Does Pain Have a Role When It Comes to Tourniquet Training?

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ABSTRACT

Background: One of the greatest conundrums with tourniquet (TQ) education is the use of an appropriate surrogate of hemorrhage in the training setting to determine whether a TQ has been successfully used. At our facility, we currently use loss of audible Doppler signal or loss of palpable pulse to represent adequate occlusion of vasculature and thus successful TQ application. We set out to determine whether pain can be used to indicate successful TQ application in the training setting. **Methods:** Three tourniquet systems (a pneumatic tourniquet, Combat Application Tourniquet® [C-A-T], and Stretch Wrap and Tuck Tourniquet™ [SWAT-T]) were used to occlude the arterial vasculature of the left upper arm (LUA), right upper arm (RUA), left forearm (LFA), right forearm (RFA), right thigh (RTH), and right calf (RCA) of 41 volunteers. A 4MHz, handheld Doppler ultrasound was used to confirm loss of Doppler signal (LOS) at the radial or posterior tibial artery to denote successful TQ application. Once successful placement of the TQ was noted, subjects rated their pain from 0 to 10 on the visual analog scale. In addition, the circumference of each limb, the pressure with the pneumatic TQ, number of twists with the C-A-T, and length of TQ used for the SWAT-T to obtain LOS was recorded. **Results:** All 41 subjects had measurements at all anatomic sites with the pneumatic TQ, except one participant who was unable to complete the LUA. In total, pain was rated as 1 or less by 61% of subjects for LUA, 50% for LFA, 57.5% for RUA, 52.5% RFA, 15% for RTH, and 25% for RCA. Pain was rated 3 or 4 by 45% of subjects for RTH. For the C-A-T, data were collected from 40 participants. In total, pain was rated as 1 or less by 57.5% for the LUA, 70% for the LFA, 62.5% for the RUA, 75% for the RFA, 15% for the RTH, and 40% for the RCA. Pain was rated 3 or 4 by 42.5%. The SWAT-T group consisted of 37 participants for all anatomic locations. In total, pain was rated as 1 or less by 27% for LUA, 40.5% for the LFA, 27.0% for the RUA, 43.2 for the RFA, 18.9% for the RTH, and 16.2% for the RCA. Pain was rated 5 by 21.6% for RTH application, and 3 or 4 by 35%. **Conclusion:** The unexpected low pain values recorded when loss of signal was reached make the use of pain too sensitive as an indicator to confirm adequate occlusion of vasculature and, thus, successful TQ application.

KEYWORDS: *tourniquet; pain; vasculature occlusion*

Introduction

The tourniquet (TQ) has played a prominent role in the US military for well over a century. For example, there is the infamous story of American Civil War General Albert Sidney Johnston, who perished due to blood loss from a gunshot wound to the leg despite having a TQ in his own pocket.[1] Or, from the medical literature, *A Manual of Military Surgery, 1861*, insisted Soldiers be trained and issued TQs to combat death resulting from hemorrhagic wounds in battle.[2]

Surprisingly, it was only recently that the TQ made its way into the kits of most US troops. Until 2005, the TQ was issued mainly to Special Operation Units for Tactical Combat Casualty Care purposes.[3] This delay in broadly issuing the TQ for troops was due to literature that described risks and morbidity with improper TQ use.[4–7] However, recent literature and anecdotal evidence demonstrates the TQ, when used properly, can be safe and life-saving, and thus issued to the majority of troops.[8–15] The interest in TQs life-saving benefits does not stop on the battlefield. Many police officers, medics and civilian responders are adopting Tactical Combat Casualty Care–like guidelines to use TQs for major limb trauma in the civilian setting.[11–13] As the TQ continues to be used both on and off the battlefield, the need for review of TQ education must not go unnoticed.

One of the greatest conundrums with TQ education is the use of an appropriate surrogate of hemorrhage in the training setting to determine whether a TQ has been successfully used. At our facility, we currently use loss of audible Doppler signal (LOS) or loss of palpable pulse to represent occlusion of vasculature and thus successful TQ application. We set out to determine whether pain can be used to indicate successful TQ application in the training setting.

Methods

Approval of the study was granted by Cook County Health and Hospital System Institutional Review Board. Study participants were randomly selected male and female resident physicians, medical students, police officers, paramedics, and health care professionals who were randomly present at our study sites. Informed consent was obtained from each volunteer.

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Study participants completed a short questionnaire to determine study eligibility, including exclusion criteria (Figure 1). A total of 41 volunteers were included in the study. The median age was 28 (range, 22–48) years and 68% were male.

