Tragedy Into Drama: An American History of Tourniquet Use in the Current War

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ABSTRACT

Background: Although the scientific results of recent tourniquet advances in first aid are well recorded, the process by which tourniquet use advances were made is not. The purpose of the present report is to distill historical aspects of this tourniquet story during the current wars in Afghanistan and Iraq to aid scientists, leaders, and clinicians in the process of development of future improvements in first aid. **Methods:** The process of how developments of this tourniquet story happened recently is detailed chronologically and thematically in a "who did what, when, where, why, and how" way. **Results:** Initially in these wars, tourniquets were used rarely or were used as a means of last resort. Such delay in tourniquet use was often lethal; subsequently, use was improved incrementally over time by many people at several organizations. Three sequential keys to success were (1) unlocking the impasse of enacting doctrinal ideas already approved, (2) reaching a critical density of both tourniquets and trained users on the battlefield, and (3) capturing their experience with tourniquets. Other keys included translating needs among stakeholders (such as casualties, combat medics, providers, trainers, and decision-makers) and problem-solving logistic snags and other issues. Eventually, refined care was shown to improve survival rates. From all medical interventions evidenced in the current wars, the tourniquet broke rank and moved to the forefront as the prehospital medical breakthrough of the war. **Conclusion:** The recorded process of how tourniquet developments in prehospital care occurred may be used as a reference for parallel efforts in first aid such as attempts to improve care for airway and breathing problems.

KEYWORDS: *hemorrhage, first aid, trauma, damage control, resuscitation, tourniquets*

Introduction

In 2009, a nephew, Army SGT Daniel Archer, and three of his buddies visited his uncle, Dr. Tom Walters, during a day off from their medic training, a postdeployment refresher. In conversation about their training, the nephew told his buddies that his uncle as a researcher was involved in getting the new tourniquet issued earlier that decade.

The buddies said, "No way," that there always had been a tourniquet issued to all.

The uncle replied, "Way," and told them the story of how history happened. Over beer and barbecue, Walters told his nephew and his buddies that only a few years earlier, all the training they would have had would have been an hour or so of instruction with a stick-and-cravat tourniquet, not the standard-issue tourniquet of today.

They were amazed and asked, "You mean it hasn't always been this way?'

"No, it has not," replied Walters.

This article gives the reader a backstage tour of recent tourniquet history to show a richer, deeper understanding of how first-aid interventions may be implemented. The use of a tourniquet went from a means of last resort to a means of first aid and so became the prehospital medical breakthrough of the wars in Afghanistan and Iraq. This story is told because, in part, casualty care investigators want to document the record as even tourniquet investigators sometimes forgot key events, recalled incorrectly the order of decisions made, mixed up one type of one-handed tourniquet with another, or

conflated policy changes that were actually disparate. Without preservation, the lost story could not be a reference for future improvements in point-of-injury care developed within a large bureaucracy such as the U.S. Department of Defense. The complexities, frictions, and key moments of the story can have substantial value for current and future readers who will be able to see how long things took, what worked, and what failed so as to use this tourniquet success as a model of how to work in a bureaucratic system to improve health care. Although the scientific content of this tourniquet story is recorded, the management process of how it succeeded is not.

The long wars led to continuous casualties and persistent pressure on the trauma system to improve hemorrhage control; the sustained scientific effort maintained momentum to improve care more than anything in the prior millennia. If the current wars in Afghanistan and Iraq had been short or light, then the pressure, the momentum, and improvement would likely have been little.

In 2010, Dr. Frank Butler, a retired U.S. Navy captain and surgeon, gave an invited talk in the United Kingdom about recent advances in military prehospital care. After describing the military's prolonged efforts to get tourniquets used on the battlefield, he was asked by an audience member, "Why did it take so long for the military to get its tourniquet act together?"

Butler replied, "Sir, I gather from your not being in uniform that you are a civilian physician. So I will redirect that question to you, because most of the civilian sector is still not using tourniquets."[1]

The purpose of the present report is to distill key historical aspects of this tourniquet story during the current wars to aid clinicians, scientists, or leaders interested in the process of improving first aid.

The Situation on 10 September 2001: The Stage Is Not Set

By 10 September 2001, despite multiple observations from several wars that indicated isolated limb exsanguination was the most common preventable cause of death on the battlefield in the 20th century,[2-8] recent research had not yet fundamentally improved military first aid as only the Israel Defence Forces, a few U.S. Special Operations Forces (SOF), and a few of the 18th Airborne Corps were involved with tourniquet innovations.[9–16] A U.S. Army general surgeon in Mogadishu, Somalia (then MAJ John Holcomb) helped steward innovative battlefield care, including improved tourniquet use.[8] After the 1993 Somalia conflict (Operation Gothic Serpent), the United States Special Operations Command (USSOCOM) held many after-action reviews in which tourniquets were a major lesson learned. These lessons anticipated many things seen later in Iraq and Afghanistan—the need for more tourniquets, forward transfusion, field antibiotics, and better pain control, as well as definition of associations between better armor and survival rates with junctional injuries. SFC Bob Mabry, an SOF combat medic on an elite combat search-and-rescue team in Mogadishu, decided not to put a tourniquet on a Ranger with a bad gunshot to the tibia in Mogadishu. Thinking he would cause the Ranger to lose his leg if he used a tourniquet, Mabry instead put on a constricting band and periodically loosened it throughout the night. The periodic constriction almost allowed the Ranger to bleed to death—and Mabry was a high-speed SOF medic. After the battle, Holcomb explained to Mabry how the band blocked venous flow but not arterial flow and so actually caused *more* bleeding. This incident focused Mabry on hemorrhage control.[8,17] Soon, an SOF medical working group (including medics SFC Mark Esposito and MSG Ted Westmoreland and rigger MSG Eli Rodriguez) started developing tourniquet designs that were refined incrementally over the years; these three veteran SOF experts later made the first prototypes of the Combat Application Tourniquet (CAT; Composite Resources, Inc., Rock Hill, SC).[18] In 1997, U.S. Navy SEALs and the 75th Ranger Regiment, an SOF unit, adopted Tactical Combat Casualty Care (TCCC) techniques including the use of tourniquets,[11,16] but few other units did. The key leader of the TCCC movement was Butler, a SEAL and ophthalmologist. He, as Biomedical Research Director for Naval Special Warfare Command, helped guide a grass-roots SOF effort to address comprehensively battlefield problems at sites such as Manuel Noriega's small airfield at Punta Paitilla, Panama, and in war-torn Mogadishu, Somalia.[6,10,11] Butler and the SEALs knew advanced trauma life support (ATLS) was then popular, but ATLS was civilian-based and did not consider the idea that the provider was under gunfire. ATLS had prioritized airway, breathing, and circulation (ABCs), in that order, whereas TCCC prioritized C first to prevent exsanguination deaths, as these were more common and more preventable. Holcomb and Butler were both ATLS experts and SOF experienced; they together recognized the operational nature of trauma care under fire, the need for innovative medicine in this understudied area, and the unique tradecraft of SOF. They worked hard to reform the system in order to change the world of first aid.

The 75th Ranger Regiment's 3d Battalion (3/75) medical leadership team of then CPT Chris Pappas, battalion surgeon, and then SFC Rob Miller, senior medic, transitioned 3/75 to TCCC.[19] The personal drive of Ranger medics like Miller, MSG Harold "Monty" Montgomery, and others advanced TCCC over the years. In 1998, 3/75 Senior Ranger medic Miller informed COL Stanley

McChrystal, Ranger regimental commander, of the TCCC program, and the commander in turn eventually made Ranger response to casualties (including tourniquet use) one of four essential components of training for *every* person in the regiment (Table 1).[16] In 1999, the Casualty Response Training for Ranger Leaders began as a course for senior leaders with Butler as keynote speaker. Additionally in 1999, Holcomb was the keynote speaker at the dedication of the 3/75 training simulation center named for SFC Perry Black, the senior Ranger medic in the 1993 Somalia conflict. The simulation center was mainly for Ranger Medic Assessment and Validation (RMAV) training for Ranger medics and the Ranger First Responder course. Rangers rehearsed for reality at 3/75 as such preparation was command-directed by the Battalion Commander LTC Dan Allyn and CSM Kevin

Table 1 *Timeline: The Situation on 10 September 2001: The Stage Is Not Fully Set*

