Transfusion and Apheresis Science 49 (2013) 380–386

Contents lists available at SciVerse ScienceDirect

Transfusion and Apheresis Science

journal homepage: www.elsevier.com/locate/transci

Advances in military, field, and austere transfusion medicine in the last decade

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ARTICLE INFO

Keywords:
Blood product development
Blood product regulation
Medical logistics
Biologicals
Plasma derivatives

ABSTRACT

Two decades of war in south-west Asia has demonstrated the essential role of primary resuscitation with blood products in the care of critically injured soldiers. This idea has been widely adopted and is being critically tested in civilian trauma centers. The need for red cells, plasma and platelets to be immediately available in remote locations creates a logistic burden that will best be eased by innovative new blood products such as longer-stored liquid RBCs, freeze-dried plasma, small-volume frozen platelets, and coagulation factor concentrates such as fibrinogen concentrates and prothrombin complex concentrates. Such products have long shelf-lives, low logistic burdens of weight, fragility, or needs for processing prior to use. Developing and fielding a full family of such products will improve field medical care and make products available in the evacuation chain. It also will allow treatment in other austere environments such as the hundreds of small hospitals in the US which serve as Levels 3 and 4 trauma centers but do not currently have thawed plasma or platelets available. Such small trauma centers currently care for half of all the trauma patients in the country. Proving the new generation of blood products work, will help assure their widest availability in emergencies.

1. Introduction

Military transfusion medicine is the specialty of developing, deploying, and using blood products for medical care in austere combat environments and in the medical evacuation chain. Field transfusion medicine is the civilian equivalent used in disaster planning and relief. Field practices are relevant in other resource-limited settings such as small or midsized hospitals that do not have all blood products available as, in the US, 50% of trauma patients are cared for outside of Levels 1 and 2 trauma centers. Interplay is frequent between military and civilian field care because the military has a mission to support disaster relief. The military has assets such as aircraft, prepackaged medical equipment, trained deployable surgical teams, deployable hospitals, and theater blood transshipment facilities and treaties to carry out such missions internationally. As a result, military casualty care research programs have provided much of the epidemiologic data that has supported field blood-use doctrine and have paid for most of the development of modern blood storage systems. Retired military personnel are often used as experts in disaster planning. Shared equipment, training, experience, doctrine, and literature have all contributed to an evolving sense of best field medical practices over the last decade [1].

The military often plans from the experience of prior wars, and so the first US invasion of Iraq in 1990 is

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http://dx.doi.org/10.1016/j.transci.2013.06.015

instructive [2]. Multiple field hospitals were deployed along with 82,000 units of packed red blood cells (RBC). In hindsight, the 250 US casualties and 250 units of RBC used in their care in the whole war could have been handled with a few smaller combat support hospitals and a dozen cardboard and styrofoam boxes of blood products. However, the critical casualty of the war sustained a trans-pelvic fragment wound and required 52 units of RBCs and ultimately fresh whole blood to treat his iatrogenic dilutional coagulopathy. The lessons that blood use at a per casualty rate is generally low but that the patients receiving massive transfusions require more than just red cells were confirmed in the actions in Somalia, Bosnia, and Kosovo. As US military budgets got smaller at the end of the decade, many large deployable military field hospitals were deactivated and small forward surgical teams were redeveloped to provide immediate far-forward care. Such teams could carry 20 units of RBCs on ice and blood bags for the collection of fresh whole blood from soldiers if plasma or platelets were needed, but the forward surgical teams did not have the assets to store frozen plasma or platelets.

Also in the 1990s, changes in the education of acute care (trauma) surgeons followed evolving theory and improving techniques. Early in this decade, "damage control surgery" was defined as an approach to stabilize patients whose injuries were too numerous or severe to be repaired in a single survivable procedure [3]. Damage control involved quick hemorrhage control by vascular shunting and organ and soft tissue packing and management of body cavity contamination by tying off gut and diverting bile and urine. These actions saved lives but created patients whom the military did not know if they could safely transport. Surgeons had learned to save a group of patients that previously died, but were now too sick for prolonged care in the austere environment. Transport of such patients out of the austere environment must occur early, in a window of relative stability. US Air Force medical evacuation personnel were first exposed to these patients in Somalia in 1993 and began developing critical care air transport teams to manage them [4]. Prolonged critical care of these most seriously injured is a profound logistic burden in even the best Level 1 trauma centers.

In the second half of the decade, efforts to prevent acute respiratory failure and compartment syndromes by reducing non-blood fluid administration achieved notable successes in clinical trials in the academic settings where the military trained its trauma surgeons [5,6]. Nevertheless, academic specialty groups like the Committee on Trauma of the American College of Surgeons continued to teach giving crystalloid fluid for volume resuscitation to maintain blood pressure and red cells to maintain oxygen transport.

The first decade of this century found the US and other allied militaries in new wars in Afghanistan and Iraq. The large numbers of seriously injured patients presented new challenges for the military. Blood product support doctrine became controversial as traditional blood logistic assumptions conflicted with evolving surgical doctrine based on successfully treating the most severely injured. The contentions about appropriate blood supply and product use played out in the medical realm as arguments about (1) the acute coagulopathy of trauma, (2) the best way to resuscitate, (3) the best way to provide plasma and platelet coagulation support, and (4) the best way to get new products to the field. This paper will describe how progress in these four areas has changed field medical care in the last decade and address field blood use today.

2. The acute coagulopathy of trauma

The existence of an acute coagulopathy of trauma had been demonstrated in casualties in Vietnam [7] and in animal models of soft tissue injury [8]. Hematologists deemed it the early hemorrhagic phase of disseminated intravascular coagulation (DIC) [9], explainable by the known concentrations and activities of the plasma coagulation factors [10]. However, Brohi and colleagues in 2003 showed this to be a common clinical event, occurring in up to 25% of a thousand severely injured blunt trauma patients brought to the Royal London Hospital by helicopter before significant fluid administration. This observation led to a rethinking of the Advanced Trauma Life Support (ATLS) paradigm for trauma resuscitation in a few centers [11]. Clearly, there were patients whose condition was likely being made worse by volume resuscitation with crystalloid, particularly when coupled with the use of plasma-poor packed red cells in additive solution. The most severely injured of these patients were bleeding and being transfused fast enough that by the time simple laboratory tests such as the prothrombin time (PT), partial thromboplastin time (PTT) and platelet count became available to guide therapy, the patients were profoundly coagulopathic and difficult to rescue with conventional blood products.

What Brohi and his colleagues specifically noted was that increases in the PT greater than 1.5 times normal in blood samples obtained at admission became increasingly frequent as injury severity increased. Further, the proportion of patients with abnormal values increased from 10% among moderately injured patients to 80% among those with multiple profound injuries. When compared among patients with equivalent injury severity, those with a prolonged PT had four times greater mortality.

In a larger study published a month later, MacLeod and her colleagues in Miami examined the records of 20,103 patients admitted to the Ryder Trauma Center directly from the scene of injury [12]. They found that any increase of the PT or PTT above normal was associated with excess mortality. In their study, increases in the PT were common, occurring in 28% of patients, but only 8% had an increased PTT. On the other hand, the odds ratios for death to be associated with an abnormal test were 3.6 for an increased PT and 7.8 for an elevated PTT. When adjusted for age and injury severity, the odds ratios were reduced to 1.35-fold excess mortality for an elevated PT and 4.26 for a prolonged PTT. The PT appeared to be a sensitive indicator of the acute coagulopathy of trauma, and the PTT was a specific marker of severe coagulopathy. The MacLeod group did not find an effect of admission platelet counts.