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The effect of oral hydration and localised heat on peripheral vein diameter and depth: a randomised controlled trial

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Conflict of Interest

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Abstract

Background: Accessing the peripheral veins for blood sampling and short-term peripheral intravenous catheter insertion is common in contemporary healthcare. Clinicians may apply heat or promote oral hydration to increase vein diameter and reveal veins to improve success rates. However, there is limited research that has examined the effect of these interventions on vein diameter and depth.

Objectives: To determine the effect of localised heat and oral hydration on vein diameter and depth.

Design: A three arm parallel randomised controlled trial was undertaken with 39 healthy participants from a University. All participants fasted from food and fluid from midnight. At 10am the next day, a mark was made at the cephalic (120mm proximal from the radial styloid) and median cubital veins (at cubital fossa) with non-permanent ink and participants underwent baseline vein diameter and depth measurement using ultrasound. Participants were randomised to either a control, heat or hydration group. Participants in the hydration arm consumed 1 litre of room temperature tap water, those in the heat group had a wheat bag applied to the area for 10 minutes and those in the control group had no intervention and were asked to sit quietly. A second measurement was undertaken immediately after the heat intervention and 1 hour after the baseline measurement for those in the hydration and control groups.

Results: The application of localised heat and oral hydration did not affect the depth of the cephalic vein. Whilst hydration had no effect on median cubital vein depth, the application of heat did make this vein more superficial compared to the control group ($p=0.033$). The application of heat resulted in a statistically significant ($p=0.006$) increase in cephalic vein diameter compared to the control group, this effect did not occur with the median cubital vein ($p=0.087$). Oral hydration resulted in a reduction in the mean diameter of both veins. Compared to the control group, the average median cubital vein diameter decreased by 0.57mm ($p=0.003$; 95% CI -0.940 – -0.193) and the cephalic vein reduced by 0.33mm ($p=0.015$; 95% CI -0.593 – -0.064) after oral hydration.

Conclusion: The use of localised heat was inconsistent in its effect on vein diameter and depth. Oral hydration caused a reduction in vascular calibre in both the cephalic and median cubital veins. The promotion of water consumption to improve venepuncture success is not supported.

Keywords

Catheterisation, peripheral; cephalic vein; heat; median cubital vein; oral hydration; vein diameter; peripheral intravenous catheter; ultrasonography; venepuncture.

Introduction

The insertion of peripheral intravenous catheters (PIVCs) for intravenous treatment and venepuncture for blood sampling are ubiquitous in modern health care. Some patients require numerous attempts which is distressing, delays treatment and is costly for health care organisations.^{1, 2} Clinicians may instigate interventions such as the use of a tourniquet, application of heat or encourage patients to drink water to improve venepuncture success. However, whilst the use of a tourniquet or blood pressure cuff has some evidence for its use,³ the use of heat and hydration are based on limited evidence.

PIVC/venepuncture

Internationally, it is estimated that over a billion PIVCs are inserted in hospitalised patients annually.⁴ However, difficulty in obtaining successful access is a problem for some patients who may endure repeated attempts.^{5, 6} Failure rates, (where more than one attempt is required with cannulation) vary, with 15-50% of patients requiring more than one attempt.⁷⁻⁹ Research in an Emergency Department setting found that 11% of patients required more than four attempts.⁹ Repeated venepuncture attempts are distressing and reduce patient satisfaction.^{1, 2, 5, 6} Some patients may develop 'needle phobia' which makes future treatment provision increasingly complex and problematic.

Successful venepuncture may be influenced by both the diameter and the depth of the vein from the surface of the skin.^{10, 11} Clinicians may apply heat or promote fluid intake to increase vein diameter and reveal superficial vein anatomy. Whilst limited research investigating the effect of localised heat on vein diameter exists, research investigating the effect of hydration on the diameter of peripheral veins and the effect of either intervention on vein depth has yet to be conducted.

