

## Military history of increasing survival: The U.S. military experience with tourniquets and hemostatic dressings in the Afghanistan and Iraq conflicts



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### Tourniquets

Tourniquets are at least half a millennium old, and yet they were not routinely fielded and used by the U.S. military at the onset of the conflict in Afghanistan in 2001. By 2014, however, an article in the *Journal of Trauma* discussing tourniquets stated, “Tourniquets have been the signature success in battlefield trauma care in Afghanistan and Iraq. Based on the work of U.S. Army Colonel John Kragh and colleagues, the number of lives saved from this intervention has been estimated to be between 1,000 and 2,000.”<sup>1</sup> How did the U.S. military come to make this remarkable journey?

The conventional wisdom in 2001 in civilian and most military trauma courses was that the use of a tourniquet for hemorrhage control would likely result in amputation of the injured limb and that the harmful effects of tourniquets far outweighed the benefits. The results of this mind-set were predictable. The review by Kelly et al. of combat fatalities from the early years of the conflicts in Southwest Asia found that 77 U.S. servicemen and servicewomen had bled to death from extremity wounds.<sup>2</sup> These deaths made up 7.8 percent of all combat fatalities reviewed. This incidence of death from extremity hemorrhage was essentially unchanged from the 7.4 percent noted in Vietnam, a quarter of a century earlier.<sup>3</sup>

The resurgence of tourniquet use in the U.S. military originated with the Tactical Combat Casualty Care (TCCC) program. The TCCC was the result of a military medical research effort conducted jointly by the U.S. Special Operations Command (USSOCOM) and the Uniformed Services University of the Health Sciences. This project was undertaken in 1993 to review the principles of battlefield trauma care employed by the U.S. military at the time and to see if these principles were supported by the available evidence. The product of this research effort was a paper titled “Tactical Combat Casualty Care

in Special Operations,” published in *Military Medicine* in 1996.<sup>4</sup>

Tourniquet use was a central focus of the TCCC paper. After recognizing the disconnect between the very significant incidence of preventable deaths from extremity hemorrhage in Vietnam and the ongoing failure of the U.S. military in the mid-1990s to field modern tourniquets and to train combat medical personnel in their use, the authors of the TCCC paper noted the following:

It is very important, however, to stop major bleeding as quickly as possible, since injury to a major vessel may result in the very rapid onset of hypovolemic shock.... Although ATLS [Advanced Trauma Life Support] discourages the use of tourniquets, they are appropriate in this instance because direct pressure is hard to maintain during casualty transport under fire. Ischemic damage to the limb is rare if the tourniquet is left in place less than an hour and tourniquets are often left in place for several hours during surgical procedures. In the face of massive extremity hemorrhage, in any event, it is better to accept the small risk of ischemic damage to the limb than to lose a casualty to exsanguination...the need for immediate access to a tourniquet in such situations makes it clear that all SOF [special operations forces] operators on combat missions should have a suitable tourniquet readily available at a standard location on their battle gear and be trained in its use.<sup>4</sup>

Despite the publication of the TCCC paper, however, and a series of briefings to military medical audiences and senior military medical leaders, the principles of care outlined in the TCCC program gained little traction in the U.S. military before the events of September 11, 2001. The only units that adopted the TCCC prior to 2001 were the U.S. Navy SEALs, the 75th Ranger

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Regiment, the U.S. Army Special Missions Unit, the U.S. Air Force Special Operations community, and a small number of other special operations and conventional units.

The value of extremity tourniquets was also taught at the Joint Trauma Training Center in Houston from 1999 to 2001, but the recommendation for expanded tourniquet use languished. Even the units that had embraced tourniquet use at the start of the recent war in Iraq and Afghanistan did not have high-quality, commercially manufactured tourniquets and had to rely on improvised tourniquets of varying quality.

