VENOUS HEMODYNAMICS ORIGINAL ARTICLE

Experimental validation of the Paraná manoeuvre compared to the squeezing test

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Abstract

Background and aim

The squeezing test (ST) is widely practiced, owing to its simple execution. In 1997, the Paraná (P) manoeuvre was proposed. This manoeuvre consists in a gently pushing-from-the-rear or pulling-from-the-front. Our aim was to compare the hemodynamic effects of ST and P during the muscle systole and diastole.

Method

57 patients underwent a diagnostic Duplex examination. 57 legs were examined, one leg for each patient, exploring just one venous segment for each leg. 37 patients were affected by incompetence of the terminal valve of the saphenous-femoral junction. 20 patients presented just telangiectasiae (C1) and were used to compare the manoeuvres in competent popliteal veins. Measurements were taken on 57 venous segments (20 competent popliteal veins, 13 incompetent saphenous-femoral junctions, 13 incompetent trunks of great saphenous vein and 11 re-entry perforating veins). Comparisons were worked out using a two-tailed paired t-test.

Results

Compared to ST, P moves 68% more blood volume in systole in the competent popliteal vein ($p=0.00014^{***}$), while the diastolic phase of P is 2.52 times longer in incompetent SFJ ($p=0.00003^{***}$), 1.83 times longer in the incompetent GSV trunk ($p=0.0015^{**}$) and 3.27 times longer in the re-entry perforating veins (p=0.07 n.s.). However, this last result, near to significance, needs further investigations. In addition, our data about the systolic acceleration did not show any meaningful result.

Conclusion

P is a better test than ST in the evaluation and quantification of reflux and could be of paramount clinical importance in improving diagnostics in venous diseases, being actually practised since 20 y in many vascular labs. P does not rely on the size of the operator's hand or the size of the patient's calf and investigates a condition which is almost near to the physiological posture balance.

Keywords Paraná, squeezing test, venous hemodynamics, dynamic manoeuvres.

Background and aim

The ultrasound assessment of the venous reflux has an important role in the examination of the venous function of the lower limbs. The conventional calf compression and release manoeuvre or squeezing test (ST) is generally practiced in many vascular labs and is performed by a sequence of compression and release of the calf, with several variants constituted for instance by the manual compression or instead the standardized pneumatic compression by means of a cuff[1-4]. Its execution is generally simple, one of the limitation being given by a big calf circumference, which cannot be easily compressed by a small hand. However, ST does not correspond to any daily activity and its results cannot be interpreted as an answer to any physiological solicitation.

In 1997, the Paraná (P) manoeuvre[5,6] (Figure 1 A & B) was proposed, which is constituted by a gentle push-or-pull manoeuvre, taking its name from the city of Paraná (Argentina), where it was conceived. Gently pushing-from-the-rear (Figure 1A) or pulling-from-the-front (Figure 1B) at the patient#s waist, the manoeuvre elicits a proprioceptive reflex in order to maintain the balance. An almost isometric contraction (systole), mainly of the calf but also of the thigh, pelvis and lumbar spine, is then followed by a relaxation (diastole). The contraction is not purely isometric, because consequently a re-equilibrating movement is generated. In systole a centripetal flow in the venous system occurs, followed by a zero flow or a reflux when valves are respectively competent or incompetent.

The aim of this paper is to compare the hemodynamic effects on flow of ST and P during systole and diastole in the examined venous segments[7].

