► **Original Article** ◀

Quantification of Superficial Venous Reflux by Duplex Ultrasound—Role of Reflux Velocity in the Assessment the Clinical Stage of Chronic Venous Insufficiency

Hisato Konoeda, MD, Takashi Yamaki, MD, Atsumori Hamahata, MD, Masakazu Ochi, MD, and Hiroyuki Sakurai, MD

Objectives: This study we compare the duplex-derived parameters of reflux in patients with early and advanced superficial venous insufficiency (SVI) to identify parameters reflecting this.

Methods: Two thousand and one hundred sixty limbs with primary reflux, categorized according to the CEAP (clinical, etiologic, anatomic and pathophysiologic) classification, and the patients were divided into two groups (group I [C_{1-3} , E_p , A_s , P_r]; group II [C_{4-6} , E_p , A_s , P_r]) were studied. The vein diameter, reflux duration(s), mean reflux velocity (MRV; cm/s), peak reflux velocity (PRV; cm/s), and total reflux volume (TRV; ml/s) were determined at the sapheno-femoral junction (SFJ), great saphenous vein (GSV) and sapheno-popliteal junction (SPJ).

Results: Age and the proportion of males were greater in group II. MRV, PRV and TRV were greater in group II at the SFJ, SPJ and in GSV ($p < 0.01$ for all), although the duration of SPJ reflux was non-discriminatory ($p = 0.78$). From receiver operating characteristic (ROC) curve, optimal cut-off points of 27.8, 47.8, and 36.2 cm/s for the PRV at the SFJ ($p < 0.01$), GSV ($p < 0.01$), and SPJ ($p < 0.01$) discriminated between the two groups.

Conclusion: PRV and MRV improved discrimination between early and advanced SVI compared to reflux duration.

Keywords: varicose vein, duplex scan, superficial venous insufficiency

Introduction

Technical improvements in duplex ultrasound over the last two decades have made it a useful tool for identifying both venous obstruction and reflux. Ultrasound-derived reflux time (RT) >0.5 s for the superficial venous system and RT >1.0 s for the deep venous system, including the common femoral and popliteal veins, have been widely used to indicate the presence of significant reflux.¹⁻³ However, previous studies have shown that RT does not correlate with the magnitude

of reflux, and therefore may not be a useful variable.⁴⁻⁶ The role of superficial venous insufficiency in the production of venous ulceration has been widely described by many authors. Superficial venous insufficiency contributes to the severity of chronic venous insufficiency (CVI). At our institute, we have conducted duplex scan in more than 2000 limbs with superficial venous insufficiency (SVI). Here we have compared the duplex-derived parameters between patients with early and advanced superficial venous insufficiency and determine the parameters that indicate the progression of superficial venous insufficiency.

Patients and Methods

Patients

Between January 1998 and July 2010, 3172 limbs in 2634 patients were evaluated using duplex scans in our department. After excluding patients with perforator reflux and deep venous insufficiency (either alone

Department of Plastic and Reconstructive Surgery, Tokyo Women's Medical University, Tokyo, Japan

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Corresponding author: Hisato Konoeda, MD. Department of Plastic and Reconstructive Surgery, Tokyo Women's Medical University, 8-1 Kawada-cho, Shinjuku-ku, Tokyo 162-8666, Japan
Tel: +81-3-3353-8111, Fax: +81-3-3225-0940
E-mail: konoeda@prs.twmu.ac.jp

or in combination with superficial reflux or with each other) 2160 limbs in 1823 patients with isolated superficial venous insufficiency formed the basis for the current study. One thousand seven hundred and thirteen limbs had great saphenous vein (GSV) venous insufficiency. Two hundred and seventy-one limbs had small saphenous vein (SSV) venous insufficiency. And 88 limbs had both GSV and SSV venous insufficiency. Subjects consisted of 512 men and 1311 women aged 27–88 years (mean, 69 years).

