ORIGINAL SCIENTIFIC ARTICLE

From Pull to Pressure: Effects of Tourniquet Buckles and Straps

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BACKGROUND: Limb tourniquet pressures > 100 mmHg before tightening system use eases achieving arterial occlusion, minimizes tightening system problems, and probably minimizes discomfort. This study examined effects of buckle and strap features on converting pulling force to strap pressure.

STUDY DESIGN: Twenty-two buckle and strap combinations were evaluated using a thigh-diameter, ballistic gel cylinder and 3 thighs. Weights of 14.11, 27.60, and 41.11 kg provided pulling force. The contribution of buckle movement was evaluated: all buckles on gel and 12 on thighs allowed limited vertical movement, 12 on gel and 4 on thighs held static.

RESULTS: Force conversion patterns per combination were similar on gel and thighs, including greatest force conversion with some buckle movement allowed. Smooth, round redirect buckles without engagement of a strap-securing mechanism had the best conversions of pulling force to tourniquet pressure; 2 achieved arterially occlusive pressures, neither commercially available. Among hook-and-loop secured tourniquets and threaded for self-securing tourniquets, the Generation 7 Combat Application Tourniquet (C-A-T7) and the Tactical Ratcheting Medical Tourniquet (Tac RMT) had the best conversions of pull to pressure (thigh applications/each weight, mean ± SD: C-A-T7 91 ± 11, 164 ± 30, 228 ± 34 mmHg; Tac RMT 82 ± 13, 150 ± 16, 222 ± 17 mmHg). Other Ratcheting Medical Tourniquets with the same buckle but different strap fabrics performed less well. Even lower pressures occurred with the Tactical Mechanical Tourniquet, the Special Operations Forces Tactical Tourniquet, the Parabelt, and the SAM XT Extremity Tourniquet (165 ± 11, 178 ± 13, 131 ± 14, and 106 ± 14 mmHg, all at 41.11 kg, respectively).

CONCLUSIONS: Buckle design and strap fabric affect the conversion of pulling force to tourniquet strap pressure. Low-friction, smooth, round redirects allow the best conversion. (J Am Coll Surg 2018; ■:1−14. © 2018 by the American College of Surgeons. Published by Elsevier Inc. All rights reserved.)

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Effective current limb tourniquets stop blood loss via the circumferential application of sufficient inward pressure applied over a sufficient surface area to stop arterial flow. Most commercial limb tourniquet designs involve a nonelastic strap, some type of buckle allowing a 180-degree strap direction change (strap redirect), a strap-securing mechanism, and a mechanical advantage tourniquet-tightening mechanism. Achieving inward pressures greater than 100 mmHg (ideally greater than 150 mmHg) before engagement of the mechanical advantage tourniquet-tightening mechanism is desirable from the standpoint of ease of achieving arterial occlusion,[1,2] minimizing tightening system problems,[1-4] and probably minimizing recipient discomfort. “Get it tight to get it right” is an apt directive, with tighter being better concerning strap tightness before engagement of the mechanical advantage tourniquet-tightening system.

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Abbreviations and Acronyms

C-A-T biner	= Generation 6 Combat Application Tourniquet modified by replacing the redirect buckle with an oval carabiner as the redirect
C-A-T7	= Generation 7 Combat Application Tourniquet
N	= Newton
RMT	= Ratcheting Medical Tourniquet
SAM	= SAM XT Extremity Tourniquet
SAM no prong	= SAM XT Extremity Tourniquet modified such that the prongs could not deploy
SOFTTW RND	= 4th generation Special Operations Forces Tactical Tourniquet Wide
SOFTTW SQR	= 3rd generation Special Operations Forces Tactical Tourniquet Wide
TMT	= Tactical Mechanical Tourniquet
Un	= unthreaded

Many of the buckles allowing the 180-degree strap redirect also secure the strap against backsliding via friction. These types of buckles are "friction buckles." A common alternate method of securing the strap against backsliding is the use of hook-and-loop fabric. This method of strap securing can be combined with the use of a friction buckle, as is the case in the double routed Generation 6 Combat Application Tourniquets (C-A-T, C-A-T Resources), or can be used with a buckle that merely allows strap direction change but does not secure the strap against backsliding, as is the case in the single routed Generation 6 C-A-T or the Generation 7 C-A-T.

Any design feature that creates resistance to strap tightening during the pull to strap tightness before mechanical advantage system engagement has the potential to adversely affect the applier's ability to pull the strap tight. Additionally, any design or application method that provides a mechanical advantage during strap pulling should improve the applier's ability to achieve strap tightness. The purpose of this study, therefore, was to examine the effects of different design features and application methods on achieving strap tightness before any mechanical advantage system engagement. The hypotheses were that low-friction buckles would be advantageous and that allowing the buckle to move as the limb is compressed would also be advantageous for achieving maximum strap tightness for any applied pulling force.

METHODS

The Drake University Institutional Review Board approved the human thigh aspects of this prospective study. The study occurred throughout the summer and fall of 2017.

The following tourniquets were donated by their respective companies for this or previous studies: the modified Generation 6 C-A-T (C-A-T biner), the modified SAM XT Extremity Tourniquet (SAM no prong, SAM Medical), all of the Ratcheting Medical Tourniquets (RMTs, m2 Inc), and the Parabelt (RevMedX). The other tourniquets were purchased: the Generation 7 C-A-T (C-A-T7), the SAM XT Extremity Tourniquet (SAM), the Tactical Mechanical Tourniquet (TMT, Combat Medical), the 4th generation Special Operations Forces Tactical Tourniquet Wide (SOFTTW RND, Tactical Medical Solutions), and the 3rd generation SOF Tactical Tourniquet Wide (SOFTTW SQR). The cam strap was also purchased (CAM, New River Gear). The buckle and strap features are shown in Table 1 and in Figure 1.

A previously purchased tourniquet that was initially planned to be used in this study is the Mechanical Advantage Tourniquet (MAT, Pyng Medical). The Mechanical Advantage Tourniquet was not used in previous studies because of high recipient discomfort when use was attempted on bare skin (severe pinching during mechanical advantage use). For this study, the Mechanical Advantage Tourniquet was tested on the ballistic gel and found to be too gel damaging (shearing stress tears).

Hook-and-loop tourniquet modifications

The Generation 6 C-A-T (C-A-T biner) was modified by using an oval climbing carabiner (REI) for the strap redirect instead of any part of the built-in buckle. The preproduction model SAM XT Extremity Tourniquet (SAM no prong) was modified by replacing the springs inside the buckle casing with metal sleeves so that the buckle's prongs could not deploy. For each tourniquet, these modifications resulted in smooth, round, low-friction strap redirects of relatively large diameters, with no buckle-related strap-securing mechanisms.

Double ring friction buckle tourniquets

The different RMT models had differences in strap widths and materials, buckle widths, redirect surface characteristics, and redirect diameters. The RMT model with the overlapping metal rings composed of the smaller diameter round stock and no rough coating is an older model (2013 RMT) that is no longer produced.

Several of the RMT models were also used with the strap only routed around the bottom of the 2 metal rings to create a redirect with the same width, surface character, and diameter, but without the friction of the normal routing of the overlapping metal rings. This "unthreaded" (un) strap routing modification removes the buckle-related strap-securing mechanism of these tourniquets.

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