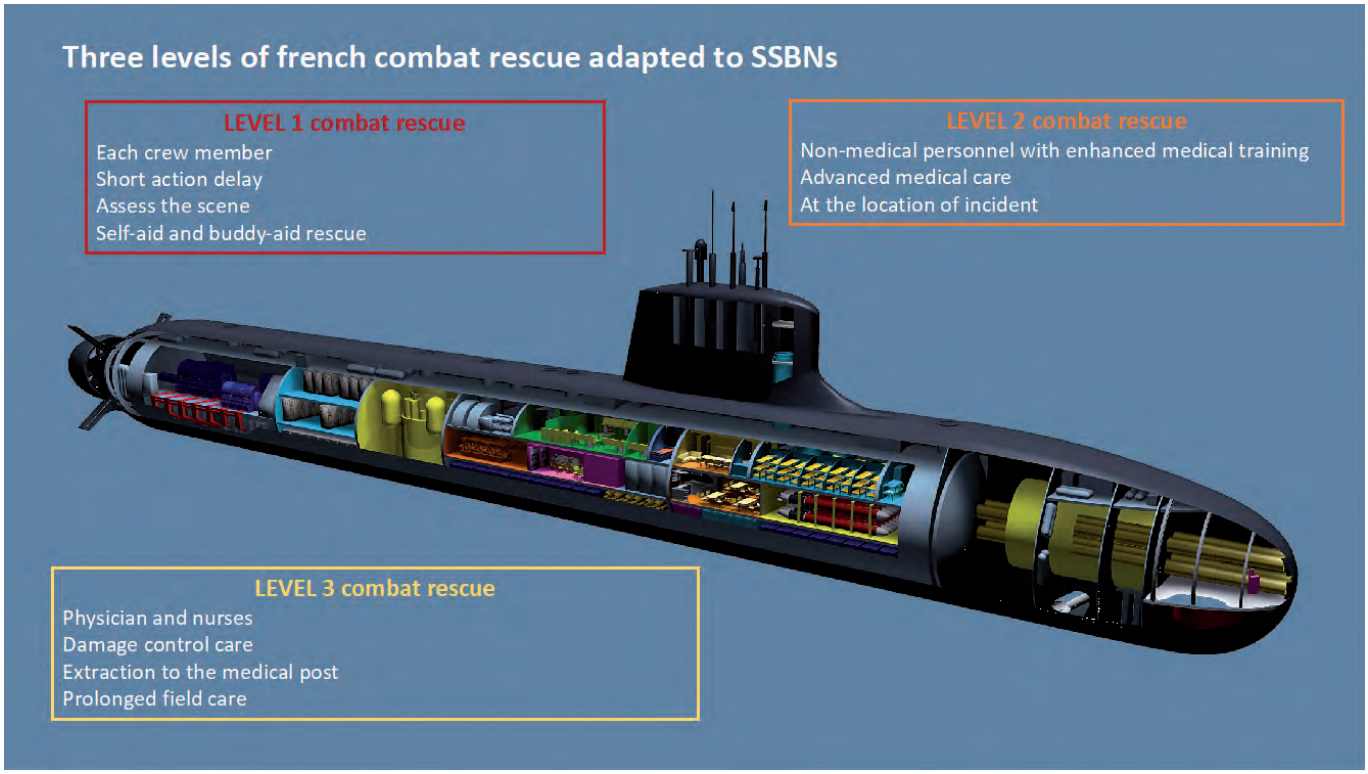

Figure 2: The three levels of combat rescue applied to submarines

III. COMBAT RESCUE ADAPTED TO SUBMARINES

On the other hand, specific submarine field comes along with inherent risks. Isolation, consistent industrial and atmospheric risks, and the narrow and difficult access to some locations make the medical care in submarine a tricky exercise. It is mandatory to consider these parameters in the medical rescue chain.

To offer an efficient answer to these challenges, submarine forces have developed a prolonged field care adapted to the submarine environment. It applies in combat situations. The final endpoint is to provide the most efficient medico-operational response in hostile environment.

To perform an efficient prolonged field care, the 3 levels of French combat rescue have been adapted.

Level 1 involves each crew member. The action delay is short, around 10 minutes, to assess the scene and bring self-aid and buddy-aid rescue. Simple combat rescue actions are performed: tactical tourniquets, airway liberation and so on. Level 2 are non-medical personnel who receive enhanced medical training. They provide advanced medical care at the location of incident until the arrival of level 3 team.

Here, level 3 physician and nurses provide damage control care and perform the extraction to the medical post where advanced therapies may be deployed.

In the end, combat rescue training adapted to submarines is essential to ensure the efficiency of incident and casualties management in a nuclear submarine. In combat situation, casualties should be managed as efficiently as possible to continue the fight.

IV. OUTCOMES OF A SECTOR OF EXCELLENCE

Over the past 50 years, the specific prolonged field care in nuclear ballistic missile submarines has permitted to treat 280 major conditions. 60% were surgical care and 40% were medical.

The treatment of such a wide spectrum of pathologies in complete isolation is a very complex and demanding exercise justifying the previously detailed enhanced medical training

Submarine prolonged field care is organized before, during and after the mission. Before, the medical suitability of the personnel is annually evaluated. During the mission, the management of daily medical and surgical pathologies as well as combat rescue in incident situations are guaranteed. After, medical and psychological follow-up of the crew are central concerns.

The excellence of French submarine prolonged field care has shown it efficiency for the past 50 years. All pathologies encountered have been treated without ever breaking up discretion and without loss of any chance for the patient.

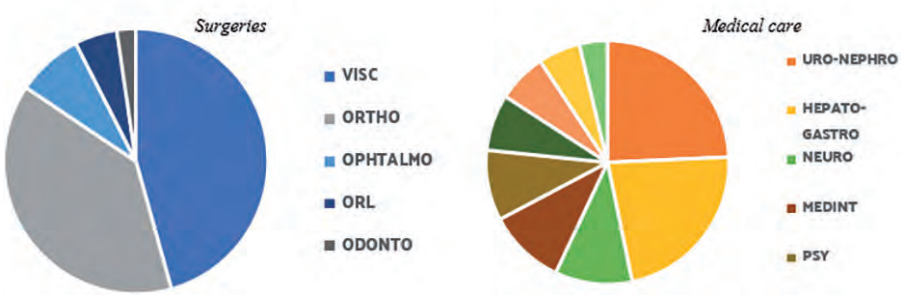

Figure 3: Distribution of medical and surgical care over the last 50 years on board SSBNs

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MÉDECIN EN CHEF Emmanuel PETIT

Le médecin en chef Emmanuel PETIT est médecin des forces sous-marines françaises. Après sa formation initiale à l'École de Santé Navale de Bordeaux, puis son internat à l'Hôpital d'Instruction des Armées (HIA) Laveran à Marseille, il débute sa carrière au sein de la force d'action navale de Toulon et participe aux opérations Harmattan et Atalanta. Il intégre la Force océanique stratégique en 2012 comme médecin-adjoint de l'Escadrille des sous-marins nucléaires d'attaque de Toulon, puis pendant sept ans comme médecin-major de sous-marins nucléaires lanceurs d'engins. Il est actuellement médecin au Service médical de la base opérationnelle de l'Île Longue à Crozon.

