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● *Original Contribution*

VALUE OF CONTRAST-ENHANCED ULTRASOUND IN DETECTING COMPETENT AND INCOMPETENT LOWER-EXTREMITY PERFORATING VEINS

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Abstract—The purpose of this study was to investigate the value of contrast-enhanced ultrasound (CEUS) in the identification of competent and incompetent lower-extremity perforating veins. Patients with chronic venous insufficiency who met the inclusion criteria were enrolled. All patients underwent pre-operative CEUS and color Doppler ultrasound (CDU) and accepted subfascial endoscopic perforator surgery. We compared the numbers of perforator veins identified by CEUS and CDU with the endoscopy result, which was considered the gold standard. Fifty cases (56 lower extremities) were enrolled. CEUS detected 132 perforating veins, and CDU detected 104 perforating veins. Endoscopy detected 148 perforating veins. The sensitivity and specificity of CDU in predicting the site of perforating veins in our study were 70.2% and 100%, respectively, and the sensitivity and specificity of CEUS were 89.2% and 100%, respectively ($p < 0.05$). CEUS could be used to detect perforating veins, including incompetent and competent veins of the lower extremity, because it was more sensitive than CDU, with intraoperative endoscopy as the control standard. (E-mail: 641429731@qq.com)

Key Words: **Contrast-enhanced ultrasound, Perforator vein, Chronic venous insufficiency.**

INTRODUCTION

Perforator vein insufficiency plays an important role in chronic venous insufficiency (CVI), which may affect more than 60% of the adult population globally (Rabe et al. 2012). Some researchers have confirmed that incompetent perforating veins are closely related to venous ulceration and post-operative recurrence of the lower extremity, and the recurrence rate is as high as 51.2% (Baron et al. 2001; Rutherford et al. 2001). Subfascial endoscopic perforator surgery (SEPS) has been found to be an effective method to cure perforator vein insufficiency (Sahoo et al. 2017), which requires correct diagnosis and localization of the incompetent perforator veins with imaging methods before surgery. The most commonly used imaging methods used for locating the veins include traditional color Doppler ultrasound (CDU) (Galeandro et al. 2012, 2014) and X-ray venography. Because X-ray venography uses radiation and is an invasive examination and because the contrast agent has renal toxicity, the overlap of vascular imaging may result in inaccurate positioning, and it is easy to miss a diagnosis. CDU was once the gold standard for diagnosing venous disease (Davies et al. 1991); however, the sensitivity of CDU is lower in diagnosing perforating veins (Pierik et al. 1997).

With the widespread use of SonoVue, a new-generation ultrasound contrast agent (Huang et al. 2018) with the advantages of tolerability and low anaphylaxis, contrast-enhanced ultrasound (CEUS) has become an effective way to diagnose arterial disease, but little research has been performed on its use in diagnosing perforator veins (Spiss et al. 2011). Our study investigated the sensitivity and specificity of CEUS in identifying competent and incompetent perforating veins by comparing them with the number of perforator veins observed by CDU and with operative findings in SEPS as the gold control standard.

METHODS

Study population

From July 2016 to July 2017, 50 patients (38 males and 12 females, mean age: 60.2 ± 9.6 y) from the Department of Vascular Surgery, Tianjin Medical University General Hospital, who were diagnosed with CVI on the basis of the Clinical/Etiology/Anatomy/Pathophysiology (CEAP) classification (Eklof et al. 2004), underwent pre-operative CEUS and CDU and accepted SEPS were enrolled in this study. The study excluded patients whose

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conditions were complicated by deep venous thrombosis, heart disease, vascular brain disease, peripheral obstructive artery disease, chronic liver disease, known kidney disease or any other chronic severe disease, pregnancy or severe obesity (body mass index ≥35 kg/m^2) (Galeandro et al. 2012). Before CEUS, patients were informed in detail about possible risks such as allergic reactions. This study was approved by the local ethics committee and institutional review board, with informed consent obtained from each patient before examination.