1993	Naval Special Warfare Biomedical R&D Task 3-93 reviews tactical trauma care led by F.K. Butler
1993	Oct 3–4 Blackhawk Down—limb bleeds caused 7% of deaths in Somalia; more prehospital tourniquets needed
1993–1995	Naval Special Warfare and Uniformed Services University of the Health Sciences study tactical care
1994	Somalia synopsis: big bleeding is bad; damage control gaps include hemorrhage control.
1994 (Mar 23)	Pope AFB, NC, disaster at Green Ramp: tourniquets used after aircraft crashes through ground troops
1995	Post-Somalia reviews, panels, reforms: need better tourniquet device, new tactical care doctrine
1996	U.S. Military Academy mechanical engineering report of undergraduate work on tourniquet use ideas
1996	Butler et al.—tactical combat casualty care (TCCC) is not prehospital ATLS. Tourniquets recommended
1996–1998	Butler is chairman, U.S. Special Operations Command Biomedical Initiatives Steering Committee (BISC)
1996	BISC funded a tourniquet review by John Holcomb that was important in accelerating R&D
1996	Oregon State University (OSU) and Walter Reed Army Institute of Research (WRAIR) start tourniquet study
1997 (Feb 28)	North Hollywood, CA, bank robbery shootout; LAPD Detective T. Angeles puts tourniquet on policeman
1997 (Apr 9)	Naval Special Warfare Commander (T. Richards) endorses Tactical Combat Casualty Care (TCCC)
1997 (Apr 12)	North Hollywood, CA: Family of robber killed in LA shootout sues because no tourniquet was used
1997	USSOCOM prioritizes and checks tourniquet traits informally and confers formally with OSU
1998	USAMRMC and USSOCOM (Biomedical Initiative Steering Committee) fund tourniquet development
1998	COL Stanley McChrystal commander: *all* Rangers do Big Four including medical training.
1998	TCCC used by Rangers as base for their First Responder Course training that is mandated for all Rangers
1998 Dec	OSU and WRAIR produce OSU report on tourniquet design, fabrication, and user testing of new devices
1999 (Jan 20)	OSU and WRAIR: Navy technical report produced, filed in DTIC
1999	Ted Westmoreland, Corey Russ, and John Haggman of Medical Working Group do SOF R&D with tourniquets
1999	*Prehospital Trauma Life Support* manual (4th ed.) is published, which includes TCCC and tourniquets
2000 (Jan 31)	Medical Working Group of SOF R&D report Army tourniquet fails, need one that works well
2000	Calkins et al., 2000—tourniquets tested and prototypes were developed
2000 (Oct 12)	Yemen USS Cole attacked by boat in suicide bombing; emergency tourniquets used
2001 Mar	OSU and WRAIR report development of three improved tourniquet designs for battlefield use; OHT fails
2001	Blood et al.—report of Marine deaths in hospital in Vietnam showed that only one of four surgeons advocated tourniquets
2001	Tourniquet use develops in SOF test bed, later becomes a comprehensive program of RD&E
2001 (May 24)	Medical Working Group of SOF R&D report medics happy with "Espo" tourniquet
2001	Mark Esposito of SOF improvises simple Velcro loop tourniquet 1-inch-wide ("Espo strap") issued to some

Connell. In 1999, COL (Ret.) Fred Garber from the Office of the Surgeon General purchased and delivered to 3/75 two human patient simulators that were integrated into the RMAV training to complement other realistic and hands-on training methods, which included combat noise, burning barrels, and moulaged casualties, for emotional inoculation in stress conditioning. In May 2000, the Rangers held another medical conference and established Ranger First Responder as a standard that it remains today. That same week, Butler held a Tactical Medicine for Leaders briefing to 3/75 and the 75th Ranger Regimental Staff. Miller, well known in SOF for his bulldog determination and fire hydrant physique, was truly visionary as he saw the importance of generating and integrating new ideas, new terms, new training methods, new gear, and new practices. Ranger medics, led first by Miller, over many years developed techniques of tactical casualty care that have helped warfighters in a boots-on-the-ground way to get things done.[20]

Without a good and available tourniquet in 1999, SOF and scientists sought better designs.[21] In 1999, TCCC guidelines were published in the prehospital trauma life support manual, which recommended tourniquets for care under fire but named no specific manufacturer of tourniquet designs.[22] In 2000, SFC Dominique Greydanus, a senior Special Forces medic and the noncommissioned officer-in-charge at the Joint Trauma Training Center (JTTC) at Ben Taub Trauma Center, Houston, TX, continued to teach tourniquet use as an essential element of optimal combat casualty care under the supervision of Holcomb, a trauma surgeon and JTTC director. However, such assertive tourniquet education was unpopular elsewhere. As of 10 September 2001, the unreliable, World War II–era U.S. Army tourniquet was the only widely fielded tourniquet in the U.S. military; this tourniquet, a strap-and-buckle design without mechanical advantage such as a windlass, was not issued to individual Soldiers but was in medical kits, whereas some SOF units were training every person to carry and use tourniquets. Some SOF medics fabricated their own tourniquets, but this practice varied widely.

In August 2001, MAJ Russ Kotwal and Miller at 3/75 finalized the first edition of the *Ranger Medic Handbook,* which included the Ranger medic's scope of practice, tourniquet guidelines, clinical practice guidelines, protocols and procedures, pharmacology, planning and operations, and packing lists.[23] The handbook concretely applied TCCC ideas to Ranger needs.

11 September 2001 through 2002: War Makes an Entrance

As the twin towers of the New York World Trade Center fell, the military had only a few Servicepersons who were actively developing better tourniquet techniques, practices, and policies. When U.S. forces went to Afghanistan in 2001, most went without tactical tourniquets, and most users had been trained not to use any tourniquet at all, until all other available methods were exhausted. Because 3/75 was the alerted Ranger battalion on 11 September 2001, they planned to deploy. The battalion was well prepared for combat; medical training was robustly TCCC-based for more than 2 years by then. The battalion had everything they needed—except a reliable field tourniquet. Miller, having recently read an article by Calkins et al. that mentioned that a ratchet device might serve as a reliable field tourniquet, discussed with MAJ Kotwal common off-the-shelf devices that could potentially be used as tourniquets.[21] MAJ Kotwal mentioned automotive solutions to include "an oil filter strap or wrench," and Miller mentioned strap-and-ratchet devices similar to those used to tie down vehicles in aircraft for airfield seizures. Miller soon visited many local hardware and home improvement stores and found a device that inspired the later creation of the Ranger Ratchet Tourniquet. Although this tourniquet weighed roughly 1 pound, Miller convinced the command and the battalion commander, LTC Stefan Banach, to fund and field it. Miller quickly contacted a Texas company to produce about 1000 ratchet tourniquets at approximately $10 each. These tourniquets were contracted, made, delivered, and fielded to 3/75 before its early October combat deployment.

On 26 November 2001 an ad hoc panel of tourniquet experts was led by Dr. Tony Pusateri, a hemorrhage researcher at the U.S. Army Institute of Surgical Research (USAISR), to select an adequate tactical tourniquet for fielding as none had been selected, tested, or recommended[24] (Table 2). Panelists could handle the devices available and try them on themselves if they wished. A one-handed tourniquet, so named for an infrequent need for the casualty to self-apply it with one hand when the other was injured, was selected. Nondominant, one-handed application was then a key feature favored by SOF. The one-handed tourniquet selected by the panel was recommended by a subsequent committee and then approved by a Combat Casualty Care Integrated Concept Team.[24] That approval led to contracting, manufacturing, and fielding; there was no testing beforehand.

Early post-9/11 experience indicated quickly to SOF that (1) the use of a tourniquet only as a last resort was not optimum, (2) late hemorrhage control was lethal, and (3) battlefield tourniquets used in 2001 and 2002 were flawed.[18,25,26] Tourniquets were often ineffective, slow (e.g., find, gather, and assemble parts to improvise tourniquets), clumsy, and inaccessible in an emergency (e.g., bottom of a bin or rucksack when needed), or training was inadequate. For example on 5 December 2001, an

Table 2 *Timeline: 2001 through 2002: War Makes an Entrance*

2001 Sep	SFC Miller and LTC Kotwal swap old Army tourniquet for 75th Ranger Ratchet Tourniquet before deploying
2001 (Nov 26)	Ad hoc committee formed at USAISR to examine WRAIR prototypes and one-handed design wanted
2001 (Nov 28)	Ad hoc committee at USAISR recommends a one-handed tourniquet (OHT)
2001 (Nov 28)	An OHT idea accepted by CCC Integrated Concept Team
2001–2004	"Just in Time" TCCC training is given to deploying Naval Special Warfare personnel
2001	B-52 drops bomb (JDAM) on U.S. and injures scores, evidencing usefulness of medical training and tourniquets
2001	B-52 incident survivors underscore to all the need for all to have a nonimprovised tourniquet at-the-ready
2001	Combat Application Group members continue to develop tourniquet prototypes
2001	USSOCOM supports Committee on TCCC (CoTCCC) formation at Naval Operational Medicine Institute
2001	SOF trauma registry used as template for what would become the Joint (later DOD) Theater Trauma Registry
2002	A Velcro-looped tourniquet issued to SOF unit members
2002 (Mar/Apr)	Operation Anaconda at Roberts Ridge: 16-hour tourniquet used with life and limb saved
2002 May	OSU and WRAIR report development of tourniquet tester device for evaluation of battlefield tourniquets
2002 Jun	USAMMDA chose Canvas Specialties, San Antonio, TX, OHT production, NSN
2002 Jun	OHT sent to USSOCOM and USAMEDDBD for customer assessment of device
2002 Aug	CAPT Steve Geibner chairs the first CoTCCC meeting (thereafter quarterly meeting is routine)
2002	A firm paid to make a OHT
2002 (Aug 16)	USAISR–USSOCOM conference reports 10000 OHTs made, ~1500 fielded to date
2002	Accrual of personal experience by medics and physicians, piecemeal reports begin.
2002 (Oct 12)	Bali, Indonesia, bombing casualties had tourniquets used in prehospital care
2002	OHT fielding ~20,000 devices: arm performance good, thigh bad; SOF nicknamed it "two loops of death"
2002	SOF medics provide postdeployment briefs at USAISR with medics, scientists, and John Holcomb

airplane dropped a bomb that injured scores of ground combatants (SOF with partisans loyal to Hamid Karzai), including most medics at the scene (the senior medic was killed outright). The least injured medic, Westmoreland, promptly triaged mass casualties and provided care, often by guiding lay Soldiers to implement his care instructions.[18,25,26] Several casualties died outright, and survivors provided evidence as to the usefulness of TCCC training for as many combatants as possible including the need for *all* to have a nonimprovised tourniquet always at-the-ready.[25,27,28] The loss of casualties from limb exsanguination despite tourniquets was unacceptable to Westmoreland, so he refocused his efforts to make a better tourniquet.[18]