Il est référent sauvetage au combat et correspondant recherche, innovation pour la chefferie du service de santé des forces sous-marines.

Il est titulaire du doctorat et du diplôme d'études spécialisées de médecine générale, des brevets de médecine de l'avant et de médecine navale, du certificat de médecine appliquée aux sous-marins nucléaires, de la capacité de médecine d'urgence, des diplômes interuniversitaires d'échographie appliquée aux urgences et de médecine subaquatique-hyperbare.

Presented at the ICMM World Congress in September 2022 in Brussels

Virtual Dental Implant Planning, Guided Surgery, and Angled Screw Channel Restorative Option To Improve Readiness – A Clinical Report

Planification virtuelle des implants dentaires, chirurgie guidée et option de restauration par canal de vis angulaire pour améliorer la préparation - Un rapport clinique

E. Hu[1]. U.S.A.

Abstract

Advances in digital dentistry allow virtual restorative-driven planning and guided implant placement, creating a predictable outcome that improves troop readiness and wellness. Virtual implant planning merges Cone Beam Computed Tomography images and Standard Tessellation Language files of proposed restorations to fully visualize the implant site. Implant position, angulation, and depth are idealized in an implant planning software based on the proposed restoration. Static surgical guides are designed utilizing computer-aided design, then manufactured using stereolithography. Implants are placed using fully guided surgical protocol to minimize deviation from planned implant position, reducing the risk of mechanical, technical, and biological complications. Well-aligned implants allow the final restoration to be screw-retained, which maintains retrievability and eliminates peri-implant complications associated with residual cement. When implants are located in the anterior maxilla or deviate away from the planned position, angled screw channel restorations can be used to maintain screw retrievability.

Keywords: Dental Implants, Digital Dentistry, Guided Surgery, Angled Screw Channel, Troop Readiness

Résumé

Les progrès de la dentisterie numérique permettent une planification virtuelle axée sur la restauration et la pose guidée d'implants, créant ainsi un résultat prévisible qui améliore la préparation et le bien-être des troupes. La planification virtuelle des implants combine des images de tomographie par ordinateur à faisceau conique et des fichiers en langage de tessellation standard des restaurations proposées pour visualiser complètement le site de l'implant. La position, l'angulation et la profondeur de l'implant sont idéalisées à l'aide d'un logiciel de planification implantaire basé sur la restauration proposée. Les guides chirurgicaux statiques sont conçus à partir d'une conception assistée par ordinateur, puis fabriqués par stéréolithographie. Les implants sont posés à l'aide d'un protocole chirurgical entièrement guidé afin de minimiser la déviation par rapport à la position prévue de l'implant, réduisant ainsi le risque de complications mécaniques, techniques et biologiques. Des implants bien alignés permettent à la restauration finale d'être vissée, ce qui maintient la récupérabilité et élimine les complications péri-implantaires associées au ciment résiduel. Lorsque les implants sont situés dans le maxillaire antérieur ou dévient de la position prévue, des restaurations à canal de vissage angulaire peuvent être utilisées pour maintenir la récupérabilité des vis.

Mots clés : Implants dentaires, Dentisterie numérique, Chirurgie guidée, Canal de vis angulaire, Préparation des troupes.

Introduction

Dental implant therapy has demonstrated long term success in rehabilitation of missing teeth. Many factors contribute to the success of dental implants, such as the amount of surrounding bone, bone quality, systemic conditions, tobacco use, provider experience, and implant location.[1] Properly planned and placed implants are essential to achieve mechanically sound and esthetically pleasing results. Sufficient implant depth is necessary to create an ideal emergence profile to maintain gingival health and cleansability. Implant angulation and position within the alveolar ridge are important to maintain a sufficient buccal plate, blood supply, and distance from adjacent teeth, implants, or vital structures.

Prosthetic-driven implant planning allows the clinician to plan with the final restoration in mind. By merging Cone Beam Computed Tomography (CBCT) images with Standard Tessellation Language (STL) files of proposed restoration in an implant planning software, it allows the clinician to virtually visualize the alveolar ridge, bone quality, and vital structures. Additionally, the clinician can plan the implant position, anticipate any alveolar ridge or sinus augmentation, and design static surgical guides.[2] Surgical guides can then be manufactured utilizing stereolithography or 3D printing.[3] Surgical guides are designed with specific guide tube dimensions and pre-determined offsets that correspond with the guided implant surgical kits, allowing full control of depth and angulation during implant placement. Planning implants with-

[1] Major, Dental Corps, United States Army; Fort Cavazos Dental Health Activity, Texas, USA.

out a CBCT, or planning without merging a proposed restoration to the CBCT, are two of the most critical mistakes in implant planning.

Implants placed in alignment with the planned restoration experience less stress along the implant-alveolar crest junction, implant-abutment/prosthetic junction, and screw-abutment junction. This stress reduction results in less crestal bone loss, less implant fracture, less abutment screw / prosthetic fracture, and less abutment screw loosening. In addition, well-aligned implants maintain screw retrievability and make it easier to address complications such as a loose screw, fractured crown, open contact, or gingival inflammation around implants. In comparison, misaligned implants with screw access in an esthetic area require the definitive restoration to be cemented intra-orally, often leaving behind residual cement that can lead to peri-implant mucositis and peri-implantitis.[4]

Implant placement in the maxillary anterior zone is often a challenge due to its tapered ridge morphology. An angled screw channel is a restorative option that allows up to 25 degrees of angle correction within the abutment or restoration to maintain screw access. In a study by Edmondson et al. evaluating 200 CBCT scans in the maxillary anterior ridge, the authors found that only 24% of the sites allowed screw retention with a straight abutment. With the angled screw channel option, another 76% of the sites were able to achieve screw retrievability and avoid intra-oral cementation risks.[5]

This clinical report demonstrates a digital workflow to virtually plan dental implants, utilize guided surgery to achieve planned implant position, and use the angled screw channel restorative option to maintain retrievability.

Clinical Report

A healthy 25 year old male patient presented with chief complaint of "I am looking for implants to replace missing front teeth". Upon initial evaluation, the patient was missing his maxillary lateral incisors. Patient previously had two double-wing resin-bonded fixed dental prostheses between his canines and central incisors. The patient presented with excellent oral hygiene, mutually protected occlusion, no known dental allergies, and denial of any tobacco use. Esthetic evaluation revealed a low smile line, a dental midline coincident with the facial midline, a normal occlusal plane, proper incisal edge position, a symmetrical smile line, and adequate lip support. Both edentulous sites showed adequate incisal-cervical and mesial-distal restorative space, keratinized tissue greater than 2mm, and a Siebert Class I buccal deficiency.