Diagnostic and classification criteria

All limbs were classified according to the CEAP classification, which was developed in 1994 by an international consensus conference (Eklof et al. 2004): class 0 = no visible or palpable signs of venous disease; class 1 = telangiectasis, reticular veins, malleolar flare; class 2 = varicose veins; class 3 = edema without skin changes; class 4 = skin changes ascribed to venous disease (*e.g.,* pigmentation, venous eczema, lipodermatosclerosis); class 5 = skin changes as defined above with healed ulceration; class 6 = skin changes as defined above with active ulceration.

Procedures

We studied perforator veins located in the middle and lower parts of the calf because of the location of the most important Cockett veins. All examinations were performed in a warm room (mean indoor temperature: 18 °C–22 °C) and were carried out by two investigators with experience in venous ultrasonography through blind operation. Disagreement between the two investigators was resolved by discussion or by the third investigator. All measurements were made using a l3- to 11-MHz linear-array transducer (Esaote, Genoa, Italy). CEUS was immediately followed by CDU.

The scanning method for CDU was described previously by Hanrahan et al. (1991) All patients underwent CDU first in an upright standing position. The evaluation for perforating veins began by tracking the posterior tibial veins and posterior arch vein and by picking up the perforating veins as they issued from these veins. The entire medial and posterior aspects must be evaluated. We detected whether there were dilated and tortuous perforator veins lying between deep and superficial veins from the distal end to the middle of the medial leg. After application of pressure to the distal end of the leg, if there was reverse blood flow in the perforator vein for which the regurgitation time was >0.35 s (Labropoulos et al. 2003; Phillips et al. 1995), we recorded the perforator vein as insufficient. We then recorded the total number of perforator veins.

All CEUS procedures were performed with the Esaote Mylab Class C ultrasound device (Esaote, Genova, Italy), equipped with a high-frequency linear array transducer (LA332, frequency: 3–11 MHz). We dissolved the ultrasound contrast agent SonoVue (Bracco, Milan, Italy) in 5 mL normal saline and fully shook it into microbubble suspension. We diluted 0.5 mL suspension with 10 mL normal saline and shook it appropriately (Huang et al. 2018). We placed a 24-gauge indwelling needle in the dorsalis pedis vein of the affected side and tightening the tourniquet around the ankle so that contrast agent flowed into the deep vein.

With the patient in the supine position and undergoing mild external rotation and abduction of the affected lower extremity, the contrast agent dilution was injected rapidly with an indwelling needle into the dorsalis pedis vein. A low mechanical index (MI: 0.01–0.04) was used for CEUS (Contrast Tuned Imaging, Esaote Biomedica). We timed and recorded the video and images as follows: popliteal vein, tibioperoneal trunk, great saphenous vein, small saphenous vein, Cockett perforating vein, anterior accessory saphenous vein of the calf, posterior accessory saphenous vein of the calf, Boyd perforating vein, anterior tibial veins and posterior tibial veins (Galeandro et al. 2012). We determined whether there was imaging of perforator veins along the deep vein that connected to deep vein and stretched obliquely. If the images were not clear enough to diagnose, we injected contrast agent dilution of the same concentration repeatedly after 5–10 min as long as all the contrast agent from the previous application had disappeared. If no perforator veins were detected while ligating the tourniquet around the ankle, we loosened the tourniquet and injected contrast agent dilution after a 5- to 10-min interval. The detected perforator vein lay between the deep and superficial veins obliquely from the beginning of the great saphenous vein in the medial side of the ankle to the middle of the leg along the great saphenous vein. Reverse flow on CEUS could indicate perforator vein insufficiency. We recorded the number of perforator veins and measured the inner diameter of each perforator vein. At the same time, incompetent perforator veins were marked on the body surface to guide SEPS.

All patients underwent SEPS after CDU and CEUS examinations. The number and location of insufficient perforator veins revealed by SEPS were recorded, and the distance to the sole of the foot was measured.

If the incompetent perforating vein was found to be within 1.5 cm at surgery, then it was judged to be correctly predicted by CDU and CEUS. The number and location of perforating veins detected with CDU and CEUS were evaluated for sensitivity and specificity.

Statistical analysis

SPSS Version 19.0 software (IBM Corp., Armonk, NY, USA) was used to perform statistical analyses. The two groups were compared with independent sample *t*-