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How long should local warming for venodilation be used for peripheral intravenous cannulation? A prospective observational study

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ABSTRACT

Background: Local warming is one of the most common venodilation techniques for achieving peripheral intravenous cannulation, but the time of application is unclear.
Objective: To compare the effectiveness of local warming applied for 5, 10, and 15 min.
Design: A prospective, observational study.
Setting: A university in Japan.
Participants: In total, 40 healthy female volunteers aged 20–45 years were recruited via e-mail.
Methods: Participants received 15 min of local warming with a warmed heat pack (40 ± 2 °C). The primary outcome was the cross-sectional area of the target vein at 5, 10, and 15 min of warming, which was measured after the intervention by blinded review using ultrasound. Secondary outcomes included forearm target site temperature at 5, 10, and 15 min of local warming, which was measured with a temperature sensor and handheld thermometer.
Results: Compared to outcomes before local warming, vein cross-sectional area at 5, 10, and 15 min of warming significantly ($p < 0.001$) increased by 2.8, 2.9, and 2.3 mm^2. The target site temperature increased by 6.9 °C, 6.4 °C, and 6.0 °C, respectively. However, no significant differences were found in cross-sectional area among the time points of 5, 10, and 15 min of local warming. The target site temperature at 15 min of local warming was significantly ($p < 0.001$) different than that at 5 and 10 min. No adverse events occurred with local warming.
Conclusion: Compared with outcomes before local warming, vein size after warming for 5, 10, and 15 min was significantly larger. No significant differences were found in vein size among the time points of 5, 10, and 15 min of local warming. Our result demonstrated the effectiveness of shorter-duration (5 min) local warming for inducing venodilation for peripheral intravenous cannulation.

What is already known about the topic?

- Peripheral intravenous cannulation is clinically indispensable.
- Local warming is among the most common venodilation techniques for promoting peripheral intravenous cannulation.
- Fifteen minutes of local warming is effective for venodilation for peripheral intravenous cannulation.

What this paper adds

- In this prospective observational study, we compared the effects of local warming on vein size at various time points.
- Local warming for 5, 10, and 15 min increased venodilation compared to that before local warming.
- We observed that 5 min of local warming appears to be sufficient to increase vein size to facilitate peripheral intravenous cannulation.

1. Introduction

Peripheral intravenous cannulation is clinically indispensable. Although up to 70% of patients required peripheral intravenous cannulation (Zingg and Pittet, 2009), it does not always succeed because the primary success rate of peripheral intravenous cannulation is 60%–88% (Sabli et al., 2013; Sumitani and Watanabe, 2010). Failed procedures not only put patients in distress and pain but also result in delayed treatment, increased risk of complication, such as infection, vein injury, and infiltration, and increased nursing/medical workload and overall hospital costs due to multiple attempts (Kuensting et al., 2009; Rauch et al., 2009).

Successful peripheral intravenous cannulation is less difficult in

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larger-sized veins (Panebianco et al., 2009; Schnadower et al., 2007), and therefore, various venodilation techniques are used in clinical practice (Ortega et al., 2008; Roberge, 2004; Sabri et al., 2013). Local warming is one of the most frequently used and effective techniques for peripheral intravenous cannulation (Kiger et al., 2014). However, the most effective duration of warming to promote venodilation is unknown.

A randomised controlled study demonstrated that local warming for 15 min increased the success rate and reduced the time needed for peripheral intravenous cannulation (Lenhardt et al., 2002). Case-control and crossover studies showed that local warming for 10 min was also sufficient (Biyik Bayram and Caliskan, 2016; Lenhardt et al., 2002). However, in clinical situations, 80% of medical and nursing staff use local warming for less than or equal to 5 min for peripheral intravenous cannulation (Kiger et al., 2014) and performing long-duration warming in a busy general medical ward or emergency department is considered impractical (Peel, 2002). These data indicate that time is limited in clinical practice and shorter yet effective venodilation methods for peripheral intravenous cannulation are required. Therefore, it is useful to examine whether the shorter-duration local warming performed by medical staff is effective for venodilation for this procedure (Rauch et al., 2009).

To our knowledge, in the study which measured vein size objectively, 15 min is the shortest duration of local warming that has venodilation effects in the vein of the forearm for peripheral intravenous cannulation (Tokizawa et al., 2017; Yamagami et al., 2017). However, this estimate was provided based on the results of 15 min alone and might not indicate the maximum venodilation time owing to limited data. To determine the shortest amount of time that provides maximum venodilation, it is necessary to examine temporal changes in vein size. Two studies have investigated vein size after warming (Huff et al., 2009; Tokizawa et al., 2017); however, we could not identify any studies that have examined temporal changes in vein size during local warming.