The first U.S. casualty to die in the war from enemy fire was a Special Forces Soldier, SFC Nathan Chapman, who died during medical air-evacuation on 4 January 2002 from isolated limb exsanguination without tourniquet use.[29] Wounded with SFC Chapman, a Central Intelligence Agency officer had a chest wound triaged as more serious than Chapman's femoral artery injury. However, Chapman's artery was severed, resulting in his exsanguination and death before the helicopter landed.[29] The loss of this SOF Soldier underscored to his surviving teammates the need of a reliable tourniquet for all. The hallmark tragedy of this story in hindsight is not surprising given what we know now about tourniquets. In contradistinction to Chapman's tragedy, during March 2002's Operation Anaconda (on the mountain Takur Ghar at a site later called Roberts Ridge), SFC Cory Lamoreaux, an SOF flight medic, used a tourniquet successfully on a casualty during care under fire for over 16 hours in a dramatic firefight, yet the casualty kept his limb and, after rehabilitation, returned to pilot duty.[30] These two casualties illustrate the failure and

success of this tourniquet history in the current war by starkly pointing out both tourniquet absence and tourniquet presence in battlefield care—a turn of tragedy into drama.

A pivotal moment for Walters, a research physiologist at the U.S. Army Institute of Surgical Research (USAISR), came on 16 August 2002 when Holcomb, USAISR commander, brought to the USAISR many SOF medics, including SEALs and Air Force pararescuemen who had just returned from Afghanistan.[18,31] Using his "A colonel and his memo can do almost anything" technique, Holcomb held his own medical conference and brought together key SOF medics, scientists, and clinicians. SFC Cory Lamoreaux and Westmoreland, both combat veteran SOF medics, told their stories of Roberts Ridge and the accidental bombing of SOF and Karzai's men, respectively.[18,32] The official purpose of that USSOCOM-USAISR conference was to serve as a professional exchange, but Holcomb's real aim was to motivate the scientists to get new knowledge "out the door."[18,26,27] When Holcomb asked the medics what they needed most, the number one thing medics wanted was a working tourniquet for all. To that end, Holcomb looked at Walters, who had expertise in muscle physiology, and said, "Dr. Walters will take care of you," which of course was a surprise to Walters, who had heretofore never studied tourniquets. CPT Mabry, by then an emergency physician, was also in attendance and because COL "Just do it" Holcomb saw the surprise in Walters' eyes, he followed it up with, "and I'm sure CPT Mabry will be able to help you out." The story would have been very different and slowed considerably if Holcomb had not then introduced Walters to CPT Mabry, also a prior 3/75 Ranger Infantryman, as the scientists had not yet appreciated the immediacy of the need.[25] CPT Mabry, a prior SOF medic in Mogadishu, helped Walters a great deal by keeping the new knowledge generated grounded to the realities of remote battlefields.[8,17,33] At this time, Holcomb, consultant for trauma to the U.S. Army surgeon general, asked CPT Mabry and Walters to write new guidelines for field tourniquet use in war, which they did.

1 January to 18 March 2003: No Intermission

In February 2003, Mr. Don Parsons, a master instructor of medic training at the U.S. Army Medical Department Center and School (AMEDDC&S), read Butler's 1996 article on TCCC.[10] Parsons, a physician assistant (PA) who was a retired Special Forces LTC and prior medic before PA school, had been out of the field for years, but a non-commissioned officer instructor brought him Butler's work for consideration. Parsons realized that the military casualty's response to battlefield trauma must be changed from simply yelling "Medic!" to aiding oneself. He also realized that the Department of Combat Medic Training (DCMT) program (directed by COL Al Morgan, the program's first emergency physician) within AMEDDC&S had no course on battlefield trauma care. Parsons thought that TCCC was the best available fill of that gap for DCMT, so, on his own initiative, he looked to Army units experienced in TCCC. A peer of Parsons, then MAJ Jeff Cain, an emergency physician also at DCMT, offered Parsons his experience of multiple 75th Ranger Regiment tours (including 3/75) including a recent Afghanistan deployment.[34] Because of SOF combat medic successes with hemorrhage control, the Rangers developed a bleeding control kit for every Ranger to address the most common cause of preventable death in ground combat; this took the scale of users from hundreds of combat medics to all Rangers (thousands). Parsons first received a Ranger kit from a PA-buddy, CPT John Detro, who was on another tour with the Ranger Regiment (3/75). Parsons assessed Detro's Ranger kit for the Army as a whole. Parsons advocated and discussed the TCCC proposal with the AMEDDC&S training team leadership, including COL Morgan's replacement, LTC Erin Edgar, a SOF flight surgeon, who also wanted the small-scale SOF success and later mid-scale Ranger success to progress further for the Army as a whole. The Ranger solutions of a common First Aid Kit and First Responder Course for everyone were templates for Army-wide (on a scale of a million) consideration by AMEDDC&S leaders in 2003 at Fort Sam Houston, TX. For the DCMT, Parsons wrote the first TCCC lesson plans that included tourniquets, and he participated in committees and panels seeking suitable tourniquets for fielding such as the One-Handed Tourniquet (OHT; Canvass Specialties, Inc., San Antonio, TX) initially and eventually the CAT.[35] To help the Army get acquainted with these new ideas and kits, Parsons wrote an article for *Infantry* magazine outlining how battlefield care should be led and why this new first aid kit was essential to saving Soldier lives.[36] Beyond the evolving Army medic experience, the new tourniquet ideas were being updated as the Combat Lifesaver Course lesson plan (for mostly nonmedics), which was revised periodically by Parsons; that course eventually became universal in 2008 for every new Army recruit by becoming entry-level Soldier training. Soldier culture and modern tourniquet use were then harmonized durably.[37] In these ways, the SOF-Ranger success was used to plan an Army success by several people over several years.

In February 2003 before the invasion of Iraq, the Committee on TCCC (CoTCCC) called for every American in the war zone to carry a modern tourniquet and receive training on how to use it as a doctrinal idea for treating battlefield casualties, with an increasing emphasis on stopping bleeding faster.[38] In Spring 2003, the USSOCOM organized a Small Business Innovative

Research contract with TIAX, LLC (Cambridge, MA) to provide tens of thousands of the 1-inch-wide One-Handed Tourniquets (OHTs), which were soon fielded rapidly in part by being carried into theater and distributed to SOF by Holcomb.[33] An early tourniquet lesson learned (gathered at annual meetings of Advanced Technology for the Advancement of Combat Casualty Care [ATACCC] and the Special Operations Medical Association) was that the 1-inch OHT did not work well on the thigh in the field and that field experience was subsequently confirmed by laboratory testing (led by Dr. "Josh" Wenke and Greydanus at the USAISR) in 2003; its distribution and use were then discontinued[39–42] (Table 3). SOF medics had mixed impressions of the OHT; some thought it was a good idea, but some saw no mechanical advantage in its design. Given such experience and Soldier anthropometry, very few Soldier thighs may be compressed well by any 1-inch device because the device width–limb circumference relationship was unfavorable. This knowledge was unknown at the time until Walters, an experienced scientist tasked as tourniquet principal investigator in 2003, broadcast such knowledge widely with CPT Mabry.[43,44]

Table 3 *Timeline: 1 January 2003 to 18 March 2003: No Intermission*

2003	Ted Westmoreland puts windlass into Velcro strap permanently with Mark Esposito and Eli Gonzalez (rigger)
2003	Esposito puts inner strap within outer Velcro strap and adds windlass clips with Westmoreland and Gonzalez
2003	The Esposito–Westmoreland ideas are main traits of Combat Application Tourniquet, named next day or so
2003	CATs shipped from Westmoreland home in Carthage, NC; batches tested routinely for quality
2003	Combat Application Tourniquet company of Southern Pines, NC, renamed Phil Durango LLC
2003	CAT initial parts made by VC Manufacturing, Cameron, NC, including farmers' wives
2003	Amanda Westmoreland of Phil Durango sews rods onto the main body of the CAT and molds plastic clips
2003	Amanda Westmoreland prints folds instruction sheets, packs all in plastic wraps, and takes and fills all orders
2003	CAT orders overwhelm Amanda Westmoreland; so mother, Charlotte Finch, and friend Melissa Finney are hired
2003 Mar	USAISR test of OHT by Wenke and Greydanus: poor thigh performance; noted traits for spiral development
2003	CoTCCC recommends that all deploying servicepersons receive modern tourniquet and get trained

This tourniquet story included SOF families who made major contributions. For example, Jennifer Johnson, wife of Special Operations Forces Tactical Tourniquet (SOFTT) inventor Ross Johnson, became for a time president of Tactical Medical Solutions, maker of the popular SOFTT. She helped in the development of components, refinement of design features, and production of devices. Additionally, in the farmlands around Fort Bragg, NC, Amanda Westmoreland, wife of Westmoreland, and her mother, by necessity became tourniquet makers by melting and bending plastic tourniquet components in their living rooms, sewing windlasses into their tourniquet bands, and packaging and distributing thousands of assembled tourniquets early in the war. When requests exceeded capacity, local farm wives joined in the work by sewing tourniquet bands to fill the gap for their friends and family members deploying to war.