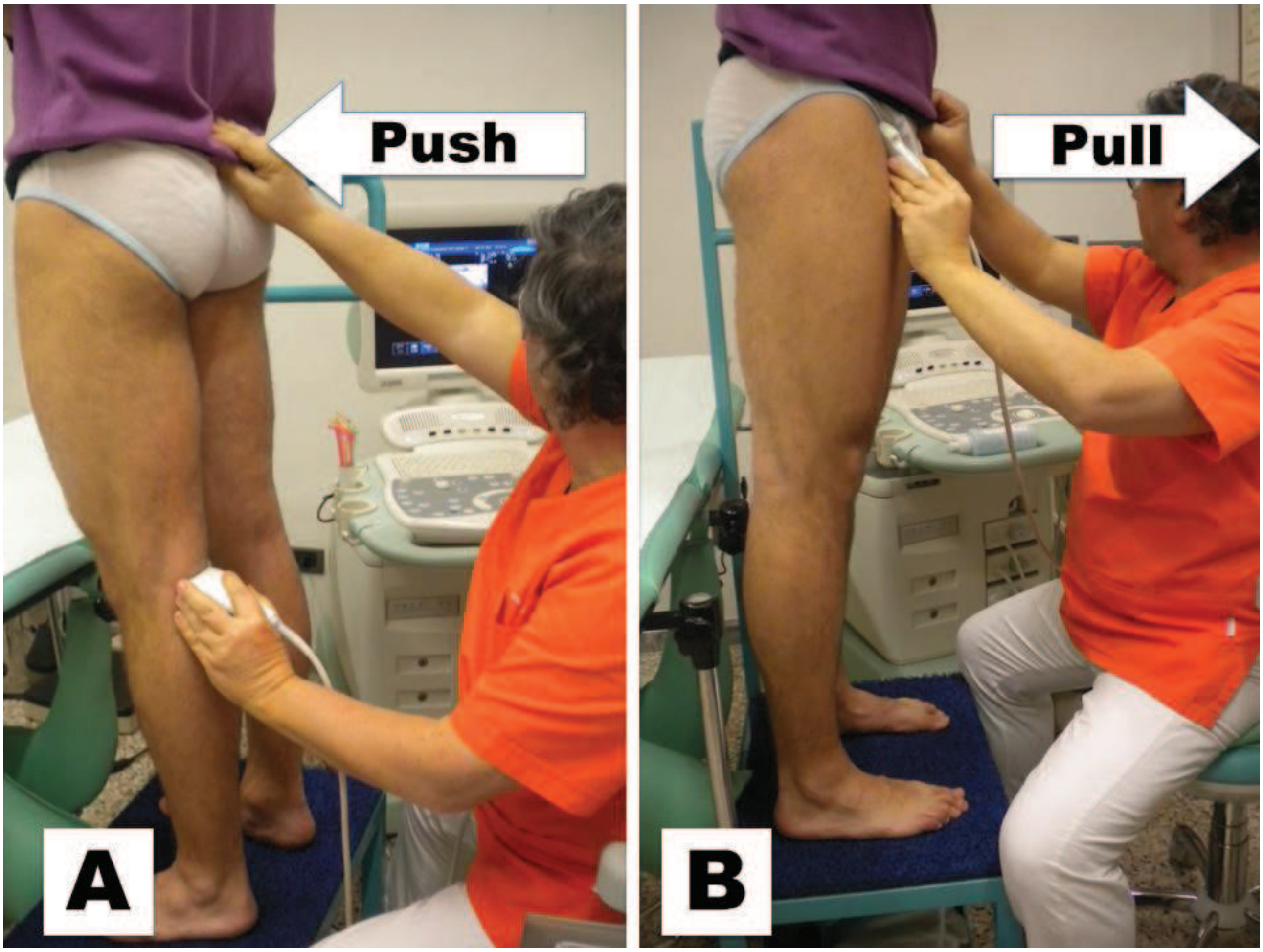

Figure 1 - The patient and the operator's positions for the 'push-pull' during the Paraná manoeuvre: push from rear at the popliteal level (A) and pull from front at the GSV trunk and perforating veins level (B).

Patients and methods

Device and settings

An Esaote Mylab 50 ultrasound device equipped with a 12 Mhz linear probe was adopted. The probe was positioned longitudinally and the best image was captured. The steering angle was then adjusted in the range 30°-45° and the sample volume width and the Doppler angle were adapted to the scanned vein.

Measurements			
	# cases (1 leg / patient)	# measurements/leg	# measurements
Competent popliteal veins	20	6 (vmaxS, T_{S1}, T_{S2} for each manoeuvre)	120
Incompetent SFJ	13		104
Incompetent GSV trunks	13	8 (vmaxS, TS, vmaxD, TD for each manoeuvre)	104
Re-entry perforating veins	11		88
Total	57		416

Table I - Legs / venous examined segments and performed measurements.
SFJ saphenous femoral junction, GSV greater saphenous vein, $vmax_S$ max systolic velocity, T_S systolic ejection time, T_{S1} systolic acceleration time, T_{S2} systolic deceleration time, $vmax_D$ max diastolic velocity, T_D diastolic refluxing time.

Patients

A consecutive sequence of 57 patients underwent a diagnostic Duplex (DUS) examination. All patients signed a written consent to allow non-invasive ultrasound measurements. 57 legs were examined, one leg for each patient, exploring just one venous segment for each leg. 37 patients were affected by incompetence of the great saphenous vein (GSV) with insufficiency of the terminal valve of the saphenous-femoral junction (SFJ). There were no healthy volunteers in this study, but 20 patients presented just telangiectasia (C1) with deep and superficial veins competence and were used to compare the ST and P manoeuvres in competent popliteal veins.