FIGURE 1 *Study participants completed a short questionnaire.*

Please circle any of the below if you have a history of:
Myocardial infarction (heart attack)
Stroke
Heart surgery
Congenital vascular defects
Hypertension
Trauma to an extremity that required fasciotomy or surgery necessitating hospital stay
Any comments or other health concerns you wish to reveal, please list below:
Please write your answers in the underlined portion:
What is your:
Sex: Male _____ Female _____
Age (years): _____
Height (inches): _____
Weight (lb): _____

To investigate whether pain may be used to predict TQ efficacy, we sought to obtain pain values once TQs were deemed successfully placed. Three different TQ systems were used: a 18.0 inch by 5.5 inch or 24.0 inch by 5.5 inch Stryker® Single-Belly Pneumatic Tourniquet (Sustainability Solutions, http://sustainability.stryker.com); 10.4cm elastic Stretch-Wrap-And-Tuck Tourniquet (SWAT-T™; H&H Medical Corp, www.swattourniquet.com); and a 3.8cm-wide Combat Application Tourniquet Generation 6 (C-A-T®; C-A-T Resources Inc, www.combattourniquet.com) (Figure 2). TQs were applied to six anatomic locations in random fashion: right upper arm (RUA), right forearm (RFA), left upper arm (LUA), left forearm (LFA), right thigh (RTH), and right calf (RCA). The circumferences of each of these sites were recorded in centimeters.

For each TQ system, we used a 4MHz handheld Doppler ultrasound (MedLine, https://www.medline.com) to find LOS and perceived this as loss of arterial pulse due to successful TQ application. The radial pulse was used to assess LOS in the upper limbs; the posterior tibial pulse was used to access LOS in the lower limb. The TQ was then activated by either inflating the cuff (pneumatic TQ), twisting the windlass rod (C-A-T), or stretching and wrapping (SWAT-T). The TQ was left on as long as necessary to record the pressure in the cuff, number of twists needed, or length of SWAT-T used to reach LOS, which was approximately 30 seconds. The participant was allotted 2 minutes between each application to provide adequate time for reperfusion of the limb before continuing the experiment.

FIGURE 2 *Stretch Wrap-And-Tuck Tourniquet and the Combat Application Tourniquet.*

We performed *t* tests and χ^2 tests to determine statistically significant differences between measured variables. Pain and pressure differences among anatomic comparisons were made using the Wilcoxon signed-rank test. A p value ≤.05 was considered significant.

LOS

Pneumatic TQ

When using the pneumatic TQ, one examiner would activate the TQ by increasing the pressure with digital dials while another examiner would assess Doppler signal. When using the SWAT-T or C-A-T, one examiner would apply and adjust the TQs while the other would assess Doppler signal.

C-A-T

With the C-A-T, which uses a windlass rod, the number of twists was recorded to determine the LOS. Each application began with placing the C-A-T snug on the limb (one location and TQ application at a time), placing the TQ mid biceps, mid forearm, mid thigh, or mid calf. The first 90° rotation of the windlass placed the windlass parallel to the strap and was considered the baseline. From this point, the TQ was activate by twisting the windlass rod. The number of turns was recorded once LOS was reached. One twist was equivalent to 360°.

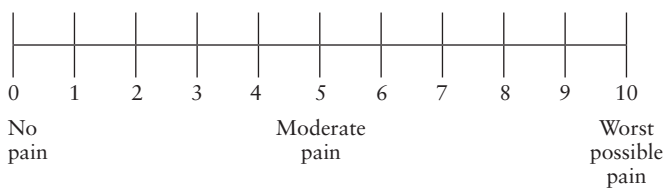
SWAT-T

To accommodate for differences in limb size when the SWAT-T (Figure 2) was used, the circumference of each limb was first measured in centimeters. The SWAT-T was then wrapped around the limb just once, without applying any compressing force. The length of the SWAT-T that was not wrapped around the limb was considered the starting length. The SWAT-T was then activated by stretching and wrapping the TQ around the limb until LOS was reached. The remaining length of unused SWAT-T was measured and this was subtracted from the starting length to determine how much TQ was actually used to occlude the vasculature.

Pain

With each TQ model, at each anatomic location, after the TQ was activated and LOS was appreciated with Doppler, subjects rated their pain on a 0 to 10 Visual Analog Pain Scale (0 being no pain, 10 being the worst pain; Figure 3). TQs were removed once the pain rating was obtained.

