

HISTORICAL VIGNETTES IN VASCULAR SURGERY

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A brief history of the tourniquet

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The tourniquet is a device first used in antiquity; it has been praised or vilified throughout the ages, as it has been at times life-saving, and at other times limb-threatening.¹ It interestingly has become a widely used tool in the current wars of Afghanistan and Iraq by most coalition medics, often with great success. Its current reputation is very positive among foot soldiers. Combat troops are reportedly going out on dangerous patrol missions with tourniquets already in place on extremities, as they wish to be fully ready to respond to extremity bleeding, if and when the mine or the improvised explosive device (IED) should go off. Some work has even been done on field uniforms, which have tourniquets actually sewn into sleeves, etc., in order to ensure the quickest access and application possible.² Response times in this current conflict are so rapid and transportation by helicopter is so efficient that prolonged tourniquet times are rare. The data being collected would indicate that we are seeing few tourniquet-induced injuries because they are removed rapidly, and we are definitely saving lives because they are used liberally. The purpose of this report is to review the history of the tourniquet throughout the ages, as it has been modified and improved numerous times by a series of innovative physicians, up to the present day.

ANCIENT USE OF TOURNIQUETS

The known history of tourniquets goes back to the Middle Ages, when Morel first used a tourniquet on the battlefield at the battle of Flanders in 1674. Guy de

Chauliac was known for wrapping a tight band below and above the site of amputation to reduce the pain and to cut down on hemorrhage. Botallo taught that one should use three tight bands, and do the amputation between the lower two. Fabricius used a stick to tighten the tourniquet above the amputation site. Scultetus employed a screw compressor. Petit invented a type of screw compressor which, when tightened, held the tourniquet in place and occluded blood vessels of the limb (Fig 1).³ Thus gradually, as time passed, tourniquets were modified and improved.¹

MODERN USE OF TOURNIQUETS

Tourniquets were definitely used by both sides during the U.S. Civil War. Soldiers were taught to carry some sort of roller or bandana with an accompanying stick to use as a windlass. According to Mabry, there was very little training in the proper use of tourniquets, and at times excessive use of them, with unnecessary limb damage or loss. But when used properly, and for the proper indications, they were life-saving.⁴ One of the interesting accounts of the Civil War was the story of the death of General Albert Sydney Johnston, a very important leader of the South, who had been injured in a duel in 1837, leaving him with some apparent leg nerve damage. This became important in 1862, at the Battle of Shiloh, when he had mistakenly gone ahead of his troops and was shot in the leg. Not realizing the seriousness of the situation, and probably not feeling the injury because of his previous wound, his boot filled with blood and he exsanguinated. It was said that he died with a tourniquet in his pocket.⁵

In the early 1900s, Dr. Rudolph Matas designed and employed the "Matas Compressor," a rigid device that could compress the femoral artery at Hunter's canal, checking for adequacy of collateral circulation below the point of occlusion (Fig 2).⁶ Interestingly, there is a modern clamp-like tourniquet called "The Croc" that is being marketed to stop high groin injury hemorrhage, and is similar in appearance to the Matas Compressor.⁷

World War I was a bloody and difficult conflict, which produced countless extremity wounds. It was a time when rapid evacuation of the wounded was often not possible, and it was not uncommon for tourniquets to be applied and left for prolonged periods of time, with predictable results.

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Competition of interest: none.

The views expressed in this paper are those of the authors, and do not necessarily reflect the doctrine or teaching of the Department of Defense, or the Uniformed Services University of the Health Sciences.

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The editors and reviewers of this article have no relevant financial relationships to disclose per the JVS policy that requires reviewers to decline review of any manuscript for which they may have a competition of interest.

J Vasc Surg 2012;55:286-90
0741-5214/\$36.00

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doi:10.1016/j.jvs.2011.10.085

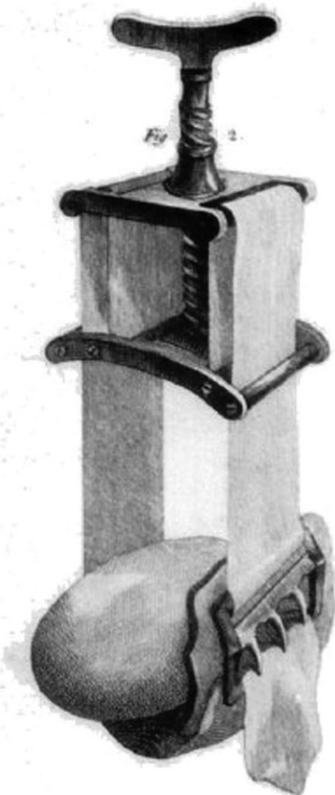


Fig 1. This illustration shows an ancient Petit tourniquet, with the screw device that allowed for excellent tightening and compression.