Although this tourniquet history was playing out in several acts, early miscues, such as the 1-inch OHT failing in its tryout, required redirection of efforts. Despite the early missteps, the actors gained valuable experience with improvement processes within the military system, giving them better understanding and new hope to redouble efforts to set things right.

19 March 2003 to 5 March 2005: Dual Theaters, Dual Paradigms, and Dual Doctrines

Similar to the ongoing Afghanistan experience, the 19 March 2003 entry into Iraq resulted in early U.S. military deaths from limb exsanguination without tourniquets. However, a report of tactical casualty care in Iraq by a battalion medical officer, CPT Michael Tarpey, of the 3d Infantry Division's Task Force 1-15 evidenced usefulness of TCCC ideas in eliminating preventable causes of death on the battlefield during the 2003 "Drive to Baghdad"; tourniquets in first aid were emphasized to stop bleeding[45] (Table 4). Such new war experiences moved clinicians to revise the outdated 1985 *Emergency War Surgery* handbook given more than a decade of experience in damage control developments including data-heavy publications with attendant updated education. Holcomb guided the 2003 revision of the handbook which was published in 2004.[46] In August 2003, Walters and CPT Mabry also issued a consensus panel report of tourniquet experts from military medicine, civilian orthopedic trauma, and industry who had gathered at the ATACCC conference to review tourniquet guidelines (Appendix).[33,47,48] At the end of a long ATACCC day of lively tourniquet discussions among panelists involving casualty anthropometry ranges, special scenarios like entrapped limbs, and worst-case limitations

Table 4 *Timeline: 19 March 2003 to 5 March 2005: Dual Settings, Dual Paradigms, Dual Doctrines*

2003 (Mar 19)	Iraq war begins; not all Soldiers in all units have tourniquets issued
2003 Mar	In Iraq, some deaths occur without tourniquets, some deceased had improvised tourniquets
2003 (Apr 21–24)	Ad hoc Tourniquet Panel prioritizes desired tourniquet traits and drafts use guidelines
2003 Apr	USAISR by Walters, Wenke, and Greydanus laboratory test of field devices, method changed little thereafter
2003 Apr	127 hours: Between a rock and a hard place. A. Ralston amputates his entrapped arm in desert accident
2003	Lakstein et al.—Israelis report clinical experience with tourniquets in 91 casualties, all survive, 5.5% morbidity
2003	War surgery courses continue to start up, grow, accelerate, mature, and diversify; some include tourniquet data
2003 Aug	Tourniquet panel at ATACCC discusses gaps, requirements, and plans.
2003 (Sep 30)	USAISR, DCDD, AMEDDC&S, and USAMMDA make Battlefield Tourniquet Requirements Statement
2003	Tourniquet panelist consultant to the Surgeon General (R. Hayda, orthopedic trauma) not a fan, life vs. limb amputations
2003 Oct	Tourniquet Panel follows up after ATACCC with drafted requirements for tourniquet device testing
2003 (Oct 30)	Request For Information (RFI) panel discusses Aug 3 recommendations; seeks off the shelf devices
2003	Klenerman publishes *Tourniquet Manual*, what may be the first modern book on the operative tourniquet
2003 (Dec 14)	USAISR briefs CCCICT (Combat Casualty Care Integrated Concept Team) traits, guidelines approved
2003–2004	Esposito hand drills rods, VC manufacturing sews CAT straps, Amanda Westmoreland sews rods on 2004 Esposito separates from military, makes company, files patent for CAT; Westmoreland serves Army
2004 Feb	USAMMDA publishes RFI prototype tourniquets for DOD research in CCC
2004 Feb	CAT production into thousands, handmade by 3 women (two Army wives and a mom) in NC
2004 (Mar 3)	Madrid bombing casualties had tourniquets applied in prehospital care
2004 (Apr 15)	RFI closed, 12 companies provide letters of intent
2004 (Apr 26)	Ted Westmoreland uses 1st CAT in combat on a serious foot amputation, "worked like a charm"
2004 (Apr 26)	Two UK soldiers rotating in Baghdad ER argue over who can keep used, bloody CAT for later reuse
2004 Spring	Westmoreland briefs Holcomb on tourniquets at OIF Trauma Conference #1; Holcomb carries CATs
2004 (Jul 1)	USAISR begins test of 10 tourniquets; funds also from Office of Naval Research (ONR), USAMRMC
2004 (Jul 27)	USAISR lower extremity tourniquet test completed
2004 (Jul 28)	USAISR sends results to USSOCOM, AMEDDC&S, USAMRMC
2004 (Jul 28)	USAISR recommends CAT tourniquet of choice for issue to all deploying Soldiers and EMT for medics
2004 (Aug 11)	USAISR upper extremity tourniquet test complete
2004 (Aug 18)	USAISR reports test results at ATACCC
2004 (Sep 10)	Special Operations Combat Medic Critical Task List includes hemorrhage control in trauma section
2004 Sep	TCCC Transition Initiative training at USAISR for SEAL Team 3 of USSOCOM, then other SOF
2004 Sep	CoTCCC recommends CAT as tourniquet of choice for issue to all deploying Soldiers
2004	SOF limited CAT fielding; reports favorable results, popular outside SOF
2004	Tourniquet doctrine refined, expanded in *Emergency War Surgery* manual
2004	Tourniquets proposed in theater, wait for data is a recipe for inaction; delay is death
2004	Baghdad study (Beekley): tourniquets stop bleeding; deaths without tourniquets occur
2004 (Jul 28)	USAISR Tourniquet recommendations: CAT to all Soldiers; EMT additionally to medics, ambulances
2004 (Oct 26)	Consumer Assessment of Improved Tourniquet Devices conducted at Camp Bullis, TX, by AMEDDBD
2004 Nov	USSOCOM USAISR OAFME study: limb exsanguination deaths still common
2004 (Nov 9)	Phil Durango cedes CAT distribution and management to North American Rescue Products, Greer, SC
2004	Phil Durango cedes CAT manufacturing to Composite Resources, Rock Hill, SC
2004 (Dec 21)	USAMEDDBD published tourniquet user report: 7 of 10 assessors preferred to take CAT into combat
2004 (Dec 21)	Materials testing of devices completed
2004–2005	SOMA talks and vendors help CoTCCC increase awareness among military SOF medics of tourniquet use
2005 (Jan 6)	Surgeon (D. Robb) directs all deploying CENTCOM combatants get issued a tourniquet and its training
2005 Jan	USA TRADOC Commander GEN Kevin Byrnes approves Soldier training that includes tourniquet use
2005 (Feb 23)	AMEDDC&S and USAMEDDBD results to CCCICT; ad hoc committee approves CAT

like one-handed use, Holcomb, USAISR commander, in continued discussion with Walters in the ATACCC lobby, stated, "We need an 80% solution today; not a 100% solution after we all retire!" Holcomb, thinking that the perfect was the enemy of the good, was prioritizing a practical, early solution for most casualties instead of prioritizing perfection for every conceivable, complex case, thereby losing all by interminably delaying implementation. However, while a tourniquet-as-first-aid idea to control prehospital limb exsanguination had been recommended, it could not be implemented as there was no issuance of a tourniquet to every Soldier. Because the World War II–era tourniquet was evidenced to be unreliable and the OHT was not working well, improvised tourniquets became by happenstance the enacted tourniquet doctrine by default. Furthermore, improvised tourniquets were poor in the war experience of users; they required time to find and gather materials (a stick and a band), wrap the band, tie the first knot, place and twist the stick, then tie the second knot and then loop and secure the stick with a third knot.[17,33] Effectiveness rates also appeared poor even in expert hands. Sticks may have been found in some areas of Afghanistan and Iraq, but it became clear that certain areas like open, empty deserts had no sticks at all, resulting in preventable deaths from limb exsanguination. Individual units began to seek tourniquets of their own choice. The old ATLS and new TCCC paradigms, as well as the dual doctrines—ATLS enacted widely, TCCC mainly in SOF—coexisted, mixed up in the two theaters.