FIGURE 3 *Numeric pain scale.*



Results

Pneumatic TQ

All 41 subjects had measurements at all anatomic sites with the pneumatic TQ, except one participant who was unable to use the TQ successfully on the LUA. The only statistically significant differences among pressures required to achieve LOS with the pneumatic TQ were between RTH (176.58mmHg) and RCA (164.65mmHg; $p < .05$). There were no statistically significant mean pain value differences among any proximal versus distal anatomic sites for the pneumatic TQ. In total, pain was rated as 1 or less by 61% of participants for LUA, 50% for LFA, 57.5% for RUA, 52.5% RFA, 15% for RTH, and 25% for RCA. Pain was rated as 3 or 4 by 45% of participants (Figures 4 and 5).

FIGURE 4 *Pain differences using each TQ model compared with anatomic location.*

	Participants	Mean	Median	Mode	Std. Deviation	Range	Minimum	Maximum	Percentile 25%	Percentile 50%	Percentile 75%
Pain LUA Pneumatic	41	1.561	1	1	1.533	6	0	6	0	1	2.5
Pain LUA C-A-T	40	1.5	1	0	1.633	7	0	7	0	1	2
Pain LUA SWAT-T	37	2.676	2	2	1.733	7	0	7	1	2	4
Pain LFA Pneumatic	40	1.625	1.5	0	1.48	6	0	6	0	1.5	2
Pain LFA C-A-T	40	1.15	1	0	1.145	4	0	4	0	1	2
Pain LFA SWAT-T	37	1.919	2	2	1.3	5	0	5	1	2	2.5
Pain RUA Pneumatic	40	1.7	1	0	1.728	6	0	6	0	1	3
Pain RUA C-A-T	40	1.35	1	1	1.67	5	0	5	1	1	2
Pain RUA SWAT-T	37	2.568	2	2	1.757	8	0	8	1	2	3
Pain RFA Pneumatic	40	1.575	1	0	1.393	6	0	6	0	1	3
Pain RFA C-A-T	40	1.15	1	1	1.075	5	0	5	0.25	1	1.75
Pain RFA SWAT-T	37	1.838	2	2	1.519	6	0	6	1	2	2.5
Pain RTH Pneumatic	40	3.175	3	4	1.615	7	0	7	2	3	4
Pain RTH C-A-T	40	3.425	3	3	1.838	8	0	8	2	3	4.75
Pain RTH SWAT-T	37	3.649	4	5	2.15	9	1	10	2	4	5
Pain RCA Pneumatic	40	2.75	2.5	2	1.971	8	0	8	1.25	2.5	4
Pain RCA C-A-T	40	2.25	2	1	1.706	7	0	7	1	2	3
Pain RCA SWAT-T	37	3.541	3	2	2.142	10	0	10	2	3	5

FIGURE 5 *Number of twists of the C-A-T, length required of the SWAT-T, pressures with the pneumatic TQ required to achieve LOS at each anatomic site.*

	Valid	Mean	Median	Mode	Std. Deviation	Range	Minimum	Maximum	Percentile 25%	Percentile 50%	Percentile 75%
Pneumatic SBP LUA (mmHg)	41	135.951	131	131	19.0735	89	90	179	123.5	131	149.5
Number of Twists LUA C-A-T	40	1.1625	1.25	0.75	0.429482	1.5	0.75	2.25	0.75	1.25	1.25
Length needed LUA SWAT-T	37	32.1351	33	35	10.87086	54	5	59	26.25	33	37.5
Pneumatic SBP LFA (mmHg)	40	133.6	129	126.01	20.2381	114	95	209	123.25	129	145.5
Number of Twists LFA C-A-T	40	1.0375	1	0.75	0.410402	1.75	0.5	2.25	0.75	1	1.25
Length needed LFA SWAT-T	37	27.6703	28.5	12	13.85733	76	5	81	18.5	28.5	34.25
Pneumatic SBP RUA (mmHg)	40	137.125	133	131.01	24.1705	130	100	230	121	133	145
Number of Twists RUA C-A-T	40	1.09625	1	0.75	0.416854	1.75	0.5	2.25	0.75	1	1.25
Length needed RUA SWAT-T	37	35.473	32	29.001	15.09688	73	11	84	24.75	32	43.25
Pneumatic SBP RFA (mmHg)	40	132.375	126.5	119.01	17.8235	73	106	179	119	126.5	139.75
Number of Twists RFA C-A-T	40	1.075	0.875	0.75	0.442893	2	0.75	2.75	0.75	0.875	1.4375
Length needed RFA SWAT-T	37	29.3378	30	30.00a	14.59978	92	4.5	96.5	21	30	35.5
Pneumatic SBP RTH (mmHg)	40	176.575	173	187	35.3647	1250.661	192	310	158.5	173	187.75
Number of Twists RTH C-A-T	40	2.00625	2	1.500a	0.538539	0.29	1.75	2.75	1.5	2	2.5
Length needed RTH SWAT-T	37	60.7568	61	57.501	16.52381	273.036	67.5	96	49.75	61	73.25
Pneumatic SBP RCA (mmHg)	40	164.65	166.5	147	25.9857	675.259	109	224	147	166.5	179.5
Number of Twists RCA C-A-T	40	1.2625	1.25	1	0.47687	0.227	2	2.5	1	1.25	1.5
Length needed RCA SWAT-T	36	40.2361	36.75	27	18.63694	347.336	92.5	81	27	36.75	54.875