Clinical assessment

Clinical manifestations of these patients were categorized according to the CEAP (clinical, etiologic, anatomic and pathophysiologic) classification of reporting standards in venous disease supported by the North American Chapter of the Society for Vascular Surgery and the International Society for Vascular surgery. All patients lesions were classified on the basis of the following: telangiectasies or reticular veins (C_1), varicose veins that were distinguished from reticular veins with a diameter of 3 mm or more (C_2), edema (C_3), pigmentation or eczema (C_{4a}), lipodermatosclerosis or atrophie blanche (C_{4b}), healed venous ulcer (C_5), or active venous ulcer (C_6). Etiologic classification included only primary venous dysfunction (E_p). Anatomic sites of the venous reflux included only superficial veins (A_s). Clinical signs of the symptoms may result from reflux (P_r) alone.

Pretreatment ultrasonographic evaluation

Pretreatment examination was performed between 1998 and 2006 using a color duplex scanner (LOGIC 500MD; GE Medical Systems, Milwaukee, Wisconsin, USA) with a 5–10-MHz linear array transducer. In 2007, the other duplex scanner (LOGIQ 7 PRO; GE Yokogawa Medical Systems, Tokyo, Japan) with a 5–10-MHz transducer was installed. After 2007, the former one was also used to detect venous reflux at the SFJ, SPJ and in the GSV. Venous reflux was assessed while the patients were standing. For evaluating the SFJ, a pneumatic thigh cuff (Hokanson, Bellevue, Washington, USA) was attached to the thigh, inflated to 80 mmHg, and then rapidly deflated. For evaluating the GSV and SPJ, a cuff was applied to the calf, inflated to 100 mmHg, and then rapidly deflated.¹⁾ We conducted Duplex scanning in GSV at 10 cm above the knee. The diameter (cm) was measured using a cross-sectional view while the patients were standing.

Venous reflux was considered to be present if the RT exceeded 0.5 s. We also assessed additional ultrasound-derived parameters: peak reflux velocity (PRV; cm/s), mean reflux velocity (MRV; cm/s), and total reflux volume (TRV; mL) calculated using the equation $TRV (mL) = MRV \times area (r^2) \times RT$. The vessel cross-sectional area was estimated from the diameter, assuming a circular vessel shape.

Statistical analysis

All data were analyzed using the SPSS software package (Version 20.0; SPSS Inc., Chicago, Illinois, USA). Comparisons of numerical data between groups of patients were made using Student's *t*-test. χ^2 contingency table analysis was used to evaluate differences between proportions. Continuous data were expressed as mean $\pm$ standard deviation (SD). A *p* value of <0.05 was considered to indicate to be statistically significance.

Results

Patient characteristics

Patients were divided into two groups according to the previous literature⁵⁾ as follows: group I (CEAP C_1 to C_3) for patients with relatively early stage SVI and group II (CEAP C_4 to C_6) for patients with advanced SVI.

The baseline characteristics of the two study groups are shown in **Table 1**. There were 1757 limbs in group I (C_{1-3} , E_p , A_s , P_r) and 403 limbs in group II (C_{4-6} , E_p , A_s , P_r). The mean age was significantly higher in group II ($p < 0.001$), whereas the proportion of female patients was significantly lower in group I ($p < 0.001$).

Table 2 shows the duplex-derived parameters at the SFJ. At the SFJ, the duplex-derived PRV, MRV, and TRV were significantly higher in group II ($p < 0.001$, < 0.001 , < 0.001 , respectively). RT, however, was significantly shorter in group II ($p = 0.003$). **Table 3** shows the duplex-derived parameters in the GSV. Similarly, in the GSV, limbs in group II had significantly higher values for vein diameter, PRV, MRV, and TRV ($p < 0.001$, < 0.001 , < 0.001 , and < 0.001 , respectively). In contrast, RT was significantly shorter in group II also ($p < 0.001$). **Table 4** shows the duplex-derived parameters at the SPJ. At the SPJ, there were significantly higher values for vein diameter, PRV, and MRV in group II ($p = 0.02$, 0.005 , and < 0.001 , respectively) than group I. However, no significant differences were observed for RT ($p = 0.78$) or TRV ($p = 0.25$) between