At the subsequent appointment, intra-oral full arch digital impressions were made using a chairside scanner (Primescan, Dentsply Sirona, Charlotte, NC, USA), and exported in the STL file format. The STL file was imported into a computer-aid-design (CAD) software (DentalCAD, Exocad, Germany), and a diagnostic wax up was designed digitally to add lateral incisors in occlusion (Figure 1). A maxillary arch CBCT scan was taken, and exported as a Digital Imaging and Communication in Medicine (DICOM) file. STLs of the initial full arch scan, diagnostic wax up, and DICOM file of the CBCT were imported and merged in an implant planning software (Bluesky Plan, Bluesky Bio, Libertyville, IL, USA). Alignment of STL and DICOM files were verified prior to starting the implant planning process. Based on the proposed position of the maxillary lateral incisors, two 3.25mm x 11.5mm tapered non-platform switched endosseous dental implants (Certain Implant System, ZimVie, Westminster, CO, USA) were virtually planned. Due to the tapered anterior ridge morphology, implants were positioned in line with the proposed restoration in a traditional cement retained crown orientation to maximize surrounding bone. However, utilization of the angled screw channel allowed each implant restoration to be planned with 10-15 degrees of angle correction in the definitive restoration in order to achieve lingual screw access (Figure 2). Once implant locations were finalized between the restorative dentist and implant surgeon, a surgical guide was digitally designed with guide tube dimensions and offsets that corresponded to the guided implant surgical kit (Tapered Navigator System, ZimVie, Westminster, CO, USA). Surgical guide design was then exported as a STL, and 3D printed using biocompatible resin (Dental LT Clear,

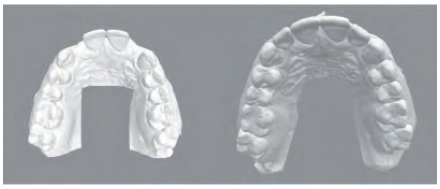

Figure 1. Intra-oral full arch digital scan (L). With digital wax up (R).

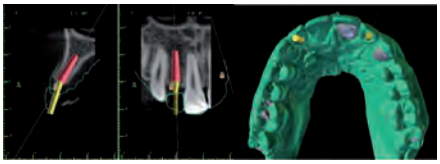

Figure 2. Virtual implanning referecing proposed restorative position.

Formlabs, Somerville, MA, USA). Following post-processing of the static surgical guide, metal guide tubes (Master Tubes, ZimVie, Westminster, CO, USA) were inserted into place (Figure 3).

At the surgical appointment, a fully thickness flap was reflected, osteotomies were created sequentially with twist and shaping

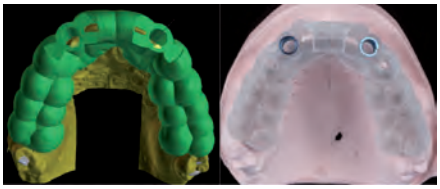

Figure 3. Surgical guide design (L). Printed surgical guide with guide tubes (R).

drills, and implants were placed fully guided using implant mounts through the guide tubes into planned edentulous sites (Figure 4). The implant site was grafted with demineralized bone containing bone morphogenic protein (Accell Connexus Bone Matrix Putty, Citagenix, Canada), and covered with a resorbable collagen membrane (BioMend Extend, ZimVie, Westminster, CO, USA) to augment the buccal plate deficiency. Stage II surgery was performed after three months of healing, and custom screw retained provisional implant restorations were delivered at the time of surgery to idealize tissue contours. A final impression utilizing custom pick-up impression copings and polyvinylsiloxane was made after one month of tissue contouring. Impression was poured in type 4 dental stone, scanned into CAD software using a dental lab scanner (Freedom HD, DOF, Korea) with scanbodies (SB3IC34, Imagine, Chantilly, VA, USA), and two cement-retained, screw-retrievable all-ceramic restorations were digitally designed. Monolithic multi-layered zirconia restorations (e.max ZirCAD MT Multi, Ivoclar Vivadent, Amherst, NY, USA) were milled using a 5-axis mill,

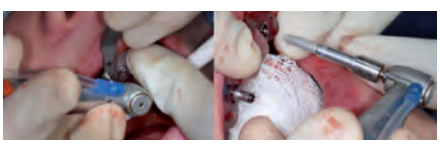

Figure 4. Fully guided osteonomy and implant placement.

and were sintered, polished, and glazed. Zirconia restorations were then cemented onto Ti-bases that allow angle correction (S-Link – SL3IC34, Imagine, Chantilly, VA, USA). Intaglio surfaces of zirconia restorations were air-particle abraded with 50microns aluminum oxide at 30psi, then treated with a primer containing 10-Methacryloyloxydecyldihydrogen phosphate (10-MDP) (Ceramic primer plus, Kuraray, Tokyo, Japan). Ti-bases were also treated with 10-MDP, then cemented to the zirconia restorations with dual-cure resin cement (Panavia V5, Kuraray, Tokyo, Japan) (Figure 5). At the delivery appointment, restorations were tried in to asses contacts, seating, occlusion and esthetics. A universal angled square driver with rounded flutes (ASDUVL, Imagine, Chantilly, VA, USA) was used to torque the delivery screws to 20Ncm (Figure 6). Teflon tape and packable composite were used to obturate screw channels. Final restorations led to an esthetically pleasing and functional result for the patient (Figure 7).

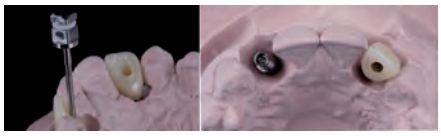

Figure 5. Cement retained, screw retrievable zirconia crowns with angled screw channels.

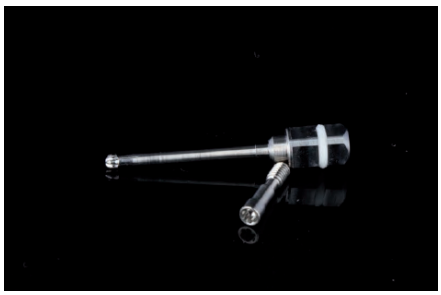

Figure 6. Universal angled screwdriver with rounded flutes.

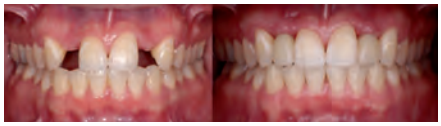

Figure 7. Pre-treatment and post-treatment.