To identify the best tourniquets, the military services furthered, quickened, and broadened tourniquet assessments.[41,47–51] Prior to serving as the lead investigator of a 2004 test of field tourniquets, Walters, had read much tourniquet-relevant literature, which helped put the test results on a solid basis of knowledge.[47] Holcomb used a long-standing USAISR policy of developing research teams in which clinicians and scientists could act in tandem. In hemostasis, the MD–PhD dyad was Holcomb and Pusateri; another pairing was Walters with COL John Kragh, an orthopedic surgeon, as a medical monitor for Walters' study who became familiar with emergency tourniquet use and related science.[41] Holcomb adopted a strategy of companies developing field tourniquets and the Army testing promising candidates, and Walters had a chili cook off–like 'tourniquet test off' and found three tourniquets that worked well: the CAT, the SOFTT, and the Emergency & Military Tourniquet (EMT; Delfi Medical Innovations, Vancouver, BC, Canada). The former two were windlass-and-band designs, and the latter was pneumatic.[41] Tourniquet tests by Walters were funded mainly by the Office of Naval Research with help from USSOCOM; yet the Navy (and Marines) rejected the test results from the Army, funded other tests, and soon favored another device, the Tourni-Kwik (TK-3 and later TK-4 models; H & H Associates, Bena, VA). In April 2004 Westmoreland used a CAT for the first time in care; it successfully stopped popliteal arterial bleeding from a leg wound in combat.[18] Westmoreland soon reported another successful CAT use on a left proximal thigh wound.[18] Policy decision-making included a 28 July 2004 USAISR recommendation that the CATs "be issued to each individual Soldier, and the EMT pneumatic tourniquet be considered for issue to combat medics. Further, it is recommended that the EMT be issued for all medical evacuation vehicles and echelon I-III medical facilities"[48,47] (see Appendix). However, this recommendation was not doctrinally enacted. In October 2004 the USAMEDDC&S Army Medical Department Board made a field assessment of user experience with tourniquets at Camp Bullis, TX, and found that 70% of users preferred to take the CAT to war.[49] With growing experience in care and testing, military medical experts recommended in 2004, as CoTCCC had the prior year, that modern tourniquets be fielded to all deployed forces.[41,46–48] Two medics in this tourniquet history, Westmoreland and Miller, overall did more for their casualties and peers than any other medics.

Butler, as chairman of USSOCOM's Biomedical Initiatives Steering Committee (BISC, chartered in 1994), and other USSOCOM leaders felt friction in getting new TCCC techniques and gear quickly to deploying SOF units. Such leaders sought means to speed (1) updating of "allowed equipment lists" with the new gear; (2) repacking medical kits with the new gear; (3) revising medical curricula with the new strategies; (4) widening tourniquet training to *all* SOF combatants, not just medics; and (5) systematically gathering feedback from SOF medics on how new techniques and gear worked in specific mission situations in order to refine TCCC guidelines.[14,15] In September 2004 Butler, as USSOCOM surgeon, requested a TCCC Transition Initiative as a USSOCOM-funded, USAISR-executed (led by Holcomb), pilot program to meet these five needs. With the unanimous support of USSOCOM surgeons from the Biomedical Initiatives Steering Committee and the Special Operations Research, Development, and Acquisitions Center (including Mr. Dave Saren), deploying SOF units were identified to get predeployment TCCC training and gear. The success of the USSOCOM way of promptly finding and filling gear gaps was recognized later by the under secretary of defense's "Better Buying Power Efficiency" Award.[52] USAISR's Greydanus gave deploying SOF personnel "Just in Time" TCCC training, which was linked to postdeployment debriefs for lessons learned. MSG Harold "Monty" Montgomery, senior Ranger Regiment Medic, reported seven Rangers saved with tourniquets in one operation.[15] A total of 67 cases in which tourniquets were used successfully were identified in the TCCC Transition Initiative. Several medics initially reported problems controlling thigh bleeding

with a single CAT, specifically with the windlass breaking as it was tightened with the force necessary to be effective on the upper thigh; the maker soon strengthened the windlass.[15] A 2004 Baghdad casualty survey at Ibn Sina Hospital in the Green Zone had a broad scope as U.S. clinician-investigators observed casualty outcomes with and without prehospital and emergency department tourniquet use.[53] The investigators, led by an Army surgeon, MAJ Alec Beekley, found that tourniquet use was associated with improved hemorrhage control, especially in the more severely injured casualties, and concluded that four of seven deaths in the study cohort would have been potentially preventable if prehospital tourniquets had been used.[53]

In November 2004 the USSOCOM requested that the USAISR work with the Office of the Armed Forces Medical Examiner and perform a preventable death analysis of all 82 SOF fatalities sustained in Iraq and Afghanistan. Although published years later, a major finding was that extremity hemorrhage was still a leading cause of preventable death, a finding that was widely broadcast in early 2005.[54] The death analysis, led by Holcomb, found that 3 of 12 potentially preventable deaths were due to extremity hemorrhage.[54] Similar rates were soon found in a larger cohort of deaths from the first 5 years of the war.[55] By December 2006 Kelly et al. noted that 77 U.S. deaths of 982 combat fatalities (7.8%) were from tourniquet-amenable injuries. Data again starkly demonstrated the persistent tourniquet gap.

COL Ted Harcke, a diagnostic and forensic pathologist, deployed again to Afghanistan in 2005 as a physician yet did not receive a tourniquet or training; such gaps were common among those who deployed to war individually as opposed to those who deployed as whole military units. Later common practice was for nearly every "medical" individual to go to the Tactical Combat Medical Care training at Fort Sam Houston or to basic tourniquet training at Combat Replacement Centers before deploying. Such training was long overdue to prepare deploying providers as hospital-based peacetime providers were otherwise new to tourniquets. In these ways, physicians learned about tourniquets slowly and progressively over time by deploying and redeploying.

Thus in 2004 and early 2005 data showed that limb exsanguination death rates remained as high as those in Vietnam when tourniquets were rarely used, but survival rates were high when they were used early.[54,55] For the larger military beyond SOF, better enactment of new ideas and fielding of new devices—already recommended and approved—was held up in the bureaucracy by cost and resistance to change. If individual military units wanted to buy a particular device, they could do so, if they had money. Unfortunately, many commercially available devices did not work well, and some units had no funds to buy recommended devices. When such tourniquet knowledge, messages, and publications were broadcast well, usually by SOF, the recommended devices became popular among units that acquired them and the unit staff gained experience using them, which they subsequently passed along to others. On 6 January 2005, the U.S. Central Command (USCENTCOM, staff surgeon was then COL Doug Robb) directed that the CAT was to be issued to combatants entering into the CENTCOM area of operations.[42,56] By 5 March 2005, this tourniquet situation had become complex, divergent, and frustrating as assertive SOF were well ahead of other units regarding individuals experienced with hemorrhage control, unit knowledge of techniques that worked, and unit experience in acquisition and resupply of tourniquets. This tourniquet story at this point remained a quiet conversation of an arcane facet of prehospital care for a small sector of society. After a plot twist, yelling started.

6 March 2005 through 2008: Dynamite, Decisions, Drama, and Data

At the predawn morning of Sunday, 6 March 2005 the *Baltimore Sun* plopped onto Americans' doorsteps in the Mid-Atlantic region including Washington, DC. On the front page, Robert Little of the *Sun* national staff headlined, "Modern Combat Lacking in Old Medical Supply: Deaths Because of Blood Loss From Wounded Extremities Could Be Reduced if All Soldiers Carried $20 Tourniquets, Some Doctors Say." Mr. Little exposed that preventable deaths occurred during bureaucratic delays in rewriting manuals, in testing which pouch was best to store a tourniquet, and in enacting required contracts to implement approved solutions[57,58] (Table 5). He described multiple key leaders with little awareness of problematic details, and he went on to detail that bodies "of Soldiers have arrived at aid stations in Iraq with makeshift tourniquets crafted from belts, wire or some other material that proved to be inadequate." Mr. Little reported examples of confused Soldiers with widely varying degrees of awareness of divergent policies and practices. For example, Mr. Little detailed the fast developing tourniquet practices of SOF, a slow "Big Army," and lagging Reserves and National Guard. Mr. Little's report of a theater-of-the-absurd within the military system ignited a news cycle that soon led to Senator Richard J. Durbin (D, IL) and Senator Carl Levin (D, MI) calling out Republican Secretary of Defense Donald H. Rumsfeld. "The experts have determined that putting a tourniquet in the hands of every Soldier is a vital life-saving measure," Durbin and Levin said in their letter to Rumsfeld.[58] "Holding up the fielding of a life-saving medical kit simply to optimize its carrying pouch suggests a mindset oblivious to the wartime needs of our Soldiers."[58] This pivotal act by these two senators was

Table 5 *Excerpts from Little's* Baltimore Sun *Front Page Article, Sunday, 6 March 2005*

Even after the bullet cut through his leg and severed his femoral artery, 1st Lt. David R. Bernstein had a chance. The shooting stopped quickly, and a Soldier trained in combat medical care was at Bernstein's side almost immediately. Helicopters landed, and minutes later the young platoon leader was surrounded by four surgeons and all the equipment of a modern battlefield trauma center.

Bernstein died that night in Iraq, despite getting the best emergency medical care the Army had to offer. But doctors who specialize in combat injuries, and who reviewed details of the case provided by *The Sun,* question whether the 24-year-old West Point graduate might have lived if the Army had had something else to offer: a $20 nylon-and-plastic tourniquet. . . .

Bernstein was riding in the passenger seat of a Humvee near Kirkuk on Oct. 18, 2003, part of a three-vehicle convoy of the 173rd Airborne Brigade, when Iraqi insurgents ambushed the convoy with rifle fire and rocket-propelled grenades. According to Joshua Sams, a former Army specialist, who was driving the Humvee that day, Bernstein was shot through his left thigh at an angle, leaving an entry wound about 1½ inches above his knee and an exit wound about 4 inches above his knee.

