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Research Paper

Tourniquet application after local forearm warming to improve venodilation for peripheral intravenous cannulation in young and middle-aged adults: A single-blind prospective randomized controlled trial

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ABSTRACT

Background: Local forearm warming before tourniquet application is often used to promote venodilation for peripheral intravenous cannulation; however, few studies have compared the effect of tourniquet application with and without local warming on vein size.
Objective: To evaluate the effectiveness of tourniquet application after local forearm warming with that of tourniquet application alone in young and middle-aged adults.
Design: A single-blind, prospective, parallel group, randomized controlled trial.
Setting: A national university in Japan.
Participants: Seventy-two volunteers aged 20–64 years.
Methods: Participants were randomly allocated to one of two groups: tourniquet application for 30 s after forearm application of a heat pack warmed to 40 °C ± 2 °C for 15 min (active warming group; n = 36) or tourniquet application for 30 s after applying a non-warmed heat pack for 15 min (passive warming group; n = 36). The primary outcomes were vein cross-sectional area on the forearm, measured after the intervention by blinded research assistants using ultrasound. Secondary outcomes were shortest diameter, and longest diameter of vein on the forearm, forearm skin temperature, body temperature, pulse, systolic blood pressure, and diastolic blood pressure. All outcomes were assessed at the same site before and immediately after the intervention, once per participant.
Results: Vein cross-sectional area, shortest vein diameter, and longest vein diameter were significantly increased in the active warming group compared with the passive warming group ($p < 0.01$). Tourniquet application after local warming was superior to tourniquet application alone in increasing vein cross-sectional, shortest diameter, and longest diameter (between-group differences of 2.2 mm^2, 0.5 mm, and 0.5 mm, respectively), and in raising skin temperature (between-group difference: 5.2 °C). However, there were no significant differences in body temperature, pulse, or systolic or diastolic blood pressure between the groups. There were no adverse events associated with either intervention.
Conclusion: Tourniquet application after local warming was associated with increased forearm vein size when compared with tourniquet application alone, and was demonstrated as being safe. Thus, with demonstrable effects on vein size, we recommend local warming before tourniquet application as a safe and effective technique for improving venodilation.

What is already known about the topic?

- Peripheral intravenous cannulation is not always successful.
- Local warming has been used to dilate peripheral veins, but little is known about the effect of tourniquet application after local warming.
- Few studies have compared the effect of tourniquet application with and without the effect of local warming.

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What this paper adds

- In this single-blind prospective randomized controlled trial, we compared the effects of local warming and passive local warming, followed by tourniquet application, on vein size in young and middle aged adults.
- Tourniquet application after local forearm warming effectively dilated veins to a greater degree than tourniquet application alone in young and middle aged adults.

1. Introduction

Although peripheral intravenous cannulation is a common clinical procedure, it is not always successful (Sabri et al., 2013). In Japan, the success rate of peripheral intravenous cannulation is also same or lower that reported for other countries (Sumitani and Watanabe, 2010). Given that such failure can be burdensome to patients (Kuensting et al., 2009), it is important to establish evidence-based methods of improving success rates. Venodilation is usually recommended in difficult cases, because larger vein size is associated with increased success (Panebianco et al., 2009; Roberge, 2004; Schnadower et al., 2007; Witting et al., 2010). Common techniques include local warming (Ortega et al., 2008) (Roberge, 2004) and tourniquet application (Roberge, 2004) (Sabri et al., 2013), with the latter method also used after local warming to facilitate peripheral intravenous cannulation (Kiger et al., 2014).

Several studies have reported that local warming at various sites may cause venodilation (Tokizawa et al., 2017van Bemmelen et al., 2005; Abraham et al., 1994). Some have focused on the tourniquet application for venodilation of the forearm (Mahler et al., 2011; Sasaki et al., 2012; van Bemmelen et al., 2005), but their results have only shown that either local warming alone or tourniquet application alone produced superior venodilation to controls (no tourniquet or heat). To date, there is no evidence that tourniquet application after local warming is superior to tourniquet application alone in achieving venodilation.