Discussion

Advantages of restorative-driven implant planning and guided implant surgery are well documented. Significantly lower angular, coronal, and apical deviation comparing fully guided placement to free-hand surgery have been reported.[6] In a randomized controlled trial comparing implant placement utilizing freehand, pilot guide (surgical template only for the 2.0mm implant pilot drill), partially guided (template for all osteotomies except for implant insertion), and fully guided (surgical template for all osteotomies, including implant insertion) protocols, it found that freehand surgery had the highest mean angular deviation (7.03+/-3.44 degrees), ranging from 0.71 to 21.3 degrees. Fully guided surgery had the lowest mean angular deviation (3.04+/- 1.51 degrees), ranging from 0.42 to 6.3 degrees.[7] In a systematic review, higher incidence of implant failure in freehand surgery (6.42%) was found compared to guided surgery (2.25%).[8]

Many critical steps are needed to achieve accurate guided implant surgery. From designing a proper diagnostic restoration, to merging different imaging modalities in virtual implant planning, to surgical guide design and the utilization of guided surgery kits, every step requires additional training, technical expertise, and attention to detail.[9] Calibration of CBCT imaging machines, accuracy of intra-oral and dental lab scanners, implant planning software, 3D printers, and fit of guide tubes, shaping drills, and surgical guides on natural teeth can all affect the accuracy of the final implant. Fully guided surgery utilizing dynamic navigation instead of static guides is an alternate method that has shown no significant difference in accuracy of implant placement.[10]

An angled screw channel is a useful restorative option to maintain screw retrievability on misaligned implants that prevent a straight screw access. However, angled screw channels should not be relied on to compensate for poorly planned or placed implants, as off-axis loading creates higher stress along implant components.[11] In addition, restorations with an angled screw channel require a larger screw access hole to accommodate for the greater degrees of angle correction. Larger access holes can compromise ceramic integrity, and it has been recommended to keep screw access no more than 1-3mm wide, at least 1mm from incisal/cervical margins, while utilizing high strength monolithic zirconia when possible to prevent fracture.[12] Crowns with high angle correction at 25 degrees have been associated with more catastrophic failure under off-axial loading.[13] In addition, high angle correction is associated with greater insertion torque loss that may lead to premature screw loosening.[14] However, some studies showed no significant differences in screw loosening after cyclic loading.[15] Many implant companies have their own angled screw channel type of restoration, which requires a special screwdriver and matching prosthetic screws. The effect on torque and screwdriver-screw engagement may vary between manufacturers.

Conclusion

Restorative driven virtual implant planning and guided implant placement help achieve the most biologically and mechanically favorable positions, while achieving esthetically pleasing results and higher patient satisfaction. Angled screw channel restorative options help maintain screw retrievability, avoid residual intra-oral cement, and allow ease when addressing complications. Minimizing biological, mechanical, and technical complications helps enhance patient wellbeing, treatment satisfaction, and mission readiness.

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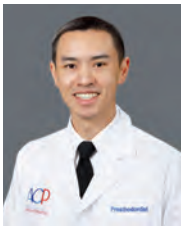
Conflicts of interest: The author denies any conflicts of interest in regards to the current clinical report.

MAJOR (dent) Eric HU



Major Hu is a Diplomate of the American Board of Prosthodontics, and a Board Certified Prosthodontist in the United States Army Dental Corps. He earned his Doctor of Dental Medicine (DMD) Degree from Midwestern University in Arizona, and received his graduate certificate in prosthodontics from Naval Postgraduate Dental School in Bethesda, Maryland. He is currently serving as a Residency Mentor for the Fort Cavazos 2-Year Advanced Education in General Dentistry (AEGD-2) Program, and Assistant Professor of Prosthodontics for the Uniformed Services University of Health Sciences (USUHS) – Postgraduate Dental College. He has won an Army wide competition for his research, published in multiple peer reviewed journals, and presented dental lectures at national and international conferences.

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Presented at the ICMM World Congress in September 2022 in Brussels

One Health : a military concept/responsibility : The South African National Defence Force

« *Une seule santé* » : un concept/responsabilité militaire : La Force de défense nationale sud-africaine

P.van der Merwe[1] . SOUTH AFRICA

Summary

The One Health approach is a collaborative effort to optimise the health of humans, animals and the environment to ensure sustainability for the future. Health is realising human aspirations and needs and changing or coping with the environment. Military security in the South African context has been redefined. It was driven by the paramount concern for the security of people, becoming an all-encompassing condition in which individuals can be Free from Fear and also Free from Want. The South African Military Health Service renders support within the human battlespace in a layered defence system with a stepped-up health approach ensuring force health protection and health sustainment. It is, therefore, well placed to be the lead One Health agent. Militaries across the globe have a responsibility to take the lead in implementing One Health to ensure health, security and sustainability for the future.

Key Words: One Health, Health, Maslow's hierarchy of needs, Military responsibility, Human security

Résumé

L'approche «Une seule santé» est un effort de collaboration visant à optimiser la santé des êtres humains, des animaux et de l'environnement afin de garantir la pérennité. La santé est la réalisation des aspirations et des besoins humains et la modification ou l'adaptation de l'environnement. La sécurité militaire dans le contexte sud-africain a été repensée : elle a été guidée par le souci primordial de la sécurité des personnes, devenant une condition intégrale dans laquelle les individus peuvent être à l'abri de la crainte et aussi à l'abri du besoin. Le service de santé militaire sud-africain apporte son soutien aux champs de bataille dans le cadre d'un système de défense à plusieurs niveaux, avec une approche sanitaire renforcée garantissant la protection et le maintien de la santé des forces. Il est donc bien placé pour être l'agent principal de l'approche « Une seule santé ». Les armées du monde entier ont la responsabilité de prendre la tête de la mise en œuvre de cette approche afin de garantir la santé, la sécurité et la pérennité.

Mots clés : Une seule santé, Santé, hiérarchie des besoins de Maslow, Responsabilité militaire, Sécurité humaine.

Introduction

One Health is an approach to improve the health status of humans, animals and the environment to ensure the physiological needs of humans are met for a sustainable future, and military forces across the world should implement it. Militaries are not only responsible for the health of the fighting force(soldiers) but often also for the health of their dependants and protecting health facilities, be it military or civilian, in times of unrest or war. Militaries, through military health services, not only play a key role in the physical health of humans, animals and the environment but have a significant impact on the social and mental health status of soldiers and their dependents. It also performs a critical role to the broader public ensuring physical needs are met and a safe and secure environment is ensured. Militaries are thus primary enablers of the comprehensive, intricate, interconnected concept of health. They are in a prime position to take the lead with the varied human resource and logistical capabilities at their disposal.

The International Committee of Military Medicine(ICMM) was established in 1921 in response to concerns over the lack of care provided during World War I. (1). The organisation strives to enhance the mutual exchange of future orientations, current scientific knowledge and past experiences among military medical services and to foster co-operation between military medicine and international health organisations, a cornerstone of the collaborative nuances of the One Health concept. If the ICMM strives to become the world's leading organisation in military medicine, it must be committed not only to share knowledge beyond geographical and ideological borders but also to adopt the principles of One Health to address the future health threats for soldiers, their dependants, also to the general public where human's needs and aspirations are to be met through optimal health systems for a sustainable future.