Many medical leaders were harsh in their criticism of tourniquets during World War I. An example was Tuffier, who was Consulting Surgeon to the French Armies in the Field and who was a well-known surgeon of his day. An article, written by Tuffier during the war, describes some of the challenges of care for the French medics. He was not enthusiastic about tourniquets, and stated that his doctors were skilled at stopping bleeding with sutures. He then declared the following: "The tourniquet is sometimes utilized under circumstances where it is actually impossible to apply a ligature, but it has caused disasters. As soon as a tourniquet is seen in an ambulance it should be taken away."⁸

The Official British Manual, republished by the U.S. Government in 1918, was entitled *Injuries and Diseases of War*. This small book has several very negative statements about tourniquets. For instance: "The systematic use of the elastic tourniquet cannot be too severely condemned. The employment of it, except as a temporary measure during an operation, usually indicates that the person employing it is quite ignorant both of how to stop bleeding properly and also of the danger to life and limb caused by the tourniquet . . . If an orderly has applied a tourniquet, it is the duty of the medical officer who first sees the patient to remove it at once, and to examine the limb so as to ascertain whether

there is any bleeding at all, and if there is, to employ proper measures for its arrest."⁹

After World War I, Tuttle wrote a *Handbook for the Medical Soldier*, wherein he emphasized using pressure points to stop bleeding. He discussed tourniquets, how they were deployed, and mentioned the "Spanish windlass," a popular way to apply and maintain pressure from a tourniquet. His rules about use of tourniquets are as true today as they were in his time: "1. Never cover over or bandage a tourniquet. 2. Write plainly on the emergency medical tag the word 'tourniquet.' 3. If the injured man is conscious, he should be instructed to tell every medical officer with whom he comes in contact that he has a tourniquet on. 4. Lastly, remember, if a tourniquet is left on a wound for 6 hours the limb will surely die."¹⁰

The lessons of tourniquets were relearned during the Spanish Civil War of 1936-39. According to Douglas Jolly, ". . . more limbs and lives are lost at the front from the improper use of the tourniquet than are saved by its proper use."¹¹

World War II again produced huge numbers of extremity wounds, and tourniquets were again deployed. And as history tends to repeat itself, again in World War II, historical accounts mention the misuse of tourniquets, the tourniquet inadvertently concealed under a blanket, the dangers of evacuation of a patient with a tourniquet in place, etc. The following is from an historical account of World War II: "Soldiers – whether medical or non-medical – regularly misused tourniquets. They applied them unnecessarily; left them unloosened for too long; and occasionally evacuated patients with tourniquets concealed by blankets or clothing, and hence not discovered until the limb was doomed. Trying to prevent such abuses, the Seventh Army surgeon directed that the 'sole indication' for applying a tourniquet should be 'active spurting hemorrhage from a major artery' and that medics in the field or at battalion aid stations should note the presence of a tourniquet on a patient's EMT in capital letters." (The EMT was the Emergency Medical Tag).¹²

The Korean War was yet again a testing opportunity for the tourniquet. General Carl Hughes, who was a young surgeon in Korea, has a positive view of tourniquets, recalling that they had saved lives, and denied seeing limbs lost because of their employ (Hughes CW, personal communication).

In Vietnam, military surgeons also used tourniquets liberally. Dr. John E. Hutton spent a year treating casualties in Vietnam, and recalls that many tourniquets were improvised, using belts, slings, gauze, and tubing. He, like General Hughes, does not remember seeing limbs lost, but does remember lives saved (Hutton JE, personal recollection). Just as was emphasized in earlier wars, there were also less positive experiences in both Korea and Vietnam with tourniquet misuse.