1 Multiple modes exist. The smallest value is shown.

C-A-T

Data from 40 participants were recorded for all anatomic sites of the C-A-T group. LOS differences between LUA (1.163 turns) and LFA (1.038 turns; $p < .05$), as well as between RTH (2.006 turns) and RCA (1.264 turns; $p < .001$) were significantly different. There was a statistically significant difference in mean pain values between RTH and RCA ($p < .001$) for C-A-T data, but not for the other compared locations. In total, pain was rated as 1 or less by 57.5% of participants for the LUA, 70% for the LFA, 62.5% for the RUA, 75% for the RFA, 15% for the RTH, and 40% for the RCA. Pain was rated as 3 or 4 by 42.5% of participants.

SWAT-T

Data from 37 participants were recorded for all anatomic locations. There were statistically significant differences when comparing length of TQ needed to achieve LOS between the RUA (35.473cm) and RFA (29.338cm), as well as the RTH (60.757cm) and RCA (40.236cm; $p < .05$ and $p < .001$). All mean SWAT pain values for proximal anatomic sites were significantly greater than for distal sites: LUA 2.68 versus LFA 1.92 ($p < .001$), RUA 2.57 versus RFA 1.84 ($p < .001$) and RTH 3.65 versus RCA 2.25 ($p < .001$). In total, pain was rated as 1 or less by 27% of participants for LUA, 40.5% for the LFA, 27.0% for the RUA, 43.2 for the RFA, 18.9% for the RTH, and 16.2% for the RCA. Pain was rated as 5 by 21.6% of the SWAT population and as 3 or 4 by 35%.

Discussion

To our knowledge, this is the first study to investigate whether pain can be used to determine if a TQ has been successfully applied in the training setting. We recognize that training is never the same as real-world experience, but the goal is to get as close as possible by substituting appropriate circumstantial surrogates. In real-life circumstances, especially with open-ended vessel injuries, the TQ is tightened until bleeding ceases. This is a self-evident task. The dilemma occurs in training, because no actual bleeding is occurring. Because the intent of training is to ensure competence in the task, educators have searched for and applied various surrogates in place of actual hemorrhage. One such surrogate that has informally been used is pain.

According to our results, regardless of the TQ type, mean pain values consistently remained below 3 out of 10 on the numeric pain scale, except for the RTH. Although mean pain values for the RTH using any TQ were higher compared with other anatomic locations, their values were low clinically speaking (RTH mean pain values: pneumatic TQ, 3.18; C-A-T, 3.42; SWAT-T, 3.65).

Such low pain values may be too sensitive a predictor of TQ efficacy; we believe, in the clinical sense, a pain value of 3 may be easily reached even by just the act of fastening the TQ around the extremity before activating the TQ.

There were limitations to this study. The study was nonblinded because subjects were aware of TQ application in real time. Another limitation is the possibility of volunteers having a preconceived notion that TQ application causes pain. Pain itself is subjective, thereby creating internal validity limitations. Furthermore, with such low pain values recorded once LOS was reported, one must investigate whether these pain levels were statistically significantly different from pain levels recorded when a TQ is simply applied to the extremity without actual activating the TQ. Last, although all three models had a 100% occlusion rate, the SWAT-T model was more user dependent, and one applicator may have stretched the TQ more taut than the next, causing interexaminer variability, thereby producing more force on the extremity with less TQ material.

Conclusion

At this time, we do not find it appropriate to solely use pain as a surrogate to LOS or palpable pulse to confirm proper TQ placement for extremities. The unexpected low pain values recorded when LOS was reached were too unreliable as an indicator.

Disclosure

The authors have nothing to disclose.

Author Contributions

JA, AJD, and AB designed the study and performed the literature search. JA and AJD wrote the initial draft. AI and KI assisted with data analysis. All authors contributed to data interpretation and critical revision of the manuscript. JA and AJD wrote the final draft. All authors approved the final manuscript.

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