The track record for collaboration between the human, animal and environmental health sectors is very sketchy, primarily

[1] Director One Health Consulting (OHCON), South Africa

driven by collaboration between interested and networking officials rather than a full-fledged national initiative. Militaries can and must play a pivotal role in ensuring greater collaboration to address future challenges, especially zoonotic diseases, where 80% of new infectious zoonotic diseases are linked to domestic or wild animals.

One Health

One-Health is an integrated, unifying approach that aims to sustainably balance and optimise the health of people, animals and ecosystems. It recognises the health of humans, domestic and wild animals, plants, and the wider environment (including ecosystems) are closely linked and interdependent. The approach mobilises multiple sectors, disciplines, and communities at varying levels of society to work together to foster wellbeing and challenge threats to health and ecosystems while addressing the collective need for clean water, energy and air, safe and nutritious food, taking action on climate change, and contributing to sustainable development (2).

One Health is an approach where the interconnectedness of the three domains, humans, animals and the environment, is researched and studied to ensure that actions are coordinated by implementing authorities to meet the health needs and aspirations of humans for the future. These aspirations and needs can only be met if optimal human, animal and environmental health is strived for and ensured. Every decision must be interrogated to establish its potential health impact on fellow humans, animals and the environment. Decisions must be balanced to have the most beneficial health outcome for all three domains.
To fully comprehend and understand the One Health approach, an in-depth and general understanding of health and the driving forces of the health domain is necessary.

Health

Human Health was defined in 1948 by the World Health Organisation as "a state of complete physical, mental and social wellbeing and not merely the absence of disease or infirmity". This definition was amended in 1984 to "the extent to which an individual or group is able to realise aspirations and satisfy needs and to change or cope with the environment" (3).

Animal Health may be defined as the absence of disease or the normal functioning of an organism and normal behaviour based on observing a certain number of individuals that determine the standard and thus health (4). In production sectors, animal health is sometimes defined as the state allowing the highest productivity. However, this narrow definition is often enriched by the interaction and balance of the three health domains and aspects of animal welfare.

Figure 1. One Health: How to Achieve Optimal Health for People, Animals and Our Planet.
https://www.isglobal.org/

Environmental Health was defined in a 1989 document by the World Health Organization (WHO) as: "Those aspects of human health and disease that are determined by factors in the environment". Environmental Health, therefore, addresses all the physical, chemical and biological factors external to a person and all the related interconnectedness between humans, animals and the environment (3).

Human, Animal and Environmental Health are thus so intricately linked that they can be seen as a branch of one another and not wholly different disciplines. It is evident they are interdependent and should be managed as such, thus, the concept of One-Health.

Health thus has to do with realising human aspirations and needs and changing or coping with the environment. Multiple sectors, disciplines, and communities at varying levels of society must be mobilised to attain a status of optimal health. They must work together to address the collective need for clean water, energy and air, safe and nutritious food in a secure and safe environment, realising and satisfying human aspirations and needs.

Human Aspirations and Needs

As the aspirations and needs of people are a challenging psychological concept to comprehend fully, an American Psychologist, Abraham Maslow, proposed the idea of a hierarchy of needs (5). It was subsequently extended to include observations of humans' innate curiosity.

A person's aspirations and curiosity can be explained by this hierarchy of needs, a motivational theory in psychology comprising a five-tier model of human needs, often depicted as hierarchical levels within a pyramid. It is usually represented by a pyramid of needs, with the most basic needs at the bottom and the more complex ones, at the top. The theory states that our actions are

Figure 2. Maslow's Hierarchy of Needs. https://www.simplypsychology.org/maslow.html.

primarily motivated by particular physiological needs. Lower needs in the hierarchy must be satisfied at least to a satisfactory sustainable level before individuals can attend to higher needs.

The most critical aspect of Maslow's hierarchy of needs is that we all start with a set of non-negotiable and basic physiological needs for food, water, warmth, and rest. In addition, we have urgent safety needs for physical security and protection from attack. If these needs are not met, a person will struggle to attain higher-level needs in the spiritual domain, love, esteem, and respect. An urge drives us for self-actualisation: a vast, touchingly nebulous and yet hugely apt concept involving living according to one's full potential and becoming who we are.

One Health: The Military Connection: Roles and Functions of the South African National Defence Force

With the dawn of democracy in South Africa in 1994, the role and functions of the newly established National Defence Force in a democracy were reviewed and redefined. National security was no longer viewed as a predominantly military and police problem. It was understood to be the securing of a state and the political regime of a particular state through military means. It has been broadened to incorporate political, economic, social and environmental matters, matters central to fulfilling humans' basic aspirations and needs. At the heart of this new approach was the paramount concern for the security of people, an all-encompassing condition in which individual citizens live in freedom, peace and safety; participate fully in the process of governance; enjoy the protection of fundamental rights; have access to resources and the basic necessities of life and inhabit an environment that is not detrimental to their health and wellbeing, One Health in essence. The bulk of threats impacting the security of people emanates from inadequate political governance, environmental degradation, poor human development, inaccessibility to vital resources, disease spread, and high levels of violent crime. Human security and sustainable development for a healthier future are inseparably linked. It was therefore resolved that the role of the military should shift in focus from solely securing the state by military means to providing security for its people by addressing critical political, socio-economic and environmental problems. The military could therefore be seen as the implementation agency for One Health. This shift has brought about the realisation that collaborative efforts are needed to ensure human security, a collective response to a range of non-military threats impacting the health of humans, animals and the environment. (6)

Therefore, human security becomes an all-encompassing condition in which individuals can be Free from Fear and also Free from Want, complying with the fundamental aspirations and needs proposed by Maslow. This understanding of security, however, does not replace the state's security with the people's security. It sees these aspects as mutually dependent and interactive. After all, the state, especially the military as an agent of the state, retains its obligation to facilitate, if not create, the necessary conditions and environment to fulfil human security.

Within this conceptualisation of security, the Defence Force is but one of the institutions of the state that will be requested to promote national and international security. Providing adequate responses to some security threats, such as health threats, the Defence Force may assume the lead role, while it will be required to play a supportive function purely with others. It necessitates requisite collaborative mechanisms and structures to be established to mobilise multiple sectors, disciplines, and communities at varying levels of society to collaborate to foster wellbeing and challenge threats to human, animal and ecosystem health.

The SA National Defence Force (SANDF) 's primary role was defending South Africa against external military aggression. The Constitution of the Republic of South Africa, therefore, provides that the SANDF may be employed for service in defence of the Republic of South Africa. It is responsible for the protection of its sovereignty and territorial integrity, for compliance with the international obligations concerning international bodies and other states, the preservation of life, health or property, the provision or maintenance of essential services, upholding of law and order in the Republic in co-operation with the South African Police Service under the circumstances set

out in law where the Police Service is unable to maintain law and order on its own; and in support of any department of state for socio-economic upliftment.

