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● *Original Contribution*

MICROVENOUS REFLUX IN THE SKIN OF LIMBS WITH SUPERFICIAL VENOUS INCOMPETENCE

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Abstract—This study investigated whether microvenous reflux can be detected in limbs with chronic venous disease using superb microvascular imaging (SMI) and colour Doppler imaging. Participants with venous disease (limbs, n = 26) and without venous disease (limbs, n = 10) were studied. The skin in the medial gaiter region was imaged using both SMI and colour Doppler to identify reflux in the small vessels in response to distal augmentation. The diameters and depths of responsive vessels were measured. In limbs with venous disease, reflux in response to provocation was visualised with SMI in a greater number of vessels (12/26 versus 4/26) and smaller vessels than with colour Doppler. Reflux in the superficial skin veins was demonstrated in one control participant (1/10) using SMI and in none using colour Doppler (0/10). Our study indicates that microvenous reflux is demonstrable in limbs with venous disease and that SMI is more sensitive than colour Doppler. (E-mail: kate.thomas@otago.ac.nz) **© 2017 World Federation for Ultrasound in Medicine & Biology. All rights reserved.**

Key Words: **Microvenous, Reflux, Superb micro-vascular imaging, Chronic venous disease.**

INTRODUCTION

Chronic venous disease (CVD) is widely accepted to be a result of progressive valvular incompetence (Cina et al. 2005). The natural history of varicose veins has traditionally been described as a descending disease (Ludbrook and Beale 1962); however, evidence supports the theory that varicose vein development is an ascending condition (Bernardini et al. 2010) initiating from perforator reflux (Labropoulos et al. 2006), or develops at any level irrespective of the site and the function of the valves involved (Labropoulos et al. 1997, 2005). The focus of earlier work is related to the changes in competence of valves in the larger superficial veins of the leg (>2 mm diameter). Although it had previously been thought that there were no valves in smaller tributaries, we now know that even smaller veins, down to microvenous vessels of less than 100 μm in diameter, contain abundant valves (Aharinejad et al. 2001; Braverman and Keh-Yen 1983; Caggiati et al. 2006; Phillips et al. 2004). A study by Vincent et al. (2011) demonstrated the presence of reflux in the venous microvasculature, using retrograde resin venography in amputated limbs. Microvalves were identified using this technique: If the resin passed through a valve and was present on both sides of the valve, it was deemed incompetent, compared with a competent valve in which the resin was held up at the valve. In individuals with reflux in larger vessels, such as the great saphenous vein, as well as microvalve incompetence, the refluxing resin was shown to extend back into the skin microcirculation. One suggestion based on this work is that microvenous reflux is required for the development of the skin changes of chronic venous insufficiency (Vincent et al. 2011). However, to substantiate this, an *in vivo* technique to image the microvenous system and microvalve function is required.

One approach is to use colour Doppler ultrasound, but historically this has been difficult because of both the limitation in discrimination of such small vessels and the sensitivity required to detect the low flow in these small vessels. In 2016, Toshiba introduced an innovative approach called superb microvascular imaging (SMI; Toshiba Medical Systems Europe, Zoetermeer, Netherlands), which uses very slow flow filtering technology that separates signals derived from low velocity flow in tiny vessels from overlaying tissue motion and effectively preserves even the subtlest low flow components (Gent 1997). Colour Doppler on the other hand uses fixed echo cancellation to differentiate between stationary reflectors and red blood cells.

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It removes very low velocity components of tissue motion; this technique therefore makes it difficult to distinguish real blood flow from motion artifacts at low velocities.

This study investigated the ability of this new SMI technology to detect flow in the microvenous network of the skin and in particular, examined whether reflux could be detected within these small vessels. If this proved feasible, then SMI may be a tool for the early detection and evaluation of the progression of CVD. Additionally, this would improve knowledge and support the understanding of reflux in the microvenous system in the intact limb.