Sams, who had been trained under the Army's "combat lifesaver" program to treat trauma injuries, tried to use the cotton straps from a standard field dressing to put a makeshift tourniquet on Bernstein's leg, but the material broke apart under the pressure. By the time he could apply something more substantial—using the sling from an M4 rifle and the nozzle from a fuel can to twist it—Bernstein's blood had soaked the ground and Sams could not detect a pulse.

"I couldn't find a stick," Sams recalls. "There was nothing around but grass, and the bag from the Humvee only had bandages and things."

the policy enactment's climax. Although having only bit parts, the senators represent in brief many leaders—legislative, executive, academic, and commercial—trying to do the best they can for their nation's people in that complex, complicated work sometimes known as democracy. This tourniquet story languished prior to this sensational news article and senatorial boost; the timeline immediately changed from slow pace to high speed, with the tipping point being an act of Congress (Table 6).

After the media storm, political repercussions promptly fueled organizational efforts to accelerate tourniquet fielding—by brigadiers through boardrooms to Baghdad into backpacks. On 22 March 2005 USSOCOM mandated that CAT tourniquets and other TCCC equipment be issued to all deploying SOF units; USSOCOM (in part through the BISC) paid for TCCC equipment issued to SOF units as the generals of the combatant commands enacted the doctrinal ideas.[59] Other units bought their own TCCC equipment initially, and later the services provided them. On 28 March 2005 after a number of meetings and a review of the extremity deaths from the Armed Forces Institute of Pathology, the U.S. Army Surgeon General, LTG Kevin Kiley, recommended that all deploying Soldiers receive a CAT as the tourniquet of choice or a SOFTT if a CAT was unavailable; LTG Kiley's decision was pivotal in enacting most of the 2004 USAISR recommendations.[60] Parsons, AMEDDC&S instructor, soon received a large shipment of CATs and began training the combat medics to use them; previously, medics were taught about but not with new tourniquets (except the OHT briefly), but now they actually trained realistically with the CAT and not just with improvised tourniquets. Furthermore, the military fielded and supplied tourniquets soon in the hundreds of thousands, and later moved to overhaul tourniquet training.[42,61] Unrecognized at the time but soon made clear, the increase in fielded tourniquets reached a critical mass in that the density of devices per Soldier per square mile of battlefield then allowed experience to soon become common; experience prior to this mass fielding was nearly impossible to accrue without an adequate density of use. Early feedback on tourniquet use was positive, with numerous lives saved without limbs lost.[15,42,62,63]

In March 2006 soon after the Samarra mosque bombing worsened sectarian violence, Kragh, a prior 3/75 surgeon, entered the Baghdad emergency department of the coalition's combat support hospital. On his first day at the hospital, dinner time came, which required a walk by the emergency department.

At the front desk, he asked the nurse, a young second lieutenant on her first assignment out of school, "How's your shift been?"

She yawned, "Fine."

Seeing the desk-top clipboard with a list of casualty care, he said, "Hey, that's interesting—you've had an emergency tourniquet used during your shift."

"No," she replied, "that's not interesting. We have one every shift."

Kragh replied, "Well, I hear you, but that's the world record—times 30,' in accrual.[13]

The nurse soon labeled this pudgy nerd to her peers as "the tourniquet guy." It was already clear that Baghdad had become a vortex of violence as an epidemic of casualties funneled into the busy trauma center where clinicians produced trauma studies.[53,64,65] Knowing little data were published to develop best tourniquet practices, however, Kragh made a do-it-yourself plan to get the data on tourniquet use that was already accruing in front of everyone's eyes. These conditions were a perfect

Table 6 *Timeline: 6 March 2005 through 2008: Dynamite, Decisions, Drama, and Data*

2005 (Mar 6)	*Baltimore Sun Times* report tourniquet gap, deaths, news cycle begins.
2005 (Mar 9)	Senators ping Rumsfeld: why no battlefield tourniquets yet? Congressional hearings ensue
2005 (Mar 9)	U.S. SOCOM CDR Special Operations Combat Medic Course Critical Task List: train TCCC as standard
2005 (Mar 22)	USSOCOM mandates TCCC equipment (e.g., tourniquet) and training for all deploying SOF
2005 (Mar 24)	USAMRMC Commander MG Martinez-Lopez approves new first aid kit including tourniquet
2005 (Mar 30)	USA Surgeon General LTG Kevin Kiley recommends: all deploying Soldiers get CAT or substitute
2005 (Mar 31)	EMT is said to be "the primary tourniquet for the Combat Medic . . ." by doctrinaires but not enacted
2005	USA Office of Surgeon General memo enacts most USAISR tourniquet recommendations
2005 May	Directorate of Combat Doctrine Development AMEDDC&S: change now to tourniquet first under fire
2005	Naval Experimental Diving Unit (NEDU) test tourniquets
2005 (Jun 7)	CCC Integrated Concept Team receives Tourniquet recommendations including CAT and EMT
2005 (Jul 7)	London, UK bombing survivors self-apply tourniquets, rescuers make tourniquets to stop bleeding
2005 Jul	CAT fielding at 277,409 devices
2005	Dorlac et al. publish *J Trauma* paper on Houston civilian limb exsanguination deaths
2005 (Aug 17)	USSOCOM commends COL Holcomb and SFC Greydanus of USAISR for TCCC training of SOF
2005 (Aug 21)	CoTCCC meeting talk CAPT Butler: evolving Concepts in TCCC; tourniquets saved 44 lives
2005 Sep	Walters et al. at USAISR publish Laboratory Evaluation of Battlefield Tourniquets
2005 (Nov 30)	TCCC Transition Initiative unit training at 39 courses, 1716 people (310 medics, 1406 operators)
2005	Tourniquet logistics, re-supply, training, and systems management improve in progressive activities
2005 (Dec 21)	CoTCCC meeting talk by CAPT Butler: Special Operations Medicine: Tactical Medicine
2006 Jan	SFC Greydanus talk TCCC Transition Initiative: tourniquets saved 67 lives, no limbs lost from tourniquets
2006 (Feb 21)	CoTCCC meeting: FK Butler: TCCC in Special Operations tallies tourniquet saves
2006 (Aug 18)	2d Israel–Lebanon war: Israelis report: 11 Soldiers had prehospital tourniquets used
2006 (Aug 31)	NY state trooper shot in thigh dies 3 Sep after bleeding, amputation surgery, no tourniquet used
2006 Oct	Baghdad survey by Kragh et al., 2009, 232 casualties, tourniquets save lives if used well (early, correctly)
2006	Besides Army, more services and nations field tourniquets especially CAT
2006 Nov	Baghdad survey continued by 1LT Michelle Littrel, consistent results in trial (clinicaltrials.gov)
2006	Besides U.S., Iraqis and Afghans field tourniquets, especially CAT, aided by U.S.
2006	CoTCCC meeting approves changes to recommendations including tourniquet removal guidelines
2007 Mar	Baghdad survey period for 1LT Michelle Littrel ends, 499 casualties, 862 tourniquets so far
2007 Mar	Baghdad survey continued by LTC Dorothy Beebe, performance and survival improves from prior
2007 (Apr 15)	Virginia Tech shooting Kevin Sterne thigh artery: electrical cord improvised then to MAT tourniquet
2007	Naval Experimental Diving Unit (NEDU) test tourniquets, phase 2
2007 Jun	Baghdad survey closed to new accrual by LTC Dorothy Beebe at 727 casualties, 1212 tourniquets total
2007 Nov	NFL player Sean Taylor shot at home in Miami and bled to death from a femoral artery wound
2007	CoTCCC relocated to function under the Defense Health Board, Deputy Assistant Secretary of Defense
2008 (Jan 6)	Wellington, New Zealand: Parolee goes on shooting rampage, kills biker, tourniquets save
2008 Feb	CoTCCC incorporates Baghdad survey data on misuse and correct use to develop best practice guidelines
2008 Feb	Hopewell Township, NJ, township officer uses belt as tourniquet on crash victim's crushed leg
2008	Beekley et al—Baghdad 2004 data: tourniquets control limb bleeding with few complications

(continues)