Heat

Heating methods such as warm towels and heat packs are used by clinicians to facilitate cannulation and venepuncture.^{12, 13} The Infusion Nurses Society¹⁴ recommend that use of dry heat to improve success of venepuncture. Kiger¹³ in a survey of clinicians who inserted PIVCs, found that 38% of health care workers used heat for patients who described themselves as having previous history of difficult venous access. Previous research has demonstrated that localised heat improves rates of successful PIVC insertion¹⁵ and improves the visibility and palpability of veins.^{16, 17} Yet, none of these studies measured vein diameter

and depth. There is scant research that has used an objective measure of vein diameter after a heat intervention. Yamagami et al.¹⁸ and Tokizawa et al.¹⁹ found that the size of the cephalic vein in the forearm significantly increased after application of a heat pack. Similarly, Van Bemmelen et al.²⁰ demonstrated that the cephalic and basilic vein diameters at the wrist level were significantly greater after submersion in warm water.

Hydration

Some clinicians inform patients that failed venepuncture attempts are due to reduced fluid intake.² This appears feasible as the venous system is a low pressure and high compliance circuit, and hence is acutely sensitive to changes in blood volume and pressure.²¹ Fluid provision increases vein size by 30-45% in the central vasculature (subclavian, inferior vena cava and internal jugular vein) and 50% in lower extremity veins (gastrocnemius and posterior tibial veins).²¹⁻²³ However, much of this research investigated the effect of intravenous hydration therapy given intraoperatively. Only one study has examined the effect of oral hydration on vein diameter and this concentrated on veins in the central vasculature.²¹ There is no published research on the effect of water consumption on the diameter and depth of smaller, peripheral veins used for venepuncture and PIVC insertion.

Method

Aim

To determine the effect of localised heat and oral hydration on vein diameter and depth.

Trial design

A three arm parallel randomised controlled trial was undertaken to determine the effect of oral hydration and heat on vein diameter and depth. Data were collected January – May 2017.

Participants

Staff and students at a metropolitan university in Adelaide, South Australia, were recruited using convenience sampling. Participants were invited to email the researchers to register interest in participating and were sent a set of screening questions concerning their medical history (previous/current illness) that would be influenced by fasting (food and fluid), age and pregnancy status.

Inclusion: Staff and students at the university over 18 years of age

Exclusion: Pregnant women and participants who had a health condition that may be affected by fasting from food or fluid.

The Human Research Ethics Committee, University of South Australia provided approval prior to the study's commencement (Protocol no. 35866). Potential participants were given an information sheet by the researcher, allowed time to read it and were encouraged to ask questions. After this, participants were invited to take part and written consent was obtained. The trial was registered with the Australian New Zealand Clinical Trials Registry (ACTRN 12617000463370).

Randomisation

Participants were randomly assigned to one of three groups - control (no intervention), hydration and heat (1:1:1 allocation ratio). Random allocations were computer-generated at point of entry to the study. The study was unblinded due to the nature of the interventions. Both participants and the sonographer undertaking the vein measurements were aware of group allocation.

Procedure

All participants were asked to fast (food and fluid) from midnight the previous night to 10am the next day, when the measurements were taken. On arrival at the research centre, participants were given a short questionnaire to determine age, body mass index (BMI), gender, medical history (diagnosed by medical practitioner) tobacco and medication use. Additionally, level of physical activity was measured using the Godin Leisure-Time Exercise Questionnaire.²⁴

Participants were asked to lie supine on an examination bed with their left arm exposed and extended, by their side, facing palm up. The arm was in a natural state without tourniquet. An experienced sonographer undertook the baseline vein measurements. Ultrasound images were taken using a Philips IU22 Ultrasound System (Philips Healthcare, Bothell, WA) set to a venous imaging protocol. A 9-4Mhz probe operating at 9Mhz frequency was used. Scanning parameters were optimised for each participant (depth, gain, TGC and zoom). Two veins (median cubital and cephalic vein) on the left arm of participants were identified and measured. The median cubital vein was measured at the cubital fossa. The cephalic vein was measured at 120mm proximal from the radial styloid. A mark was made at both sites with non-permanent ink. The transducer was manoeuvred transversely along the mark and

angled from left to right to obtain the clearest image of the vein in cross section and reduce artefacts in the image. Light transducer pressure was used to avoid vein compression. The diameter of each vein was measured using the greatest difference between the anterior and posterior wall, in a transverse plane using inbuilt callipers on the sonography unit (figure 1).

Figure 1: Ultrasound image of median cubital vein measurement using inbuilt callipers.

The calliper was placed such that the top of the cross bar of the anterior calliper aligned with the inside of the top echogenic vein edge and the bottom of the posterior cross bar calliper aligned with the inside of the bottom echogenic vein edge. The distance between the superior echogenic vein edge to the skin surface in transverse section was also measured using the machine's in built callipers. Both the vein diameter and distance of the vein from the skin surface were repeated at a pre-determined time point, according to the group the participant was randomised to.