The above functions, however, do not carry equal weight. The primary function of the South African National Defence Force is to defend South Africa against external military aggression; other functions are secondary. With the redefinition and extension of the functions of the Defence Force, it has evolved from a position where functions were performed in silos to one where they are fulfilled jointly/collaboratively. It enhances the effectiveness and efficiency of operations by synchronising the actions of all Services and Divisions, and it attains synergy of Defence effort. Jointness is a crucial characteristic of the defence business, producing synergistic networked effects at every command level. Within operations, jointness will be achieved through unity of command spanning over allocated forces. Jointness will be nurtured and enhanced in the design and development of force components and preparation of defence capabilities. This collaboration allows for developing effective defence policies, strategies, and plans, albeit more military in nature, basically the One Health approach.

South African National Defence Force

The South African National Defence Force is structured as four arms of service, the Army, Airforce, Navy and Military Health Service, with a Joint Operations Command for jointness and integration of effort (7).

The South African Military Health Service renders support within the human battlespace in a layered defence system with a stepped-up health approach ensuring force health protection and health sustainment through best value evidence-based quality health services to ensure world-class clinical health service (8).

It pursues a "dual-mission" approach. Force Health Protection protecting military forces from health threats and promotes and sustains a healthy combat force whilst deployed. Various health professionals are integrated into Force Health Protection, ensuring policy integration and delivery of health services. Force Health Sustainment protecting the health of forces whilst at base and in training, their families and other eligible persons, including dignitaries and veterans. The focus is on sustaining and improving the health of defence members and includes activities to protect military forces from health threats while at home, employing a comprehensive health plan, initiating health promotion and executing prevention activities. This "dual-mission" is supported by an overarching Population Health Improvement (PHI) process that includes several strategies to improve the overall health of defined populations by targeting issues identified as health threats to specific groups. It focuses on groups instead of on individuals.

Within the military, however, the South African Military Health Service is not responsible for other aspects of "health", such as Occupational Health and Safety and Physical Training, both functions of the Human Resource Division and environmental management, a function of the Logistics Division.

Although the delivery of health services ensuring the physical, mental and social wellbeing of soldiers, their families and other authorised humans, as well as the health and welfare of animals, are overseen by the South African Military Health Service in an integrated, unifying approach is strived for, other aspects of health within the scope of One Health are not fully integrated to be sustainably balanced to optimise the full spectrum of the health of people, animals and ecosystems.

The South African National Defence Force/ South African Military Health Service also has minimal capabilities in managing wider health threats that might impact the broader society, save for assistance rendered to other state departments in times of need. Capabilities are mainly focused on managing chemical threats.

Although well-structured and placed to be the government's One Health agent, it must develop the necessary military capabilities/capacity to fulfil this responsibility fully to ensure that all individuals in society are Free from Fear and also Free from Want.

Conclusion

One Health should not only be implemented by militaries across the world to ensure an integrated, unifying approach that aims to sustainably balance and optimise the health of soldiers, their families, military utilised animals and the environment they operate in. Militaries across the globe have a primary responsibility to take the lead in ensuring that all agencies, all sectors, all disciplines, and all communities at varying levels of society are mobilised to work together to foster wellbeing and challenge threats to health and ecosystems, addressing the collective need for clean water, energy and air, safe and nutritious food, taking action on climate change, and contributing to sustainable development.

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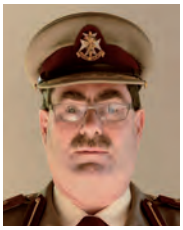
Colonel (Ret.) Dr Paul van der MERWE



Dr Paul van der Merwe is a veterinarian (BVSc; BVSc(Hons)), a wildlife specialist (MMedVet(Fer)) and hold diplomas in Senior and Home Owners Association Management. He joined the South African Defence Force in 1986 and progressed through the ranks to be promoted to a Colonel in 2004. Before retiring in March 2022, he served as the Director of Animal Health for the South African National Defence Force. He was a member of the Transformation Steering Committee of the South African Military Health Service (SAMHS) and managed primary health care in the SAMHS for four years. He chaired the ICMM's Veterinary Technical Commission for ten years. He currently serves as the President of the South African Veterinary Association(SAVA) and chairs the SAVA's Disaster Management/ One Health and Congress Organizing Committees. He is the Director of One Health Consulting (OHCON) and consults for various international and national organizations. He is married and has two daughters, a veterinarian and a forensic geneticist.

CISM ANTI-DOPING - PRINCIPLES AND VALUES

By Lieutenant-Colonel Jan Van den Dool (NED), CISM Sports Director, Major Jefferson Martinez Monjardim Couto (BRA), CISM Anti-Doping Manager

CISM is based on the intrinsic value of military sports. This intrinsic value is often referred to as "the spirit of sport". These values are in line with what is foreseen in the CISM Green Paper: Solidarity, Friendship, Respect, Equality, Integrity, and Determination.

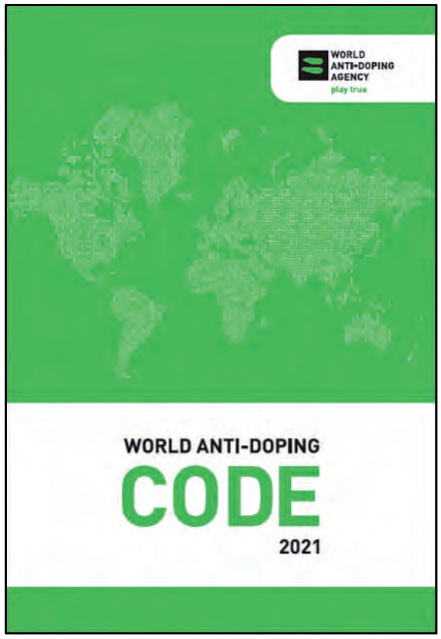
CISM seeks to protect the health of Athletes and provide the opportunity for Athletes to achieve human excellence without the Use of Prohibited Substances and Methods. The CISM Anti-Doping Policy provides directions for a clean environment for the practice of sports and competitions, in light of the CISM Statutes. This environment is guided by the ethic of human excellence through the dedicated perfection of the natural talents of each Military Athlete.

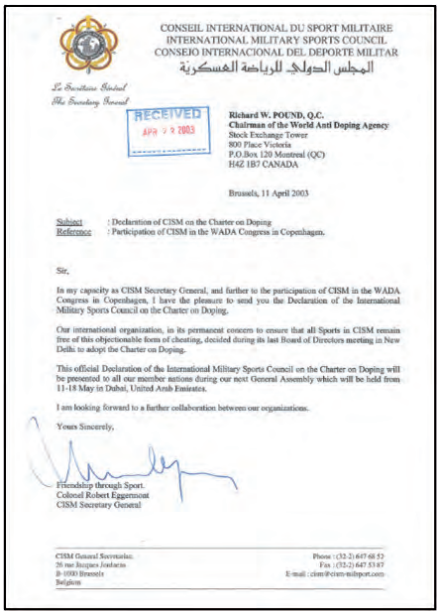
The organization and operation of CISM must be governed with the conviction that doping should be considered cheating or an unsporting act, as CISM respects and follows the World Anti-Doping Code.