MATERIALS AND METHODS

Study population and demographic characteristics

We studied 2 groups of limbs: (i) 10 control limbs in 10 patients (normal limbs with no venous disease and no reflux on duplex ultrasound), and (ii) 26 limbs with clinical CVD and ultrasound-detected reflux in 24 patients, further referred to as CVD limbs. Demographic characteristics are presented in Table 1. We used the Clinical Etiology Anatomy Pathophysiology (CEAP) classification system for this study. The distribution of the clinical class *C* according to the CEAP classification in all participants is presented in Figure 1. The study was approved by the University of Otago Human Ethics Committee (Health) (Dunedin, New Zealand), reference number H15/111, and conformed to the standards set by the Declaration of Helsinki. Participants were informed of experimental procedures and provided written informed consent.

Experimental protocol

The participants were examined on a bed (Tanzanite AMC2520, Forme Medical, Carrum Downs, Victoria, Australia) tilted to 45° reverse Trendelenburg, with the limb being assessed relaxed, and the contralateral limb bearing weight. This setup allowed for optimal venous filling. The sonographer initially swept the transducer across the medial gaiter region to identify an area demonstrating reflux on augmentation in larger subcutaneous tributaries. Adequate gel for offsetting and preventing any transducer compression of the skin vessels was used. Once an appropriate area was identified, the transducer was manually kept constant in position by the sonographer throughout the assessment. The same chosen site was investigated with colour Doppler and SMI at rest and during several provocation manoeuvres. Video clips were recorded for each manoeuvre with each imaging modality, colour Doppler and SMI.

Table 1. Participant demographic characteristics

	No venous disease	Venous disease
Limbs	10	26
Women	9	10
Men	1	16
Average age (y)	34	56
Age range (y)	22–53	34–81

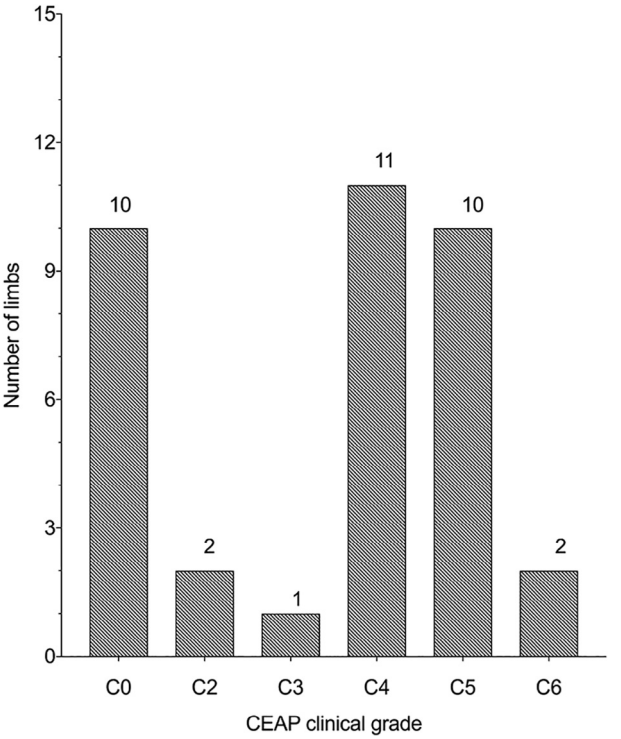

Fig. 1. Distribution of Clinical Etiology Anatomy and Pathophysiology classification in all limbs.

A linear array PLB-1005 BT 12–14 MHz transducer was selected, and a venous ultrasound preset was selected on the Toshiba Aplio 500 ultrasound machine (Aplio 500, Toshiba Medical Systems, Europe). Depth, focal zone and gain were all optimised for each participant. Transmission frequency was always 18 MHz, and the mechanical index was always less than 1.8. Once the linear array transducer was secured in an appropriate location and the image was optimised, the provocation manoeuvres were performed.

Provocation tests

Figure 2 shows the setup of the experiment. Following a few seconds of baseline recording, a pneumatic cuff (custom-made) rapidly inflated and deflated around the foot to induce a distal augmentation. A similar period of recording was obtained using augmentation of a proximal calf cuff (TD312, Hokanson, Bellevue, WA, USA), a Valsalva manoeuvre and a plantar flexion isometric contraction induced by pressing toes downward against a fixed barrier. Ultrasound cine loops were recorded throughout the assessment with both colour Doppler and SMI.