Participants allocated to the fluid arm were given 1 litre of room temperature tap water and asked to consume this over 30 minutes. The second measurement occurred 1 hour after the baseline measurement. Those in the arm receiving heat intervention had a heat pad applied for 10 minutes to the forearm and cubital fossa area after their baseline measurement.¹⁷

The heat bag used was a Hot Wheat bag (Medi-Ice Pak, Australia). It was heated for 90 seconds in accordance with the instructions on the heat bag in a Sharp Carousel 1100W microwave set to maximum power. The second vein measurement was undertaken immediately after the intervention. Participants in the control arm did not receive fluid or heat and were asked to sit quietly until the second vein diameter and depth measurements 1 hour after the baseline measurement.

All measurements were performed by a single accredited medical sonographer with extensive clinical and teaching experience. The validity of ultrasound to measure vessel diameter has been established in previous research examining vein mapping in the upper extremities for arteriovenous fistula development, and in the lower extremities prior to coronary artery bypass graft procedures.^{25, 26} The sonographer used in this research demonstrated reliability in previous research and thus no additional reliability testing was necessary.²⁷

Sample size estimation

There was a paucity of data to inform this power analysis. We assumed a large effect size ($d=1.0$), a required alpha of 0.05, 80% power, and a correlation between baseline and post-intervention measurements of 0.7. Based on a linear mixed effects model with two time points, 13 subjects were required in each study arm.²⁸

Data analysis

Descriptive statistics were used to present participant variables such as age, gender, activity levels, vein diameters and distance of the vein from the skin surface. Differences in vein diameter and depth were analysed using linear mixed effects model (Stata 11 statistical package, Stata Corp., College Station, TX, USA). Groups were compared at baseline, with differences adjusted for in the main model if required. The results are reported according to CONSORT statement guidelines.

Results

Study population

40 participants were screened for eligibility, one was excluded due to pregnancy, 39 participants (13 in each group) were included in the analysis. Data collection occurred January – May 2017.

The mean age of participants was 43 years (SD 11.8), 69% were female ($n=27$). Most were right handed (92%; $n=36$) and 36% ($n=14$) had a medical condition diagnosed by a medical officer (Table 1). One participant was a current user of tobacco products (3%). The mean BMI was 27 (SD 5.1). From Table 1 it can be seen that the control group had a higher percentage of males, were somewhat older, had more BMIs in the middle range and were

somewhat less active. These variables were adjusted for in the initial analysis, but had little impact on the interaction coefficients, and were therefore omitted from the final model.

Table 1: Characteristics of participants

Characteristic		Intervention		
		Control n (%)	Heat n (%)	Hydration n (%)
Gender	Female	7 (54)	10 (77)	10 (77)
	Male	6 (46)	3 (23)	3 (23)
Age (years)	18-35	1 (8)	5 (39)	4 (30)
	36-55	8 (62)	7 (54)	8 (62)
	≥ 56	4 (30)	1 (8)	1 (8)
Dominant hand	Left	1 (8)	1 (8)	1 (8)
	Right	12 (92)	12 (92)	12 (92)
Medical Condition	Yes	4 (31)	5 (39)	5 (39)
	No	9 (69)	8 (61)	8 (61)
BMI	≤24.9	2 (15)	4 (33)	6 (46)
	25-30	7 (54)	4 (33)	6 (46)
	≥30.1	4 (31)	4 (33)	1 (8)
Activity levels	Insufficiently active (≤14)	2 (15)	0 (0)	0 (0)
	Moderately Active (15-23)	2 (16)	0 (0)	1 (8)
	Active (≥24)	9 (69)	13 (100)	12 (92)

Vein diameter and depth

The baseline and post-intervention mean vein diameters and distance from the skin surface for each group are presented in Table 2. For all diameter measurements there was an evident increase in mean vein diameter after the heat intervention, but a decrease in mean vein diameter in the hydration group. Table 2 shows that the heat and hydration interventions had an inconsistent effect on vein depth.