The expanded use of tourniquets in the military did not occur as a gradual evolutionary process but rather as the result of a series of discrete events in 2004 and 2005. First, in 2004, the USSOCOM funded a U.S. Army Institute of Surgical Research (USAISR) study of preventable deaths in special operations units in Afghanistan and Iraq. This study, first authored by the USAISR commander at the time, Colonel John B. Holcomb, MD, FACS, found a 15 percent incidence of preventable deaths among the special operations fatalities that had occurred through November 2004, including a number of deaths from extremity hemorrhage that could have easily been prevented with nothing more than an effective tourniquet.<sup>5</sup>

Second, Dr. Holcomb directed that USAISR researchers conduct a comparative study of commercially available tourniquets. This study, conducted by Tom Walters, MD, and colleagues, recommended three tourniquets for use by the military: the Combat Application Tourniquet (C-A-T), the Special Operations Forces Tactical Tourniquet (SOFTT), and the Emergency and Military Tourniquet (EMT).<sup>6</sup> All these tourniquets had been proven in the laboratory to be 100 percent effective in stopping arterial blood flow to extremities. The EMT, a pneumatic device, was less well-suited for battlefield

use. The Committee on Tactical Combat Casualty Care (CoTCCC) subsequently recommended the C-A-T and the SOFTT as the preferred battlefield tourniquets.

Third, the TCCC Transition Initiative was funded by the USSOCOM and conducted by the USAISR. This effort, led by Sergeant First Class Dom Greydanus, was basically the medical equivalent of a rapid fielding initiative. It provided TCCC training and equipping to deploying special-operations units and incorporated methodology for determining the success or failure of the newly introduced TCCC measures. The TCCC Transition Initiative (and the U.S. Army) chose the C-A-T as the tourniquet to field.

The TCCC Transition Initiative was a resounding success and documented 67 uses of tourniquets in special-operations units with good effect and with no loss of limbs to tourniquet ischemia.<sup>7</sup> The first four-star endorsement of the TCCC and tourniquets occurred when General Doug Brown, Commander of the USSOCOM in 2005, mandated TCCC training and equipment for all deploying special-operations units. The U.S. Central Command, largely through the efforts of former Colonel Doug Robb, also mandated in 2005 that all individuals deploying to that combat theater be equipped with tourniquets and hemostatic dressings.

As awareness of the success of the TCCC Transition Initiative and the U.S. Central Command directive spread throughout the military, conventional units began to adopt the TCCC, including tourniquets. In 2005 and 2006, tourniquet use expanded rapidly throughout the U.S. military. The beneficial impact of the battlefield use of commercially manufactured tourniquets was very well documented by an army orthopaedic surgeon, Colonel John Kragh, during his time at a combat support hospital in Baghdad in 2006.<sup>8</sup>

By the end of 2011, Colonel Brian Eastridge's landmark study "Death on the Battlefield" found

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that potentially preventable deaths from extremity hemorrhage had dropped from the 7.8 percent noted in the previously mentioned Kelly study to 2.6 percent, a decrease of 67 percent.<sup>9</sup> The studies by Kragh and Eastridge and other U.S. military authors established the benefit of battlefield tourniquets in combat casualties. Eastridge's paper documented that as of June 2011, there were 4,596 total U.S. combat fatalities. Of these deaths, 119 servicemen and servicewomen died from isolated extremity hemorrhage. If the incidence of death from extremity hemorrhage had continued at the 7.8 percent rate observed in the Kelly study, the number of deaths from extremity hemorrhage would have been 358. In considering this number, it should be noted that Kelly's 7.8 percent incidence of death from extremity hemorrhage included fatalities up to the end of 2006 and so reflected at least some decrease in extremity hemorrhage deaths as a result of the 2005 push to expand the use of tourniquets in the U.S. military.

Holcomb, Champion, and others have documented that casualty survival in Afghanistan and Iraq was significantly higher than that observed in World Wars I and II and the Vietnam conflict.<sup>10</sup> This increased survival was the product of both increased use of personal protective equipment and improvements all along the continuum of care from point of wounding to discharge from the hospital. However, in a military with the highest survival rate in our nation's history, the 75th Ranger Regiment demonstrated that further improvements were possible. Kotwal and his colleagues reported an 87 percent reduction in potentially preventable deaths (3 percent compared with 24 percent in the U.S. military as a whole) through the establishment of a command-directed casualty-response program that included TCCC training and expertise for every person in the regiment—not just medics.<sup>11</sup>

At this time, the U.S. military has more experience with combat tourniquets than any military force in history, and U.S. servicemen and servicewomen no longer step onto the battlefield without an individual first aid kit that contains one or more tourniquets.