Iraq and Afghanistan: The current wars against terrorism in Iraq and Afghanistan have seen the use of the tourniquet encouraged, as evidence has continued to demonstrate consistent life-saving benefits and low risks. The

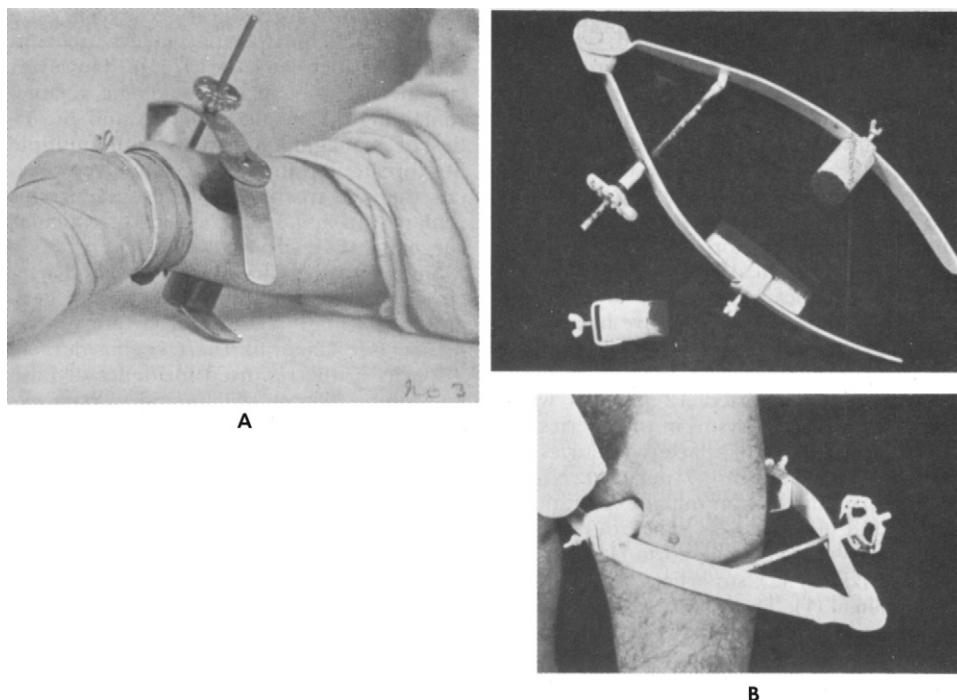


Fig 2. These photographs show a “Matas Compressor”, and were taken from Rich and Spencer, *Vascular Trauma*, W. B. Saunders Company, Philadelphia, 1978, p. 235.

use of tourniquets in the ongoing wars against terrorism in Iraq and Afghanistan represents one of the true advances in battlefield medicine of our era. At the beginning of these conflicts, the use of tourniquets on the battlefield was largely frowned upon because of experience from previous wars and lack of modern data. Implementation of a Joint Theater Trauma System (JTTS) in the wars in Iraq and Afghanistan in 2004 and 2005 allowed for real-time, evidence-based process improvement; fresh data indicated a need for better methods to control extremity hemorrhage. This same JTTS, its registry (JTTR), and the Joint Combat Casualty Research Team in the theater of war soon generated data that confirmed not only the utility of tourniquets but a survival benefit with their use. This data was quickly translated into the development and distribution of commercially available tourniquets in 2005 and 2006. Training in the use of these devices soon followed. The JTTS then generated Clinical Practice Guidelines, which directed the appropriate use of tourniquets, while at the same time our armed forces maintained a trauma system which afforded short MEDEVAC times (generally less than 1 hour). The effectiveness of tourniquets in the context of this war does not necessarily translate to their universal effectiveness in future wars or in the hands of civilian first responders. Tourniquet use, like other surgical adjuncts, must be applied in the context of the type of injury, location in which the injury occurred, anticipated tourniquet times, etc. History will record that, at least in Afghanistan and Iraq, tourniquets have had a huge, positive effect, saving



Fig 3. This is a recent photograph of a C-A-T, the Combat Action Tourniquet, applied to the arm of an active-duty Army soldier.

lives and limbs. Use of tourniquets will be remembered as one of the seminal lessons of those wars, in regards to trauma care.

Kragh et al have written a series of articles about the risks and benefits of modern tourniquets. They have demonstrated that in battle, wounded patients have had a high percentage of survival when tourniquets were applied to bleeding extremities, with a very low risk of complications

(nerve injury or limb shortening).^{13,14} In a very recent review, Kragh and colleagues looked at some 499 patients who had tourniquets applied in a combat hospital in Iraq, and found very little morbidity from tourniquets in this large cohort of patients. Interestingly, their article mentions that some 13 patients had paradoxical bleeding (increased, not decreased bleeding) because of the phenomenon of the inadequately deployed, or “venous” tourniquet.¹⁵ The present doctrine used by the U.S. military is that every soldier in the field has a tourniquet and knows how to use it. The present tourniquet, deployed with our war fighters, has been modified and improved. It is lightweight, and can be applied with only one hand. It has a built-in windlass, and overall seems to be very dependable and satisfactory for the intended task (Fig 3).