Table 1 Baseline characteristics of study patients

	Group I (C ₁₋₃ , E _p , A _s , P _r) n = 1757 limbs	Group II (C ₄₋₆ , E _p , A _s , P _r) n = 403 limbs	p-value
Age (y)	59.1 ± 12.9	62.7 ± 11.3	<0.0001
Female gender, no (%)	1322 (74.6)	231 (57.3)	<0.0001

*CEAP Clinical classification: C₁: telangiectasies or reticular veins; C₂: varicose veins; C₃: edema without skin changes; C_{4a}: pigmentation or eczema; C_{4b}: lipodermatosclerosis or atrophie blanche; C₅: healed venous ulcer; C₆: active venous ulcer

Table 2 Duplex-derived parameter at the saphenofemoral junction

Parameters	Group I (C ₁₋₃ , E _p , A _s , P _r) n = 1322 limbs	Group II (C ₄₋₆ , E _p , A _s , P _r) n = 231 limbs	p-value
Diameter (cm)	0.70 ± 0.28	0.84 ± 0.27	0.02
Reflux time (s)	4.65 ± 2.67	4.29 ± 2.06	0.003
Peak reflux velocity (cm/s)	26.2 ± 15.8	42.1 ± 24.3	<0.001
Mean reflux velocity (cm/s)	11.2 ± 5.93	16.0 ± 8.41	<0.001
Total reflux volume (ml)	28.3 ± 33.3	39.2 ± 38.3	<0.001

Table 3 Duplex-derived parameter at the great saphenous vein

Parameters	Group I (C ₁₋₃ , E _p , A _s , P _r) n = 1215 limbs	Group II (C ₄₋₆ , E _p , A _s , P _r) n = 204 limbs	p-value
Diameter (cm)	0.56 ± 0.15	0.67 ± 0.17	<0.001
Reflux time (s)	6.63 ± 3.78	5.57 ± 3.00	<0.001
Peak reflux velocity (cm/s)	43.8 ± 22.2	62.9 ± 24.1	<0.001
Mean reflux velocity (cm/s)	11.2 ± 5.93	16.0 ± 8.41	<0.001
Total reflux volume (ml)	47.3 ± 47.4	71.1 ± 58.5	<0.001

*; $p < 0.01$

Table 4 Duplex-derived parameter at the sapheno-popliteal junction

Parameters	Group I (C ₁₋₃ , E _p , A _s , P _r) n = 313 limbs	Group II (C ₄₋₆ , E _p , A _s , P _r) n = 46 limbs	p-value
Diameter (cm)	0.56 ± 0.18	0.64 ± 0.19	0.02
Reflux time (s)	7.01 ± 4.32	6.08 ± 3.66	0.78
Peak reflux velocity (cm/s)	32.2 ± 20.0	42.0 ± 20.5	0.005
Mean reflux velocity (cm/s)	12.1 ± 7.79	16.2 ± 7.76	<0.001
Total reflux volume (ml)	39.5 ± 44.4	39.2 ± 38.3	0.25

*; $p < 0.01$

the two groups. We generated receiver operating characteristic (ROC) curves to determine the discriminating power of the PRV and RT cut-off points. From the ROC curves, several conclusions were immediately apparent (Fig. 1A–1C). We used the Youden index to obtain optimal cut-off points, which is the maximum vertical distance or the difference between the ROC curve and the diagonal or chance line. An optimal cut-off point of 27.8, 47.8, or 36.2 cm/s for PRV at the SFJ, in the GSV, and at the SPJ,

respectively, had the power to discriminate early from advanced SVI. An optimal cut-off point of 5.45 s for RTs in the GSV had the power to discriminate early from advanced SVI. RT at the SFJ and SPJ did not have any power to discriminate early from advanced SVI. The proportion of female patients was significantly lower than in group I, therefore we analyzed a relationship between gender and vein diameters each of segments. In group I, mean vein diameters of male patients were 0.70 ± 0.22 , $0.57 \pm$