To our knowledge, only two experimental studies have investigated the effect of tourniquet application after local warming (van Bemmelen et al., 2005; Sasaki et al., 2014), and the results showed no significant differences in vein size after tourniquet application with and without local warming for 2 min. However, this study was limited, because it was not randomized or controlled, it had a small sample size (n = 24), it did not have a sample size estimate, and it used only a short duration of local warming. In a cross-over study in Japan, it was reported that there was a significant difference in vein size after tourniquet application with and without local warming for 15 min (Sasaki et al., 2014), but this study was also limited by its small sample size (n = 25), lack of a sample size estimate, and failure to choose suitable veins for peripheral intravenous cannulation (median cubital vein). Therefore, no published research has established the efficacy of venodilation combining tourniquet after local warming for peripheral intravenous cannulation.

By contrast, other experiments and randomized trials have shown that tourniquet application after local warming can improve both the success rate and procedure time of peripheral intravenous cannulation (Lenhardt et al., 2002; Biyik Bayram and Caliskan, 2016). Nevertheless, although these studies detailed the clinical benefits of tourniquet application after local warming, they did not measure the actual vein size. Because local warming can decrease pain (Biyik Bayram and Caliskan, 2016; Jeong and Yoon, 2016; Liu et al., 2003; Mahajan et al., 2010; Trimble, 2003), it is conceivable that reduced pain, rather than venodilation, may have contributed to successful peripheral intravenous cannulation. Thus, it is important to determine whether venodilation is improved by tourniquet application after local warming.

In the present study, we aimed to assess the effectiveness of tourniquet application after local forearm warming in comparison with tourniquet application alone in young and middle-aged adults. We hypothesized that the combination would be superior to tourniquet application alone in increasing vein size in this population.

2. Methods

2.1. Trial design

This study was a prospective, parallel group, single-blind, randomized controlled trial. Participants were randomly assigned to one of two parallel trial groups, initially in a 1:1 ratio, based on the presence or absence of active warming. Both groups received tourniquet application after heat pack application. All participants provided written informed consent. The trial was registered with the University Hospital Medical Information Network (registration number: UMIN000021106), and has been reported in accordance with the Consolidated Standards for Reporting Trials statement for reporting parallel group randomized trials (Moher et al., 2010).

2.2. Participants

The trial was conducted at a national university in Japan between March 2016 and April 2016. All interventions were performed in the same room. The ambient temperature was set at 22 °C ± 2 °C, which was confirmed by a digital thermometer (PC-5400TRH, Sato Keiryoki Mfg. Co., Ltd., Tokyo, Japan).

Eligible participants aged 20–64 years were recruited from the university via posters and flyers between February 2016 and April 2016. The age of participants was limited because venous response is known to be affected by the extremes of age (Young et al., 2006). We excluded those receiving treatment for severe skin diseases, wounds, or eczema on the forearm.

2.3. Interventions

2.3.1. Target vein selection

The area of the forearm considered optimal for peripheral intravenous cannulation was warmed before applying the tourniquet (Scales, 2005), and the target vein on the intervention side was defined based on previously described criteria (Hadaway and Millam, 2005; Ingram and Lavery, 2007; Scales, 2005; Kimori et al., 2011). Briefly, target veins were selected based on the hypothetical use of a 20-gage, 30 mm long, 1.1 mm external diameter catheter (BD Insyte™ AutoGuard™ BC Shielded IV Catheter with Blood Control Technology; Nippon BD Co., Tokyo, Japan). We defined target veins as those (1) on the nondominant arm; (2) ≤30 mm distal from the antecubital fossa, but ≤120 mm proximal to the radial styloid; and (3) as peripheral as possible. We only used cephalic, median, or basilica veins running ≥30 mm in a straight line, lying ≤10 mm deep, and with a diameter ≥1.1 mm. Ultrasound was used to select the target vein; our first preference was the cephalic vein, because it is large, easily stabilized, and accessible (Scales, 2005), but the median or basilica veins were used if it was unsuitable. The participant was excluded if no suitable vein could be found. To ensure that measurements were taken at the same site before and after the intervention, the investigator outlined the target vein with surgical tape (Micropore, 3 M health Care, Tokyo, Japan) before starting the intervention (Fig. 1).

2.3.2. Procedure

Fig. 1 summarizes the steps of the intervention. Participants were randomly allocated to either an active warming group (tourniquet application after active local warming of the forearm)