These Anti-Doping Rules are adopted and implemented in accordance with CISM's responsibilities under the WADA Code and in furtherance of CISM's continuing efforts to eradicate doping in sports.

As provided in the Code, CISM shall be responsible for conducting all aspects of Doping Control. Any aspect of Doping Control or anti-doping Education may be delegated by CISM to a Delegated Third Party, however, CISM shall require the Delegated Third Party to perform such aspects in compliance with the Code, International Standards, and these Anti-Doping Rules. CISM shall always remain fully responsible for ensuring that any delegated aspects are performed in compliance with the Code.

The CISM Board of Directors (BoD) is responsible for formally adopting these Anti-Doping Rules in accordance with CISM`s responsibilities under the Code and appoints the Sports Department which is responsible to implement these Anti-Doping Rules.




CONSEIL INTERNATIONAL DU SPORT MILITAIRE
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CONSEJO INTERNACIONAL DEL DEPORTE MILITAR
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APR 2 2 2003

Richard W. POUND, Q.C.
Chairman of the World Anti Doping Agency
Stock Exchange Tower
800 Place Victoria
P.O.Box 120 Montreal (QC)
H4Z 1B7 CANADA

Brussels, 11 April 2003

Subject : Declaration of CISM on the Charter on Doping
Reference : Participation of CISM in the WADA Congress in Copenhagen.

Sir,

In my capacity as CISM Secretary General, and further to the participation of CISM in the WADA Congress in Copenhagen, I have the pleasure to send you the Declaration of the International Military Sports Council on the Charter on Doping.

Our international organization, in its permanent concern to ensure that all Sports in CISM remain free of this objectionable form of cheating, decided during its last Board of Directors meeting in New Delhi to adopt the Charter on Doping.

This official Declaration of the International Military Sports Council on the Charter on Doping will be presented to all our member nations during our next General Assembly which will be held from 11-18 May in Dubai, United Arab Emirates.

I am looking forward to a further collaboration between our organizations.

Yours Sincerely,

Friendship through Sport.
Colonel Robert Eggermont
CISM Secretary General

Fundamental Rationale for the Code and CISM's Anti-Doping Rules

Anti-doping programs are founded on the intrinsic value of sport. This intrinsic value is often referred to as "the spirit of sport": the ethical pursuit of human excellence through the dedicated perfection of each Athlete's natural talents.

Anti-doping programs seek to protect Athletes' health and provide the opportunity for Athletes to pursue human excellence without the Use of Prohibited Substances and Methods. Maintain the integrity of sport in terms of respect for rules, other competitors, fair competition, a level playing field, and the value of clean sport to the world. The spirit of sport is expressed in how we play true, in this way, Doping is fundamentally contrary to the spirit of sport

CISM has accepted the World Anti-Doping Code (the 'Code') since 11th April 2003. These Anti-Doping Rules are adopted and implemented in conformance with CISM`s responsibilities under the Code and are in furtherance of CISM's continuing efforts to eradicate doping in military sport.

Anti-Doping Rules, like Competition rules, are sports rules governing the conditions under which sport is played. Military Athletes and other Persons who participate in the Military World Games, Winter World Games, World Military Championships, and Continental and Military Sports Events

sanctioned by CISM accept rules as a condition of participation and shall be bound by them.

CISM ANTI-DOPING EDUCATIONAL SYMBOL – *"SANGUE-BOM"*

Preventive methods are important instruments used by the World Anti-doping Agency (WADA) to preserve the spirit of fair play, health, performance, dedication, and respect for the rules and laws that are placed on all participants in sports competitions. However, a major barrier found in educational programs is the diversity of languages and the scarcity of compatible platforms.

The CISM, as a signatory institution of the WADA CODE and its rules, created a mascot (Sangue-Bom) with the intention of breaking the barriers of languages and representing all the values adopted by these renowned institutions.

"Sangue-Bom" represents the CISM spirit of fair play, health, performance, fun, dedication, and respect for rules and laws which are posed to all participants. "Sangue-Bom", in Portuguese, is an expression that literally means "good blood", but it is also slanged to describe a person with good character, a true "comrade", "buddy", in essence, a good partner.

In short, the name is a simple tribute to all athletes who carry in their hearts the real spirit of sport. The animal is a Honey Badger and wants to be with all the athletes, to be a partner in all the CISM competitions.

The symbol of a clean and true athlete; is the anti-doping symbol of CISM.
CISM has 74 "Good Blood" images across all our Category 1 sports, men's and women's, and other images on training, feeding, and Fair play promotion. Together, we can preserve the spirit of sport, avoid problems, confirm great results and help competitors to be real champions!

"Sport is not a game you simply win or lose.
Its ethos goes beyond winning.
Win by cheating, and everybody loses.
The community against doping is dedicated to fair competition.
WADA is proud to be the world's unifying force for doping-free sports.
They exist…to guide…to enable…to inspire athletes and sports to make the right choices.

Together, let's raise the game, and Play True."

CISM AIMS TO REVITALIZE PARA-SPORT PROGRAM

Mr Steven Dinote (USA), President CISM Para Sport Working Group, Commander Dimuthu Thissera (Sri Lanka), CISM Parasport Manager

INTRODUCTION

The International Military Sports Council (CISM) is the second largest multi-sport organisation in the world after the International Olympic Committee (IOC). Founded in February 1948, CISM has grown from five-member nations to 140. Military members who may previously have met on the battlefield, now meet in friendly competition on the sporting field and through collaborative solidarity activities.

The aim of CISM is to promote sport activity and physical education by uniting armed forces under the motto of "Friendship through Sport".

CISM hosts 20 events annually including the Military World Games, World Military Championships, symposiums, and other continental and regional events.

In 2012, CISM held the first Para-Sport Working Group in Warendorf, Germany to examine the prospect of introducing adaptive sport for wounded, injured and sick (WIS) military members within the CISM organisation. The outcome led to the introduction of the first ever integrated track and field competition featuring both able-bodied and disabled athletes under the same venue. This pilot event was hosted by the German Armed Forces at the Bundeswehr Sports School in Warendorf from 9-16 September 2013, featuring 34 para-athletes from eight nations among their able-bodied comrades.

Following the success of the pilot event, successful integrated events followed, including the 2015 Swimming Open Competition (France), and integrated Archery and Track and Field as part of the 2015 Military World Games held in Mungyeong, South Korea.