### Hemostatic dressings

Hemostatic dressings were not part of the original TCCC guidelines. These agents were developed shortly after the onset of hostilities in Afghanistan. Both the HemCon bandage and QuikClot granules were developed commercially, and other options soon followed. The challenge to the U.S. military was to decide which of the available hemostatic options to field. Comparative studies were carried out both at the USAISR and the Naval Medical Research Center in Bethesda, MD. These studies showed that both agents improved survival compared with control groups in animal models of lethal bleeding.

The U.S. Marine Corps was the first service to field a hemostatic agent and selected the granular agent QuikClot, which was judged to be the best option available at the time. When the U.S. Army made its decision on which hemostatic agent to field, the HemCon dressing had also become available. The two agents were found to be approximately equal in efficacy, but QuikClot produced an exothermic reaction when it contacted a liquid (such as blood), which caused pain for the injured individual and produced burns. The Army elected to field HemCon, as did the USSOCOM. The use of these two agents expanded rapidly throughout the U.S. military after 2003. Two retrospective studies, one on each agent, were published by Wedmore et al. and Rhee et al. and reported good success with battlefield use of these agents.<sup>12,13</sup>

The TCCC has given these individuals a vastly improved set of tools and skills to better accomplish their heroic and lifesaving deeds on the battlefield, and tourniquets and hemostatic dressings are now a permanent fixture in their aid bags.

Newer hemostatic dressings became available in 2008 and underwent testing at the USAISR and the Naval Medical Research Center. These studies found that both Combat Gauze and WoundStat were consistently more effective than HemCon and QuikClot granules. As a result, the CoTCCC modified the TCCC guidelines to recommend Combat Gauze as the first-line option for the treatment of life-threatening hemorrhage not amenable to tourniquet placement because the combat medics involved in the decision expressed a strong preference for a gauze-type hemostatic agent rather than a powder or granules. WoundStat was recommended for use when Combat Gauze was not successful in controlling the hemorrhage. Subsequent safety testing at the USAISR found that WoundStat produced thromboembolic complications in animal models.<sup>14</sup> These findings caused the CoTCCC to remove WoundStat as a recommended agent, and its use was subsequently discontinued in the U.S. military.

Combat Gauze is now the hemostatic dressing most widely used by U.S. forces on the battlefield. The first report of Combat Gauze use in combat noted a 79 percent success rate in 14 uses among Israeli Defense Force personnel.<sup>15</sup> Large U.S. retrospective studies of Combat Gauze effectiveness in U.S. casualties have not yet been done.

Newer hemostatic dressings are the subject of ongoing research. A study from the Naval Medical Research Unit—San Antonio, TX, found that both Celox gauze and ChitoGauze produced higher 150-minute survival rates in the standardized USAISR femoral bleeding model than Combat Gauze. Survival was nine of 10 animals with Celox gauze, seven of 10 with ChitoGauze, seven of 10 with Combat Gauze XL, and six of 10 with Combat Gauze.<sup>16</sup> These differences are noteworthy but were not statistically significant. As of this writing, neither Celox gauze

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nor ChitoGauze have been tested in the USAISR hemostatic safety model described by Kheirabadi.<sup>13</sup> The U.S. military also does not have as much successful experience with these two agents as it has with Combat Gauze. For these reasons, the two agents are recommended by the CoTCCC as backup choices to Combat Gauze.

### Conclusion

64 | Never in its long and distinguished history has the U.S. military been so successful at saving the lives of individuals wounded in combat. Many dedicated professionals in the Military Health System have played key roles in bringing about the highest casualty survival rate in history: our courageous combat medical personnel, who perform amazing feats of medical care in the midst of the battle; the helicopter evacuation crews, who willingly risk their lives over and over to evacuate our casualties to safety; the superbly skilled surgical and intensive care teams in our hospitals; the Critical Care Air Transport Teams that fly desperately ill casualties thousands of miles to higher levels of care; the rehabilitation specialists, who enable our casualties to maximize their recovery of life skills and function despite their injuries; and finally, the professionals at the Joint Trauma System, who work ceaselessly to provide oversight of the entire system and make it function smoothly. To all these men and women, our nation owes a great debt.

Because most combat fatalities occur in the prehospital phase of care, our nation's combat medical providers play an especially important role in ensuring the highest casualty-survival rate possible. The TCCC has given these individuals a vastly improved set of tools and skills to better accomplish their heroic and lifesaving deeds on the battlefield, and tourniquets and hemostatic dressings are now a permanent fixture in their aid bags. ♦

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