Table 6 *continued*

2008	Kragh et al—2006 data—R4: right tourniquet used in right way at right time for right casualty is best care.
2008 May	Portland, ME policeman unintentionally shot his thigh while preparing for duty, died shortly thereafter.
2008 (Jun 10)	Prehospital Trauma Chair of American College of Surgery Committee on Trauma letter to ASDHA: care is lifesaving
2008 Jul	Wichita, KS, policeman survives gunshot in both legs, tourniquet used
2008	Tien et al.—Canadians report tourniquet and TCCC use data; tourniquets are lifesaving with few complications
2008	Houston, TX: CAT tourniquets placed in the Emergency Department of Memorial Hermann Hospital
2008	Houston, TX: CAT tourniquets placed on six LifeFlight helicopters, use rate at >30 cases a year
2008	San Antonio, TX: Civilian tourniquet uses increase to six prehospital cases within 2 years
2008	Kalish et al. publish *JEMS* paper on Boston civilian limb exsanguination deaths
2008 (Nov 26)	Mumbai, India, massacre includes emergency tourniquet use to stop bleeding
2008	CAT 2004 model found in an SOF kit and replaced by a modern CAT; old one still useable
2008 (Dec 1)	World War II–era tourniquet's National Stock Number withdrawn from federal Logistics Information System

storm that would allow a clinician-scientist to survey tourniquet use in order to fill many knowledge gaps. At the time of the accrual rate insight, Holcomb was the senior surgeon-researcher-leader present; his leadership ensured success of the plan. In October 2006 the first deployed research team came into Baghdad and assisted with data gathering to continue that tourniquet survey (eventually registered as National Clinical Trial NCT00517166 at ClinicalTrials.gov). The teams were formed and made ready by the leadership of Holcomb. Eventually the observations of tourniquet use accrued to 727 casualties with 1212 tourniquets, surpassing prior reports. The bulk of the survey work was done by two nurses in the Baghdad emergency department, then 1LT Michelle Littrel (later Michelle O'Neill) and LTC Dorothy Beebe, who collected much data over 10 months during the preparation and execution of the Baghdad surge.[66–69] The quality and quantity of their reporting were so broad and deep that many tourniquet controversies were resolved. Much of what we take for granted about tourniquets today is from these two nurses' performance improvement project in Baghdad. "As a rule, not many medical people venture into a battlefield with scientific investigation in mind," but these two nurses did.[3,70,71] As members of a rotating, multidisciplinary research cell, coordinated out of the USAISR (commanded by Holcomb), these two nurses successfully ran a large project requiring much teamwork. No two nurse-authors have done more to save combat casualty lives in the current war than these two at Ibn Sina Hospital, which so happens to be named for the clinician-author, also known as Avicenna, of the earliest known clinical trial report. The survey evidenced lifesaving benefits in preventing hemorrhagic shock by controlling hemorrhage; those benefits were scalable by tourniquet indications (use yes/no; indicated yes/no; prehospital/hospital use; and use before shock onset/after), which painted the clearest picture to date of how and when to use emergency tourniquets.[65,67,72–75] The documentation of tourniquet effectiveness by the two nurses permitted trainers to instruct better, doctrinaires to decide better, and stakeholders to lead better. To date, 2000 U.S. military lives are estimated to have been saved by tourniquet use. The CAT effectiveness rate was 79%; Holcomb had the early "80% solution" he sought presciently at ATACCC 3 years earlier.[64] The two leading men of this tourniquet history over the whole were the two surgeons, Holcomb and Butler, who did the most for its success.

After completion of widespread fielding of the new tourniquets, namely CAT and SOFTT, a chronic problem became acute as Soldiers had both new and old tourniquets. An effort ensued in 2005 to purge the old, World War II–era tourniquets from care as they remained in military supplies, despite the recognized fact that they did not work and they were not recommended by anyone for use.[76] The old tourniquets were present both in the field and within the stocking system, the Federal Logistics Information System (FLIS). The FLIS was for ordering and resupply and had the old tourniquet with its National Stock Number (NSN) of 6515-00-383-0565. When someone wanted to order a new tourniquet, they could easily order an old tourniquet by mistake. Much bureaucratic consternation over the years eventually found a remedy when one PA, a medical logistics leader, Lt Col "Boots" Hodge from the Defense Medical Standardization Board (later sectioned as the Defense Medical Materiel Program Office, DMMPO), realized

that he could fix the problem in one act by deleting its NSN. On 1 December 2008 the NSN was withdrawn, and the old tourniquet was no longer able to be ordered, stocked, or resupplied. Having cut a Gordian knot, the next problem was addressed. The FLIS did not differentiate well among tourniquets as it did not indicate to purchasing officers (experts in logistic processes, not casualty care) those items that were equivalent substitutes and those that were not. There had been confusion over item names, approved items lists, common (commercial or trade) names, and technical procedures. For example, a person who listed "tourniquet, combat application" in bureaucratizing the CAT's trade name, made a mistake as that item name was unapproved, and it was on no approved item list. Eventually, Hodge and his assistant MAJ Jim Fulton, a prior Special Forces medic, improved the logistic system to differentiate well among tourniquets. A fix was to add the "tourniquet, combat application" to the "approved item list" under an already approved item name, "tourniquet, nonpneumatic." In the common name field, "TCCC-approved" was added after the trade name. Additional descriptors were used as needed like "Combat Application Tourniquet" or "Special Operations Forces Tactical Tourniquet" in the trade name field with their abbreviations. DMMPO efforts continued under Air Force Maj Brandi Ritter, a PA with experience caring for SOF and Navy CDR Tyson Brunstetter to coordinate joint interoperability of first aid kits among military services, to conduct anticounterfeit work, and to analyze tourniquets after use. These ongoing efforts continue to provide necessary checks and balances to ensure quality control and to address any challenges that may arise. Logistically, the Marines initially preferred a different tourniquet (TK-4, TourniKwik, H & H Associates) because it was small and inexpensive and reportedly worked well in tests,[50,51] but eventually the Marines switched to the CAT because of poor TK-4 performance and poor interoperability (design, training, and techniques of use conflicted with those of other military services and nations). Such sustained teamwork with comprehensive follow-through by joint logistic and medical leaders was essential to modernizing and harmonizing complex systems—namely, medical care, logistics, and training. To further advances in care using tourniquets, Holcomb formed a full-time tourniquet program at the USAISR to gain a high level of expertise, and COL Lorne Blackbourne, USAISR commander after Holcomb, perpetuated that program. Successes and failures in this tourniquet history are often overlooked or misperceived, but knowing them may prevent or limit future miscues.

2009 to Today: Closing and Curtain Call

After the scientific breakthroughs from 2006 to 2008, much "mop-up" work was then done to consolidate or refine new knowledge gains.[66,75,77–80] A recent and encouraging example of tourniquet change was the improvement in fielded designs. The CAT has undergone six significant design refinements (generations 1 to 6), and those designs made it to the battlefield quickly as evidenced by a joint study of the Armed Forces Medical Examiner System and the DMMPO[81] (Table 7). Tourniquet counts recovered from deceased casualties seen at Dover Air Force Base, both used and unused (carried), promptly mirrored changes in tourniquets supplied as new models made it through the supply system quickly to the combat kits of users. In 2010 CAT generations 1 to 4 represented 39% (45 of 123) of recovered CATs; but for 2011 to 2012 that proportion dropped to 18% (29 of 165) as 82% (136 of 165) became newer designs (generations 5 and 6). This fast change is in sharp contrast to the norm; as detailed above, the military system took more than six decades to purge the World War II–era tourniquet. The primary reason for the speed was better feedback to and from the field for a comprehensive set of medical, logistic, and training stakeholders. Harcke, a Ranger, served the Army for more than five decades and experienced these slow and fast tourniquet changes firsthand. As an indicator of how much this tourniquet story had changed by 2012, the CAT became the item of highest expense in all the medical supplies (Class VIIIa) in orders at the AMEDDC&S. To further underscore the changed speed of knowledge generation and to offer civilians the lessons learned of tourniquet developments in war, we published a 2012 report on tourniquet use in children, which appeared—by an unfortunate coincidence—at the time of the mass killing of children in Newtown, CT.[82] Another indicator of change was that after tourniquets use became common, limb exsanguination was demoted as the most common preventable cause of death on the battlefield to second most common. Such changes were brought about primarily by two casualties, two medics, two surgeons, two senators, and two nurses. Bleeding at the trunk–appendage junctions where regular tourniquets cannot fit was promoted from second to first, but junctional tourniquets are another story for another day.[54,55,72,83–89]

The spirit-of-the-time of this tourniquet story is that of COL (Ret.) Robert Mosebar, MD, an American physician and the father of the Army's Combat Lifesaver, who died in 2011. Today, he is remembered as a past doctrine enactor in the halls of U.S. military medicine. He began his long and illustrious military career in World War II as a medic and litter-bearer in the Philippines, where he spent his first night in war in a foxhole with his deceased platoon leader, whom he saw bleed to death. He was also in the Korean War as a registrar for a Mobile Army Surgical Hospital, in the Vietnam War as a corps surgeon, and later in service to the Army in its AMEDDC&S as a senior medical consultant to the Directorate of Combat