The objective of this study was to compare the effectiveness of local warming according to time. We hypothesised that local warming for 5, 10, and 15 min is superior to no warming for venodilation. If this hypothesis were correct, we would examine the differences in vein size at 5, 10, and 15 min of local warming.

2. Methods

2.1. Study design and setting

This prospective, observational study was performed at a single university in Japan. Between November 2013 and December 2013, 40 healthy participants were recruited from among university students via the university e-mail system. We included only women aged 20–45 years who had the target vein on the forearm. Participants were limited by age and sex to reduce the influence of individual differences in venous response (Monahan and Ray, 2004; Young et al., 2006). Exclusion criteria included treatment for skin disease and the presence of wounds or eczema on the forearm.

We defined and selected a target vein, vein site, and vein size on the forearm based on previously described criteria (Hadaway and Millam, 2005; Ingram and Lavery, 2007; Kimori et al., 2011; Scales, 2005) and the hypothetical use of a 20-gauge, 30-mm-long, 1.1-mm-external-diameter catheter (BD InsyteÔ AutoGuardÔ BC Shielded IV Catheter with Blood Control Technology; Nippon BD Con., Tokyo, Japan). This catheter size is considered suitable for adult patients (Hadaway and Millam, 2005). In brief, the target vein was defined as a cephalic, median, or basilic vein running ≥30 mm in a straight line, lying at ≤10 mm deep, and with a diameter of ≥1.1 mm on the non-dominant arm, distal (≤30 mm) from the antecubital fossa but proximal (≤120 mm) to the radial styloid and as peripheral as possible. Ultrasound was used to select the target vein. Our first preference was the cephalic vein because it is large, easily stabilised, and accessible (Scales, 2005). Median or basilic veins were used if the cephalic vein was unsuitable. After application of the exclusion criteria, all 40 participants were enrolled.

2.1. Procedure

Before the administration of local warming, baseline characteristics including age, body mass index, and dominant arm were recorded for all participants. Then, the participants rested in a supine position in the same test room for least 15 min. The mean air temperature during the study was 23 ± 1 °C. A single investigator selected a suitable target vein on the non-dominant forearm according to the criteria using an ultrasound system (LOGIQe, GE Healthcare, Japan Co., Tokyo, Japan) and marked the site with a pen. Then, the investigator placed a heat pack warmed to 40 ± 2 °C with hot water on the target site and covered it with a perforated cotton towel to maintain warmth. The pack was applied for 15 min.

The heat pack was marked in advance with a pen in an ellipse matching the shape of the linear array probe to superimpose the marked target vein on the heat pack. A cut-out in the shape of the probe was also made in the towel so that the marked area on the heat pack was visible to the probe user when heat pack was on the forearm (Fig. 1A–D).

2.2. Outcome measures

The primary outcome was the cross-sectional area of the target vein in the area of local warming after 5, 10, and 15 min of local warming. The investigator visualised and saved venous short-axis views at the target site in B-mode with a high-frequency (8 to 13 MHz) linear array probe using the ultrasound system.

Ultrasound visualisation was conducted before local warming (baseline) and at 5, 10, and 15 min of local warming with the heat pack) on the forearm (see Fig. 1D). The investigator also conducted ultrasound visualisation of the vein before applying the heat pack and compared them with measurements with the non-warmed heat pack in place to ensure that the weight or material of the pack had no impact on vein measurement.

After the procedures, an independent research assistant (different from the investigator) blinded to the study protocol measured the smallest and largest vein diameters on frozen images with electronic calipers of the ultrasound system. All ultrasound visualisation (by the investigator) and measurements (by the research assistant) were performed with a single ultrasound system.

The measurements were taken with electronic calipers placed at the interface between the vein lumen area and vessel wall, and the results were expressed in tenths of millimetres. The vein cross-sectional area was computed according to the following ellipse formula: vein cross-sectional area (mm^2) = $\pi \times$ [smallest diameter (mm)/2] $\times$ [largest diameter (mm)/2]. Because the visualised vein image in the short axis presents not as an exact circle but as an ellipse, an ellipse formula is often used to calculate vein cross-sectional area (Lewin et al., 2007; Wang et al., 2009).

The secondary outcomes included the target site temperatures at the target vein after 5, 10, and 15 min of local warming. To measure target site temperature, we made the participants wear temperature sensors (540E-TS1-AS, Anritu Meter Co., Tokyo, Japan) and recorded the temperature with a handheld thermometer (HD-1000, Anritu Meter Co., Tokyo, Japan) at four time points (baseline and at 5, 10, and 15 min of local warming). The temperature sensor on the skin surface at the target site was shielded from the applied heat pack. Participants wore the temperature sensor from the period before the application of the heat pack to the end of local warming