CISM PARA-SPORT

CISM strongly believes in the right of all human beings to pursue their physical and intellectual development, without discrimination. One important principle is to promote models of best practice that encourage inclusive opportunities and recognition of military athletes with disability equal to those of their non-disabled peers. CISM believes in international solidarity in accordance with their respective mandates and principles. The conceptualisation of the CISM Para-Sport program supports the following:

1. It should be showcase world class sport opportunities for athletes with disabilities, which are credible and compelling within a global medium and that reach large populations of spectators.
2. Promote models of best practice that encourage inclusive opportunities and recognition for athletes with disabilities equal to those of their non-disabled peers.
3. Develop support of sport opportunities for male and female athletes with disabilities and illnesses sustained as part of their military duties.
4. Empower Para-athletes as leaders in their societies and within their Armed Forces.
5. Strengthen the position of WIS military personnel and veterans.

CISM continues to invite member nations to incorporate Para-Sport disciplines as a means of reflecting the goals of CISM development and the ideals of the military sports movement.

PARA-SPORT 2.0

The original objectives of the CISM Para-Sport Working Group were to establish

CISM as the recognized leader in developing opportunities for WIS military personnel by introducing Paralympic-style competition under the auspices of CISM for military athletes at the elite level. The overall objectives were met with successive events and the Working Group looked to expand the program by creating solidarity opportunities to educate and integrate Para-Sport activities for developing nations, as well as establish a guide for future integrated championships.

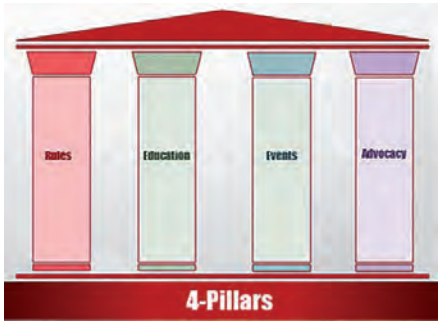
Presently, CISM has established the second evolution of the Para-Sport Working Group known as CISM PARA-SPORT 2.0. Under the auspices of the CISM Sports Commission and close collaboration with the CISM Sports Department and Presidents of the respective CISM Sport Committees, CISM PARA-SPORT 2.0 has identified four key priorities as part of the strategic objectives. They are:

Priority 1

"Structured Para-Sport organization in CISM and the finalizing the Para-Sport Regulations".

Priority 2

"Enhance Para-Sport knowledge within CISM Sports Department, CISM Sport Committees, Member Nation Chiefs of Delega-



tion and relevant athletes through Regional Development Centres, training centres and external resource institutions".

Priority 3

"Continue Organising Para-Sport events".

Priority 4

"Encourage CISM Member Nations".

CISM PARA-SPORT 2.0 has taken these priorities and has organised smaller focus groups within four pillars to strategically

address CISM priorities with the goal of bringing disabled military members together along with their able-bodied comrades.

CISM/ICMM COLLABORATION AND CONCLUSION

As CISM PARA-SPORT 2.0 continues internal collaboration, the Working Group looks to expand its external partnerships such as the International Committee of Military Medicine (ICMM). Future cooperative exchanges of shared medical information and research not only benefits military adaptive sports initiatives but enhances the total well-being and health of military members and veterans as they continue their pathways to recovery and reintegration.

Potential partnerships include medical advice for adaptive sports, exchange of releasable academic information, cooperative use of facilities and observation opportunities, and the development of activities and joint research projects involving the academic communities of all institutions.

CISM welcomes the organization of jointly agreed conferences, forums, seminars, and other events to further the betterment of military health among all military members and veterans. CISM PARA-SPORT 2.0 serves as the perfect catalyst to enhance military health and medical knowledge.

"Leaving no man behind!'

CISM International Symposium TUNIS - TUNISIA (29th October – 04th November, 2023)

Tunisia will be the host nations of the CISM International Symposium in 2023. A perfect place to bring together researchers from the military and civilian world in the field of sports performance and the body's physiological responses in the practice of physical activity and readiness. Hosting the CISM International Symposium will be another step in the scientific development of the region and an opportunity to share its culture, traditions, and receptivity. All CISM member nations are warmly invited and strongly encouraged to participate in this Academic Event which promises to be great and unforgettable.

Disseminate among your researchers and interested personnel how great this academic event will be and the theme and sub-themes proposed for this year:

"FROM SCIENCE TO PRACTICE"

- Physical training evaluation methods in armed forces
- Physical and psychological preparation of the soldier
- Elite athlete performance enhancement
- Military athlete injury prevention
- Sport participation and military leadership enhancement
- Military and sport medicine

For more information:
https://www.milsport.one/news/international-symposium/tunis-tunisia-2023

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UNDER THE AEGIS OF THE INTERNATIONAL
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13 - 16 Sep.
2023

Triumph Luxury Hotel
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WELCOME MESSAGE

Under the Aegis of the International Committee of Military Medicine (ICMM) and On Behalf of Egyptian Armed Forces Medical Services (AFMS).

The Director of Egyptian Military Medical Services has the honour to welcome all our delegates and guests from all over the world to the outstanding 12th ICMM Pan-African Regional Congress from 13 -16 September, 2023. at the home of the most ancient civilization Cairo, Egypt.

You are cordially invited to attend a wide range of scientific sessions of the Congress, kindly, I ask you to support the members of your national military health services who could offer oral presentation or a poster presentation in this important military medical congress.

For your participation and other members of your national military health services you can find more information about the scientific aspects (abstracts) and organizational aspects (registration, hotels.., etc) of this Congress at official website of the Congress **(pacmm2023.org).**

We are all in The Egyptian Armed Forces delighted to welcome you to share an extraordinary educational and cultural program in the land of Pharaohs, Egypt !

Maj. Gen. Med
Hesham Elshishtawy
Congress President

TOPICS

1. Surgical Treatment in Military Hospitals
2. Medical and Dental Treatment in Military Hospitals
3. Medical and Surgical Treatment in Fields and Military Units
4. Environmental, Preventive, and veterinary Medicine
5. Aviation and Naval Medicine
6. Scientific and Medical Research
7. Nursing
8. Covid 19
9. Military Personnel Screening
10. Pharmacy

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• Up to a quarter of a manuscript page.

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• No more than three authors
• The one named first is the responsible author.
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• Summarising core statement.
Main part
• Logical, concise, to the point, aligned with the target group (readers).
Conclusion
• Summarising result.
Keywords
• Every article should be submitted with the relevant keywords

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- 10 breaths/minute (1 breath every 6 seconds) for adults

Ensure that volume corresponds to normal chest movement — i.e., 450 ml for an adult weighing 75 kg

PROTECTIVE LUNG VENTILATION

Provide consistent, high-quality ventilations, customizing tidal volume, rate, FiO_2, PEEP, and ventilation pressure for each patient

Protective lung ventilation is synonymous with low tidal volume ventilation (4-8 mL/kg predicted body weight)[1]

Low tidal volume ventilation reduces ventilator-associated lung injury (VALI):

- Volutrauma (hyperinflation and shearing injury)
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- Biotrauma (release of inflammatory mediators)[1]

Customize PEEP on ventilator to reduce trauma to patient's alveoli

[1] Life in the Fastlane website, www.litfl.com/protective-lung-ventilation/. Accessed June 25 2021.

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