Fig. 1 Ability of the peak reflux velocity. **(A)** An optimal cut-off point of 27.8 cm/s for the peak reflux velocity at sapheno-femoral junction (SFJ) had a discriminatory power between early and advanced chronic venous insufficiency (CVI) with a sensitivity of 74% and a specificity of 63% (area under the receiver operating characteristic (ROC) curve 0.74, 95% confidence interval (CI) 0.71 to 0.77, $p < 0.001$); **(B)** An optimal cut-off point of 47.8 cm/s for the peak reflux velocity in the great saphenous vein (GSV) had a discriminatory power between early and advanced CVI with a sensitivity of 78% and a specificity of 58% (area under the ROC curve 0.73, 95% CI 0.70 to 0.76, $p < 0.001$); **(C)** An optimal cut-off point of 36.2 cm/s for the peak reflux velocity at sapheno-popliteal junction (SPJ) had a discriminatory power between early and advanced CVI with a sensitivity of 65% and a specificity of 64% (area under the ROC curve 0.68, 95% CI 0.60 to 0.74, $p < 0.001$).

0.14, and 0.58 ± 0.17 at the SFJ, in the GSV, and at the SPJ respectively. Besides, mean vein diameters of female patients were 0.70 ± 0.34 , 0.56 ± 0.15 , and 0.56 ± 0.18 at the SFJ, in the GSV, and at the SPJ respectively. There was no significant difference between gender and vein diameters at the SFJ, in the GSV, and at the SPJ ($p = 0.76$, 0.79 , 0.55 respectively). Similarly, in group II, mean vein diameters of

male patients were 0.86 ± 0.24 , 0.69 ± 0.15 , and 0.61 ± 0.16 at the SFJ, in the GSV, and at the SPJ respectively. Moreover, mean vein diameters of male patients were 0.83 ± 0.28 , 0.66 ± 0.18 , and 0.65 ± 0.20 at the SFJ, in the GSV, and at the SPJ respectively. There was no significant difference between gender and vein diameters at the SFJ, in the GSV, and at the SPJ ($p = 0.33$, 0.10 , 0.32 respectively).

Discussion

In this study, we sought to determine whether the peak reflux velocity and the mean reflux velocity improve the power to discriminate between the early and advanced stages of superficial venous insufficiency.

The role of superficial incompetence in the development of venous ulceration has been described by many authors.⁷⁻¹¹⁾ Shami, et al. described the importance of superficial venous incompetence in advanced CVI. They investigated 59 consecutive patients with venous ulcers using duplex ultrasonography and found that 53% of patients had superficial venous incompetence alone.⁷⁻¹¹⁾ Labropoulos, et al. found that 84% of patients with leg ulceration had general superficial venous incompetence and stated that venous ulceration is highly associated with reflux along the entire length of the GSV or with extensive reflux in both the GSV and small saphenous vein.⁷⁻¹¹⁾ Mugnusson, et al. investigated primary venous insufficiency and found that 49% of the limbs studied had isolated superficial venous reflux. Furthermore, Yamaki, et al. found no major differences in the frequency of isolated deep and perforating vein incompetence between CVI classes. The frequency of reflux increased only if superficial venous insufficiency also occurred.⁷⁻¹¹⁾

In the 1990s, several authors attempted to quantify venous reflux and associate clinical presentation with the duration of reflux. Weingarten, et al. found that the reflux times were longer in advanced CVI, but did not demonstrate a significant difference.¹²⁾ In our study, the RT of group I was longer than that of group II and the RT had no discrimination power at SPJ. Several investigators have attempted to quantify the degree of reflux with clinical manifestations in patients with isolated superficial venous insufficiency and found that the peak reflux velocity was markedly higher in limbs with clinically advanced disease in the superficial venous system. Here we found that the diameter, PRV and MRV improved the power to discriminate between early and advanced superficial venous disease at all points. However, the RT and reflux volume did not improve the power to discriminate between the early and advanced stages of superficial venous insufficiency. Our subjects included a total of 2160 limbs, which is a larger group than that included in previous studies. Our previous study showed that a burst of reflux, with a superficial venous reflux peak velocity greater than 30 cm/s combined with an