Table 7 *Timeline: 2009 to Today: Closing and Curtain Call*

2009	Kragh et al.—2006 survival data: tourniquets prevent shock onset and improve survival rate and duration
2009 (Mar 4)	ASDHA Asst Secretary of Def (Health Affairs) Cascells endorses TCCC use and training
2009 (Mar 9)	Defense Health Board TCCC brief; Trauma & Injury Subcommittee recommends: all to be trained
2009	Training, doctrine, supply, and trauma system management refined based on data toward best practice
2009 (6/10)	Ft Hood shooting, 55 casualties, Soldiers saved policewoman Kimberley Munley with tourniquets
2009 Jun	U.S. Navy Surgeon General message to Navy require corpsmen training in TCCC
2009 (6/22)	Washington, DC: Passengers use tourniquets at train crash (Metro Red Line near Takoma station)
2009	Minor morbidity associated with tourniquets, uncommon, minor and temporary
2009	Based on 2001–2009 data, USAISR and CoTCCC estimate 1000 to 2000 U.S. military lives were saved at war
2009	Tourniquet Summit: testing is not research per se now that methods are stable; new test dollars
2009 Aug	Defense Health Board recommends that all deploying servicepersons are TCCC-trained
2009	Isolate limb exsanguinations demoted as #1 preventable death; junctional bleeding now #1
2009 (10/30)	USMC Commandant directs enactment of TCCC guidelines in Marine forces
2010 (1/26)	Australian surfer cut arm on surfboard and had improvised rope tourniquet work immediately
2010 Mar	Tourniquet Working Group in Stafford, Virginia discusses testing needs, DOD participants
2010 Apr	USA Training and Doctrine Command (K O'Brien) mandates TCCC into Combat Lifesaver Course
2010	All U.S. military services and most coalition services use TCCC-based training for medics and providers
2010 Apr	CoTCCC meeting: note 5 of 101 Pakistani casualties had tourniquet use; 5 more without died in field
2010 (Aug 11)	Combat Ready Clamp, a junctional tourniquet, is approved by the FDA for difficult inguinal bleeds
2010	1000 to 2000 U.S. lives saved with battlefield tourniquets: *NY Times, Washington Post*
2010	J. Gooch publishes *Biocompatible Polymeric Materials and Tourniquets for Wounds,* Springer
2010 (Oct 4)	COMMARCORSYSCOM directs replacement of TK-4s with CATs in IFAK and vehicle medical kit
2010 Nov	Crescent, IA M Lee dropped a hunting gun, was shot in the knee, and was saved by son with tourniquet
2010 Winter	Sztajnkrycer publishes in TEMS on law enforcement officer death; 1.6% isolated limb exsanguination
2011 (Jan 8)	Tucson AZ shooting limb injured casualties deputies used tourniquets (first aid kit photo shows SOFTT)
2011 (Jan 22)	San Antonio, TX policeman M Thornton's Leg was nearly severed; H Vera saved him with a tourniquet
2011	America, Britain, Canada, Australia, and New Zealand armies recommend TCCC for first aid
2011	Used tourniquets analyzed: wear-and-tear data lead to better designs, training, and surveillance
2011	Kotwal et al.—Rangers optimized comprehensive, universal care for highest survival; prehospital tourniquets
2011 (May 4)	RFI opened another round of tourniquet testing; Joint Operational Evaluation of Field Tourniquets
2011 (Jun 7)	RFI closed Joint Operational Evaluation of Field Tourniquets, 10 designs submitted
2011	Kragh et al.—historical review of battlefield tourniquets published: repetitions of lessons learned and lost
2011 (Jun 27)	Austin, TX: Boy Scout leader (former Soldier) saves student with tourniquet at truck vs bicycle crash
2011 Jul	Salt Lake City, UT: detectives T. Anderson, J. Sayes, and A. Sweeny applied tourniquets to shot officers
2011 Jul	Ransomville, NY: Niagara County sheriff in cruiser guardrail crash lost both legs, saved by tourniquets
2011 Jul	Eastridge *J Trauma* DOW autopsy cases: 31% bleeding mechanism potentially survivable, 31% extremities
2011 (Jul 22)	Oslo, Norway, massacre: people used their clothes as tourniquets.
2011 Aug	Kotwal et al.—TCCC helps eliminate preventable deaths on the battlefield
2011 (Aug 24)	Lower Frederick, PA: Daughter puts tourniquet on mother's leg after mother was shot by drunken father
2011 (Sep 6)	Carson City, NV, shooting at IHOP: two casualties saved with improvised tourniquets
2011 Sep	C-A-Tourniquet® was featured in the fall premiere episode of ABC's television show *Grey's Anatomy*

(continues)

Table 7 *continued*

2011 (Sep 11)	Spring Valley, NY: tourniquet on amputated leg saved life of man in motorcycle crash on throughway
2011 (Sep 14)	Test Plan published Joint Operational Evaluation of Field Tourniquets, Phase I
2011 (Sep 16)	Reno, NV, air races crash, spectators had amputations, at least two spectators made and used tourniquets
2011 Sep	Cape Town, South Africa: M. Cohen, mauled by shark and saved by improvised tourniquet use
2011 (Sep 27)	Meeting of USAMEDDC&S's DCDD, Delfi, and USAISR to discuss enact possible EMT fielding
2011 (Nov 10)	U.K. off-duty nurse saves crash victim's life using bra as improvised tourniquet
2012 Mar	Deputy applies tourniquets to Indiana mother's two amputations to stop bleeding and save her life after tornado
2012	Houston, TX, 2000 CAT tourniquets distributed across the greater Houston EMS systems
2012	Aurora, CO, shooting: a woman outside the theater improvised a belt as a tourniquet to a stranger's wounds
2012	2000 lives estimated saved by tourniquet use (U.S. active duty combatants in theater)

Doctrine Development, those responsible for deciding whether to enact doctrinal ideas. After visiting Israel in the 1980s, he brought to America the prehospital ideas of improved buddy-aid on the battlefield, including point-of-injury tourniquet use. However, the depth and breadth of the penetration of tourniquet use into the culture of the American Soldier were limited then as only improvised tourniquets were available far-forward. These limitations were due in part to the fact that his doctrinal idea had little support, especially before Somalia; and so tourniquets, although officially a part of the Soldier's culture, remained a means of last resort. At age 80, when he retired in 2004 after serving 60 years, few new service persons knew Mosebar as the embodiment of recent military medical history and modern doctrinal development. Although history, war, and aging are relentless, Mosebar's doctrinal idea persevered and was enacted eventually and fully. After he died at age 87, his daughter said in his obituary, "My dad used to say that prior to Iraq and Afghanistan, too many of our Soldiers bled to death on the battlefield. It [saving lives] was his passion."[90]

Although we distilled history to tell this tourniquet story briefly, readers know that actual history plays out in real time as a real mess. History rarely marches simply, incrementally, efficiently, or orderly; it really lurches complexly in fits, starts, stalls, dead ends, tragedies, and dramas. While it may seem as though the best time for the military to improve things like first aid would be peacetime, real change tends to come only when a nation is focused as in war, as this tourniquet story warns. The dramatic story of improvements in tourniquets is one of improvisation without a director or control booth. Future improvements for airway or breathing problems can use this tourniquet story as an example to improvise anew and tackle existing problems to turn defeat into victory.

In summary, despite data from the prior century indicating tourniquets were needed to save lives, by 11 September 2001 the military had not been able to improve fundamentally its first aid hemorrhage control; and this tourniquet story after 9/11 began in tragedy but changed into triumph. From a few key insights, a set of energetic leaders, an ensemble cast, a fielding of millions of tourniquets, a data-heavy survey of use, a persevering team effort, a few diligent committees, and a number of incremental refinements in policy over years, the story line may seem in hindsight to have been scripted; but as this story played out, no scene was predetermined, no act was inevitable, and no plot twist was without luck. Although much of this history was made to happen, history could have turned differently at any point—remember Parsons' personal push to improve medical training. We knew at the start that success was not foreordained as tourniquets languished almost endlessly as the most controversial first aid item for two millennia.[91] We tell this story so that others can use it as an example of how a complex system could be made to do the right thing. It is a story best heard not in the heat and smoke of a Baghdad bombing but with buddies over beer aside the warmth of a Texas Hill Country barbecue pit.

APPENDIX

Tourniquet Recommendations from the USAISR
28 July 2004

Nine battlefield tourniquets systems were offered for testing to the United States Army Institute of Surgical Research via a request for products. These included seven commercially available systems and two prototype systems. Eighteen human subjects were used to test the effectiveness of each device in accordance with an institutional review board–approved protocol. Success was based on ability to occlude arterial blood flow in the

proximal thigh (elimination of Doppler pulse in the posterior tibial artery). Additionally, the subjects rated each tourniquet for pain using a visual analog pain scale.

Two tourniquets were rejected based on weight and/or faulty design. Of the remaining seven tourniquets, three were effective in 100% of the subjects. These included one pneumatic and two strap-type tourniquets: the Emergency Medical Tourniquet (EMT) (Delfi Medical Innovations); the Combat Application Tourniquet System (CATS) (NSN: 6515-01-521-7976) (Phil Durango, LLC); and the Special Operation Forces Tactical Tourniquet (SOFTT) (NSN: 6515-08-137-5357) (Tactical Medical Solutions LLC), respectively.

The two strap tourniquets used a built-in windlass as the mechanism for tightening. Of the two successful strap-type tourniquets, the CATS was less painful, easier to use, smaller, and lighter than the SOFTT (59 grams vs. 160 grams). The design of the SOFTT limited the ability of the windlass to tighten the tourniquet (i.e., it was limited to approximately three turns). This limitation can be overcome through training the user to pull the tourniquet snug before attempting to tighten with the windlass. The EMT pneumatic tourniquet was wider and thus significantly less painful than any device tested and is much less likely to induce nerve damage compared to either of the strap tourniquets. The EMT weighs 215 grams and when packaged is similar in size to the SOFTT.

Based on these facts, it is recommended that the CATS be issued to each individual Soldier, and the EMT pneumatic tourniquet be considered for issue to combat medics. Further, it is recommended that the EMT be issued for all medical evacuation vehicles and echelon I–III medical facilities.

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Disclaimers

The opinions or assertions contained herein are the private views of the author and are not to be construed as official or as reflecting the views of the Department of the Army or the Department of Defense.

This study was conducted under a protocol reviewed and approved by the U.S. Army Medical Research and Materiel Command Institutional Review Board and in accordance with the approved protocol (Review of Protocol H-12 009/IRB File #M-10207 – A History of Tourniquets in the Current War.

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