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TACTICAL COMBAT CASUALTY CARE: TRANSITIONING BATTLEFIELD LESSONS LEARNED TO OTHER AUSTERE ENVIRONMENTS

Bleeding Control With Limb Tourniquet Use in the Wilderness Setting: Review of Science

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The purpose of this review is to summarize tourniquet science for possible translation to wilderness settings. Much combat casualty data has been studied since 2005, and use of tourniquets in the military has changed from a last resort to first aid. The US Government has made use of tourniquets a health policy aimed to improve public access to bleeding control items. International authorities believe that education in first aid should be universal, as all can and should learn first aid. The safety record of tourniquet use is mixed, but users are reliably safe if trained well. Well-designed tourniquets can reliably attain bleeding control, may mitigate risk of shock progression, and may improve survival rates, but conclusive proof of a survival benefit remains unclear in civilian settings. Even a war setting has a bias toward survivorship by sampling mostly survivors in hospitals. Improvised tourniquets are less reliable than well-designed tourniquets but may be better than none. The tourniquet model used most often in 2016 by the US military is the Combat Application Tourniquet (C-A-T), and civilians use an array of various models, including C-A-T. Evidence on tourniquet use to date indicates that most uses are safe and effective in civilian settings. Future directions for study relevant to the wilderness setting include consideration of research priorities, study of the burdens of injury or capability gaps in caregiving for various wilderness settings, determination of the skill needs of outdoor enthusiasts and wilderness caregivers, and survey of wilderness medicine stewards regarding bleeding control.

Keywords: resuscitation, hemorrhage/prevention and control/shock, tourniquet/medical device/removal, emergency medical services, injuries and wounds/penetrating trauma, first aid, austere/out-of-hospital/prehospital

Introduction

Recent experiences of US military services have included a historically high survival rate of war casualties. One reason for this high survival is early, effective caregiving at the point of injury.[1,2] One improvement in military first aid has been the widespread use of tourniquets to stop bleeding from limb wounds.[3–6] As a consequence of this survival improvement, the administration of President Obama changed US public health policy in 2015 to improve public access to tourniquets.[7]

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Although international authorities consider recent developments within the science of bleeding control with tourniquet use to be weak evidence, such authorities state that tourniquet use is a recommended first aid intervention.[8,9] Furthermore, such authorities state that they believe education in first aid should be universal. Everyone, including the lay public and nonmedical military personnel, can and should learn first aid, which can include tourniquet use.[8,9] A scientific review of tourniquet use to control life-threatening bleeding is now timely to aid in potential application to specific aspects of civilian care. The purpose of the present review is to summarize tourniquet science for possible translation to wilderness settings.

Burden of Injury that Indicates Tourniquet Use

Penetrating trauma is common, disabling, and potentially lethal in settings like battlefields and cities, but it is less

common yet more challenging in rural and wilderness settings.[4,10,11] Although combat evidence has advanced the state of first aid science in mechanical control of prehospital bleeding, many of those findings were gained in urban centers like Baghdad, Iraq, in 2006 when time from injury to hospital was similar to that of civilian care.[4,12,13] In Baghdad, the duration of tourniquet use was brief (91% were $\leq$2 hours).[4] Exsanguination deaths from limb-wounded civilians have occurred but are not well evidenced, and some authors have considered them potentially preventable by early tourniquet use.[3,14–23] New surveys of the burden of injury in wilderness settings, including limb wounds in need of bleeding control, could help develop best caregiving practices. This knowledge gap may be considered to become a research priority.

Safety of Tourniquet Use

Opinions on tourniquet safety are mixed in surveys of war casualties because older reports, often from authors caring for civilians, indicated that care led to unacceptable rates of morbidity.[24–28] Recent military surveys have reported minor morbidity because most complications were infrequent, temporary, and incomplete.[4,29]

The US military took a different approach by training all servicepersons in tourniquet use and supplying tourniquets to them.[30–33] Limb ischemia from tourniquet use is important because skeletal muscle, the main tissue of the limbs, is the tissue type most sensitive to ischemic duration. Muscle ischemia can cause muscle cell damage, myonecrosis, myoglobinemia, kidney failure, limb loss by surgical amputation, and death.[4,29] Morbidity of tourniquet patients is sometimes evidenced as higher than expected.[34–37] In morbidity−mortality analyses, only survivors have morbidity, so higher morbidity rates may be expected if there was lifesaving benefit to tourniquet use.

A policy of last resort often meant that the intervention was done too late to be lifesaving, and bleeding control with tourniquet use eventually became first aid, as recommended by international authorities.[8,9] However, either the treatment effect size of tourniquets, such as the percent survival with or without tourniquet use, appears to be small or a survival bias exists in the way we gather data.[38,39] Altogether, such findings indicate that tourniquet science needs more research to clarify risks and benefits.[38,39]

Effectiveness of Tourniquet Use

The effectiveness of tourniquets can be assessed mechanically, physiologically, and situationally. Efficacy of bleeding control in the laboratory setting as a yes−no outcome, such as in a bleeding manikin, has merit in differentiating performance of tourniquet models, users of tourniquets, and techniques of use. Such knowledge can help inform selection of the best devices, assess the performance of students or instructors, and develop best tourniquet practices.[40–42] In care research, due to a survivor bias, hemorrhage control is rarely associated with improved casualty outcomes, but one study did associate bleeding control and improved survival.[43] Moving along the causal chain from bleeding to its control and on to shock control, rarely is tourniquet use associated with the latter,[44] and such absence of association is likely due to survivor bias. One research study of casualty data from a war trauma registry did show a shock control finding.[44]

Best care seeks to be safe, effective, and fast, and for tourniquet use, absence of any one of these elements may be lethal.[1,4,5,29,43] A small but growing body of science on training tourniquet users indicates that quality of training appears important to user performance.[32,45,46] For example, Wall et al reported a survey of tourniquet knowledge among civilian prehospital providers, and many did not know information important for optimal tourniquet use.[47] Poor knowledge was found in all groups irrespective of certification and experience. Most (91%) did not know that wider tourniquets require less pressure for arterial occlusion, and most (69%) did not know that stopping venous flow without arterial control is harmful.[47] Useful metrics of user performance include time to stop bleeding, blood volume lost, pressure under the tourniquet, ease of use, and safety data like mishaps, device breakage, and user injury. Much of this type of information is difficult to obtain from a care setting, but the caregiving records in the military today are better than before for details of bleeding control status, device identification, intervention effects, and the time progression of casualty status.

Through sustained and comprehensive efforts to improve such recording, the military came to understand better tourniquet performance and thereby improve user performance. The science of tourniquet user development is in need of data to improve awareness of the need to focus on the performance of people and not only on the performance of tourniquets. Training users to be effective may take a couple of tries, but training them to be simultaneously effective, safe, and fast may take more repetitions of use to gain the desired skill level. Such training of users to a higher level of performance likely takes more resources like time of both instruction and practice.

Tourniquet use was recommended in an evidenced-based guideline published in 2014 by Bulger et al from