Table 2: Mean vein diameters and depth

		Baseline			Post intervention		
		n	Mean (mm)	SD	n	Mean (mm)	SD
Diameter							
Cephalic vein							
	Control	13	2.99	1.21	13	3.08	1.15
	Heat	13	2.87	0.95	13	3.33	1.07
	Hydration	13	1.84	0.80	13	1.60	0.78
Median cubital vein							
	Control	13	4.37	1.15	13	4.61	1.16
	Heat	13	5.06	1.39	13	5.62	1.21
	Hydration	13	3.55	1.39	13	3.22	1.38
Vein depth							
Cephalic vein							
	Control	13	4.31	1.92	13	4.30	1.81
	Heat	13	5.12	2.46	13	5.07	2.54
	Hydration	13	3.53	2.03	13	3.63	1.96
Median cubital vein							
	Control	13	3.00	1.48	13	3.07	1.57
	Heat	13	2.79	1.07	13	2.52	1.22
	Hydration	13	2.83	1.77	13	2.70	1.77

Results of linear mixed effects models

In the linear mixed effects models, the application of heat resulted in a statistically significant ($p=0.006$) increase in cephalic vein diameter compared to the control group (Table 3). Although in the same direction, the effect of heat on the median cubital vein was not statistically significant ($p=0.087$). In contrast, hydration was associated with a statistically significant reduction in the diameter of both veins. This intervention had a larger effect on the median cubital vein diameter than the cephalic vein. Compared to the control

group, the average median cubital vein diameter decreased by 0.57mm ($p=0.003$) after hydration.

Heat and hydration did not appear to change the depth of the cephalic vein from the skin surface. Similarly, hydration did not have an effect on the distance of the median cubital vein from the skin surface. However, heat did appear to reduce the distance of this vein from the skin surface ($p=0.033$).

Table 3: Effect of heat and hydration on vein diameter and depth

		*Coefficient	p	95% CI
Diameter				
Cephalic vein	Heat	0.37	0.006	0.103 – 0.632
	Hydration	-0.33	0.015	-0.593 – -0.064
Median cubital vein	Heat	0.33	0.087	-0.047 – 0.670
	Hydration	-0.57	0.003	-0.940 – -0.193
Vein depth				
Distance of cephalic vein	Heat	-0.04	0.834	-0.422 – 0.341
	Hydration	0.12	0.537	-0.261 – 0.501
Distance of median cubital vein	Heat	-0.364	0.033	-0.697 – 0.030
	Hydration	-0.166	0.321	-0.493 – 0.161

**Based on a linear mixed effects model, coefficients are interactions between study group and time.*

Discussion

This study found that heat was inconsistent in its effect on the diameter and depth of peripheral veins in the forearm. Heat increased the mean diameter of the cephalic vein, but not the median cubital vein to the same extent. Heat had no statistically significant effect on the depth of the cephalic vein when compared to the control and appeared to result in the median cubital vein becoming more superficial. Whilst hydration did not appear to affect the depth of either vein, it did result in a consistent reduction in the diameter of both veins. On average, compared to the control group, the cephalic and median cubital veins decreased in diameter by 0.33mm and 0.57mm respectively.

Heat

Heat was effective in increasing the diameter of the cephalic vein in this study. These results support an earlier study by Tokizawa et al.¹⁹, who reported that the lower arm cephalic vein diameter in healthy individuals increased from 2.8mm (2.1–3.4mm) to 3.4mm (2.8–3.7 mm) after application of a heat pack to the local area. Similarly, Van Bemmelen et al.²⁹ found that the cephalic and basilic veins of healthy individuals increased in diameter at the wrist level after submersion in warm water. This effect has been demonstrated in people with health conditions as well. Katragunta et al.³⁰ demonstrated that heat increased the diameter of the cephalic vein of health consumers undergoing preoperative mapping for arteriovenous fistula (AVF) development. The present study, demonstrated that heat did not increase the diameter of the median cubital vein, which was unexpected as this vein is more superficial than the cephalic vein and hence it would be assumed would respond more to heat. However, this effect was approaching statistical significance and perhaps this result is due to the small sample size.

Previous research concerning the effect of heat on vein depth could not be located. The present study showed that heat was effective in reducing the depth of the median cubital vein but not the cephalic vein. Further research is needed to determine if heat is effective in revealing the peripheral veins of people with health conditions.

Hydration

A novel finding of this study was that oral ingestion of 1L of water decreased peripheral venous calibre. This was a surprising finding of this study, because clinicians may assume that water consumption would increase plasma volume and therefore, increase venous diameter.