RT <3 s, was highly associated with advanced SVI.¹³⁾ Here we found that the mean PRV in group I was greater than 30 cm/s in the GSV and at the SPJ. However, the individual mean RT in group II exceeded 3 s at the SFJ, in the GSV, and at the SPJ. Moreover, we generated ROC curves. The sensitivity of PRVs had relatively good discriminatory powers at the SFJ, in the GSV, and at the SPJ. However, specificities in these veins were not significant (Fig. 1). Furthermore, according to the ROC curves RTs did not have any discriminatory power at the SFJ or SPJ. As a result, RT may represent a meaningless parameter for assessing clinical severity and mean of reflux. Furthermore, RTs were significantly longer in group I than in group II, while RTs >0.5 s have been used as a cut-off value for superficial venous incompetence.¹⁴⁾ Because of this discrepancy, RT may not be an appropriate parameter for clinical characterization of disease progression. There appears to be different outcomes for the GSV and SSV. Labropoulos, et al. showed that patients with venous disease at SPJ present most frequently with CVI classes 2 to 4, whereas classes 5 and 6 are uncommon.¹⁵⁾ Lin, et al. described that prolonged reflux time of the SSV is associated with deep venous reflux, especially in the popliteal segment, and increasingly severe clinical manifestations of chronic venous disease.¹⁶⁾ We considered that it is easy to affect SSV incompetence to the deep vein system rather than GSV due to lack of reservoir system. Our study population included only superficial venous insufficiency. Classes 5 and 6 suffered from SPJ involved deep venous insufficiency were excluded from our study. It may have affected different outcomes for the GSV and SSV.

To assess quantification by duplex scan, accuracy and repeatability is important. In this study, we used a pneumatic pump to evaluate each parameter. Several authors have attempted to compare a manual compression release with a pneumatic cuff maneuver. The pneumatic cuff maneuver seems to yield more reliable results; however, previous studies have often failed to detect any difference especially concerning RT.¹⁷⁻²⁰⁾ Notably, Yamaki, et al. found that PRV produced by manual compression release was significantly higher at the SFJ and in the GSV.¹⁸⁾ Regarding reproducibility, reflux assessed by cuff compression was more reproducible than that assessed by manual compression.¹⁹⁾ To acquire

accuracy and reproducibility, we recommend that clinicians use a cuff inflator.

Some authors have found that the diameter of the GSV was significantly correlated with the clinical severity.²¹⁻²³ The diameter is an important parameter that influences other parameters produced by duplex scan. The larger the diameter, MRV and PRV in patients with early SVI the more severe the clinical symptoms may become in future. However, PRV had more significant discrimination rather than diameter and MRV. According to the cut-off point obtained from the ROC curves, patients with CEAP C₂ and C₃ with high PRV may be indicated for surgical intervention.

Our study has some potential limitations. Each parameter produced by duplex scanning might not be represented in all patients with SVI and anatomical patterns of reflux that have not been investigated in this study and each parameter produced by duplex scanning are at least as useful as single-segment parameters. Furthermore, the positive values produced by the ROC curves were 65% to 78%. This suggests that there are overlapping values of single segment parameters between early and advanced SVI, and it is unknown whether some cases of early disease may develop advanced pathology in the future. For this reason, we will continue regular follow-up of patients with CEAP C₂ and C₃ for a long period of time to determine predictive values of these measurements in the progression SVI.

The proportion of male patients was significantly higher in severe group than in moderate group. Although we expected that diameters of male patients were larger than them of female patients, in this study, there was no relationship between saphenous vein diameters and genders. Therefore, gender was not affected diameters and TRV.

In conclusion, the PRV and MRV improved our ability to discriminate between early and advanced stages of SVI. GSV diameter also appeared to have some value as a discriminatory measure and correlate with RT, PRV, and MRV at the SFJ and in the GSV. The RT did not have any power to discriminate between the early and advanced stages of superficial venous insufficiency. Further studies will be needed to determine the predictive values of these parameters in the progression of SVI.

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Disclosure Statement

None.

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