MODERN TRAUMA TRAINING

Interestingly, the manual given students who take the American College of Surgeons Advanced Trauma Life Support (ATLS) course has evolved, when it comes to training of tourniquet use. The 8th edition (the most current manual, published in 2008) is more positive in its approach to tourniquets, as compared with past editions. We now teach the following: “An acutely avascular extremity must be recognized promptly and treated emergently. Although controversial, the use of a tourniquet may occasionally be lifesaving and/or limb-saving in the presence of ongoing hemorrhage uncontrolled by direct pressure. A properly applied tourniquet, while endangering the limb, may save a life. A tourniquet must occlude arterial inflow, as occluding only the venous system can increase hemorrhage. The risks of tourniquet use increase with time. If a tourniquet must remain in place for a prolonged period to save a life, the physician must be cognizant of the fact the choice of life over limb has been made.”¹⁶

OPERATING ROOM TOURNIQUETS

Tourniquets have been used in surgery to temporarily occlude blood flow for centuries. Initial descriptions of tourniquet use in surgery pertained to amputations. In 1873, Esmarch described use of a rubber bandage to exsanguinate the limb and application of a tourniquet made from rubber tubing.¹⁷ Subsequent reports of tourniquet palsies and other complications related to the variable pressure and duration of tourniquet use called for attention. The use of pneumatic tourniquets for surgery is credited to Harvey Cushing in 1904.¹⁸ According to pioneer hand surgeon, Sterling Bunnell, the creation of a bloodless field for hand surgery was essential to allow visualization of delicate structures and decrease the trauma associated with hemostats and frequent sponging.¹⁹ The modern pneumatic tourniquet is automatically regulated, and there are scientifically based guidelines for tourniquet width, pressure settings, and duration of use. Wilgis did a series of experiments on dogs that demonstrated that tourniquet use results in progressive venous blood acidosis distal to the tourniquet that is proportional to the duration of ischemia. The acidosis was noted to gradually return to normal after

release of the tourniquet, leading to guidelines for reperfusion periods when prolonged ischemia is required, 5 to 10 minutes after 1 hour, 10 to 15 minutes after 1.5 hours, and 15 to 20 minutes after 2 hours of ischemia.²⁰ Duration of ischemic time should be minimized to protect muscle and nerve function. Several authors have attempted to identify the safest duration, and 2 hours is most commonly recommended, although some have reported successful use for periods of 3 to 4 hours. Other recommendations for the safe use of tourniquets in surgery include frequent calibration and maintenance of tourniquet machines to ensure reliable pressure measurements, use of a wider cuff (4-5 inches) when possible to avoid focal compression of nerves and vessels, utilizing the optimum pressure, and performing all preparations for surgery before inflating the tourniquet. With safe parameters for tourniquet use well established, the benefits of a surgical field free of bleeding and of minimizing operative blood loss have made tourniquet use standard for extremity surgery. Nonetheless, surgeons must be aware of the potential harmful physiological effects of prolonged limb ischemia and focal pressure application. Compartment syndrome, paralysis, and prolonged stiffness have been reported following tourniquet use for surgery. Adherence to the guidelines above should minimize these complications.

CONCLUSION

The simple tourniquet can stop arterial bleeding and save lives. The modern day tourniquet is very lightweight, portable, easy to apply in most circumstances, and uncomplicated in concept and construction. Once applied, it normally does not make transportation of the wounded more challenging (as opposed to attempting to hold pressure on a bleeder). First responders should definitely be trained in its use, and always warned about its misuse. Tourniquets should never be used when simple pressure will suffice, or a pressure dressing can control the bleeding. Tourniquets should never be partially applied, which can have the perverse effect of failing to occlude the artery, but occluding the vein, thus actually increasing venous bleeding. Tourniquets should never be forgotten; application times should always be very carefully noted, and the tourniquet should be removed as soon as possible. All of us should realize that if a tourniquet is fully employed for an excessive period of time (6 hours or greater), the limb involved is at great risk of ischemia and/or nerve damage and eventual amputation.

AUTHOR CONTRIBUTIONS

Conception and design: DW, PM, NR
Analysis and interpretation: DW, PM, TR, NR
Data collection: Not applicable
Writing the article: DW, PM, TR, NR
Critical revision of the article: DW, PM, TR, NR
Final approval of the article: DW, PM, TR, NR
Statistical analysis: Not applicable
Obtaining funding: Not applicable
Overall responsibility: DW

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Submitted Oct 4, 2011; accepted Oct 14, 2011.