The exact mechanism is unclear but a possible explanation for reduced venous diameter is the activation of the sympathetic nervous system from drinking water. It is thought that absorption of water into the portal circulation may stimulate peripheral osmoreceptors, triggering activation of sympathetic motor neurons, which increase peripheral arterial resistance.^{31, 32} Increased total peripheral resistance, would therefore reduce blood flow to superficial structures including the skin, leading to reduced blood flow returning via the venous circulation and reduced venous diameter.³² However, the impact that such osmoreceptor activation on peripheral venous architecture remains unexplored. Further,

although not conclusive, previous research in healthy participants has indicated that drinking 500ml of water is associated with increased plasma levels of neurotransmitters that are associated with sympathetic nervous system stimulation and precipitate vasoconstriction.^{31, 33, 34} This may help explain the effect found in this study - the smooth muscles in the superficial veins of extremities contain sympathetic nerve innervations, hence it is feasible that this process explains the reduction in vein diameter in the present study.³⁵

The results of this study do not support previous research examining the effect of oral hydration in the central vasculature of health consumers with Multiple Sclerosis.²¹ Diaconu et al.²¹ found a statistically significant increase in the cross-sectional area of veins in the central vasculature after consuming 1.5 litres of an isotonic sports drink. Perhaps the difference in effect is due to the solution consumed. Water is hypotonic and research where healthy participants were given an isotonic saline solution (0.9% saline) and water to drink (cross-over design) found that whilst water triggered a sympathetic response, the saline solution did not.³⁶ Future research could examine the effect of solution type, including isotonic sports drinks (which would be more palatable than 0.9 % saline) on the diameter and depth of superficial veins. Such research could be conducted in clinical settings with consumers requiring a PIVC to understand the effect of different solutions on vein diameter and depth, and determine whether these solutions effect cannulation success.

Clinical implications

Clinicians believe that hydration increases the chance of PIVC insertion success.^{2, 6} This is despite most clinicians having little understanding of why PIVC insertion fails. Unfortunately, most PIVC insertion is still attempted 'blind' (without ultrasound), so that clinicians are unable to completely assess the vasculature. Palpation and inspection are basic tools and may not be good indicators of vein diameter and depth. Ultrasound is an important tool to allow a complete vascular assessment to facilitate PIVC insertion and venepuncture. The results of the present study indicate that clinicians should reconsider informing patients that difficulty inserting PIVCs and undertaking venepuncture is due to reduced water intake.

Due to the distressing nature of multiple attempts and cost to the health care organisation, reducing the number of venepuncture attempts should be a priority in health care.³⁷ Whilst

the exact mechanism of the effect of drinking water on the reduction of vein diameter is unknown, it appears that drinking water may make peripheral cannulation and venepuncture more difficult. Hence, other interventions are needed to improve the success of these common procedures, especially for people who experience difficulty with obtaining successful blood samples and PIVC insertion.

Strategies used in other patient cohorts to improve vascular access success may also be useful for those that experience ongoing difficulty with venepuncture and PIVC insertion. Hand exercises are recommended for patients requiring an AVF to increase vasculature diameter to improve maturation rates.³⁸ Research in this patient cohort has demonstrated that 4-6 weeks of hand grip exercises increase forearm vein calibre.^{39, 40} Although it would be difficult to plan for future PIVC insertions and venepunctures in all patients, for some patients with known difficulty with accessing the venous system and ongoing need for venepuncture and cannulation, this may prove useful. Research is needed to determine the effect of hand grip exercise on the diameter and depth of peripheral veins and the effect of this on venepuncture and cannulation success.

Limitations

Due to the nature of interventions, both participants and the sonographer were aware of allocation. Further, as measurement of vein diameter is influenced by the ultrasound operator, there is a potential for bias. However, every effort was made to control for this with the use of a consistent approach to measurement. Lastly, we included only healthy volunteers and the findings may not be generalisable to people with health conditions.

Conclusion

Repeated attempts at venepuncture and PIVC insertion cause vasculature damage, are distressing for the patient and may delay treatment. It appears that localised heat has an inconsistent effect on vein diameter and depth and the promotion of water intake may be contraindicated as a strategy to increase vein diameter. Further research is required to examine the effect of drinking water (and other solutions) and heat on peripheral veins.

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