Manoeuvres

The ST manoeuvre was performed manually, according to the modality generally practiced in almost all vascular labs.

The P manoeuvre was effected from rear when measuring on PV, from front when on SFJ or GSV and in a variable way when on a re-entry perforating vein, according to its anatomical site. For instance, from rear when measuring on a perforating vein of the calf, from front when measuring on a medial perforating vein along the saphenous channel.

Each manoeuvre was divided into phases: the evocation phase or systole, the rest phase or diastole:

- ST: compression was the systole, relaxation the diastole.
- P: push/pull was the systole, the spontaneous postural adjustment the diastole;

Measurements and computations

Measurements were taken on 20 competent popliteal veins (PV), 13 incompetent SFJs, 13 incompetent GSV trunks and 11 re-entry perforating veins. All observations were performed by the same operator, thus this study was designed in a simplified form, not gathering at all intra-observer differences.

In order to avoid mutual influences among data in the same patient, measurements were taken in standing position just on one lower limb and just on one venous segment per patient, with a total of 57 segments: PV measurements in the clinical classes C0-C1, non-PV measurements in the clinical classes C2,C3,C4, i.e. no trophic lesions, neither open nor closed, in the observed sequence.

On the total of 114 segment records (57 × 2, i.e. for both P and ST) 416 measurements were performed (Table I).

In all the examined veins, the requirement for the valve incompetence was a time length greater than the threshold value of 0.5s

In the SFJ the valve incompetence was assessed adjusting the Doppler direction perpendicular to the terminal valve plane, (Figure 2) whilst for the GSV trunk the sample volume was set 15 cm below the groin and the Doppler direction adjusted along the saphenous axis. All measurements were performed adopting a longitudinal section of the investigated venous segment.

A re-entry perforating vein was defined as a connection between the superficial and the deep system, fed by the GSV reflux and entering into the deep veins of the leg, having an anterograde superficial-to-deep (-) diastolic velocity, while the systolic velocity could be anterograde i.e. re-entering (-), null (0) or refluxing (+).

In a re-entry perforating vein, the blood re-entering in diastole is generally much more of the blood eventually directed outward in systole. Measurements were taken at the most linear part of the perforating vein.

The time length (s) of the velocity curve in systole (TS) and diastole (TD) was measured. In addition, TS was subdivided into TS1, the acceleration time, and TS2, the deceleration time (Figure 3).

The systolic acceleration (a_S) ($cm{\cdot}s^{-2}$) was computed dividing the max systolic velocity Vmax by T_{S1}

$$\mathbf{a_S = Vmax/T_{S1}}$$

The area under the velocity curve (AUC) (cm) was computed according to the formula:

$$\mathbf{AUC_S = T_S \cdot Vmax_S /2}$$

$$\mathbf{AUC_D = T_D \cdot Vmax_D /2}$$

$$\mathbf{AUC_{S+D} = AUC_S + AUC_D}$$

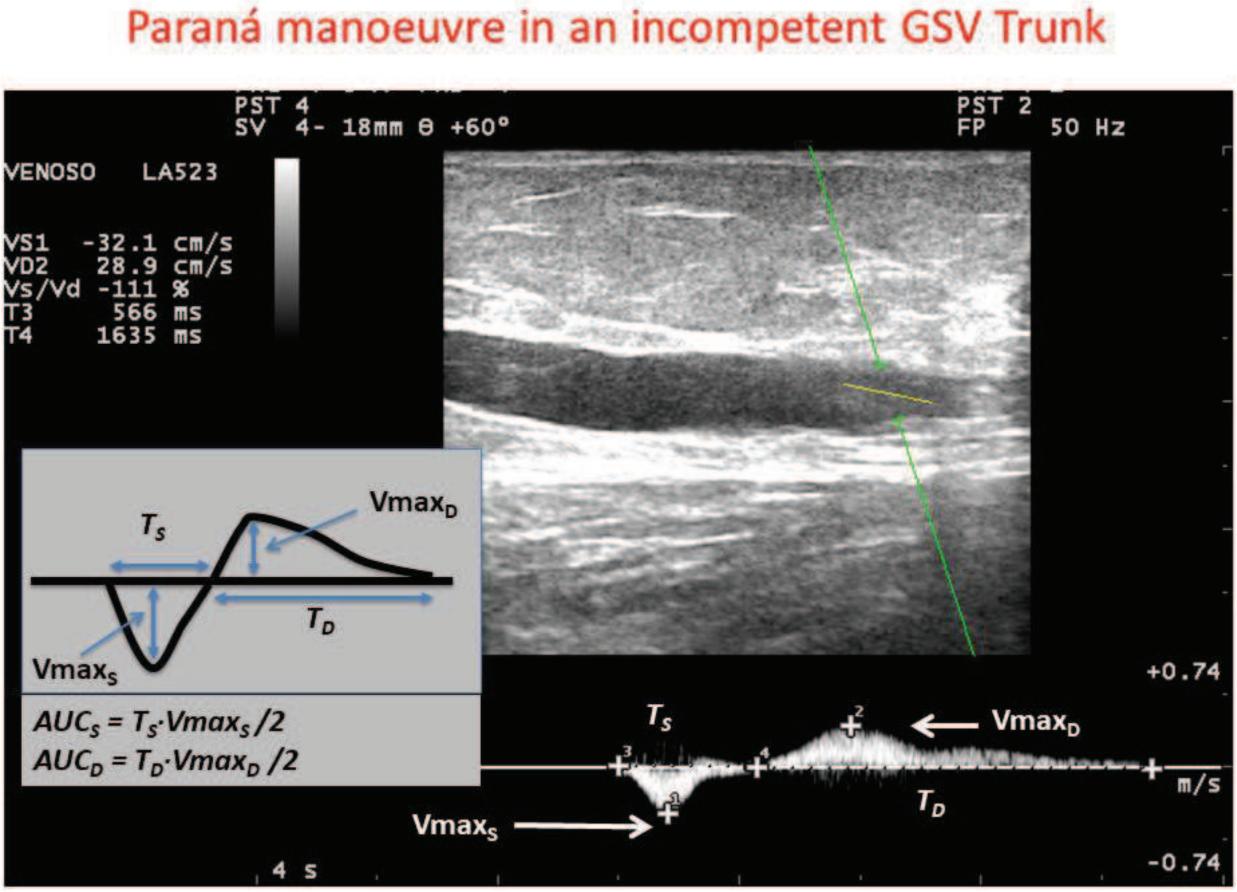

Figure 2 - The Paraná manoeuvre in an incompetent GSV trunk. The measurements were taken 15 cm below the groin. GSV greater saphenous vein, T_S systolic ejection time, T_D diastolic refluxing time, Vmax max systolic velocity, AUC area under the curve.

The above formulas could be theoretically justified using two equivalent methods: estimating the mean velocity Vmean = Vmax /2 (cm·s-1) or, in an equivalent way, computing the area of the triangle with base=time and height=Vmax.

Although the AUC is graphically an area, it assumes a special meaning instead, according to the adopted graphical representation. Taking into account the dimensions of the variables which are reported in the current graph, the AUC has the dimension of a length (cm). Assuming a constant venous calibre in the same subject and in the same position, the non-dimensional AUC ratio was considered numerically equivalent to the non-dimensional volume ratio, the calibre being cancelled in the math operations.

Indeed, the AUC (cm) was considered dependent in a linear way and through the (assumed constant) area section on the mobilized blood volume (cm^3). Thus, in the comparisons ST *vs.* P, the AUC values could be interpreted as blood volume values, ejected in systole or refluxing in diastole, i.e. making it possible to compare the efficacy of the two dynamic manoeuvres. The essential point is that the measurement of the cross sectional area is not needed for the comparison, as the assumed constant area is cancelled in the ratio computation.

Statistics

Each measurement was expressed as a value ± sigma (the standard deviation). Each mean was expressed instead as a value mean ± se (the standard error of the mean). The coefficient of variation cv was given by the ratio cv sigma/mean. These notation choices did not influence at all the statistical computations, which were applied using the required computations and all the available data.

The notations $p<0.05$(*), $p<0.01$(**), $p<0.001$(***) and n.s.(not significant) were adopted, though only the first threshold was used for statistical significance.

The ST and P manoeuvres were performed in sequence and the order of application was chosen randomly, with an adequate resting period, approximately worth twice the diastolic refluxing time. Data from ST and P were compared in order to underline any difference in the hemodynamic effect of each manoeuvre.

The comparison between ST and P results was effected by a two-tailed paired t-test, while a two-tailed F-test caught the inequality of variances in the two groups. NB! the F test has an asymmetrical distribution, thus F tests are generally one-tailed, dealing with the variance ratio of ordered groups of data. A two-tailed F test is a one-tailed F test, performed when no hypothesis is formulated in advance about which of the two groups has the greater variance, i.e. the greater variance is always divided by the smaller one or more simply groups of data are non-ordered.

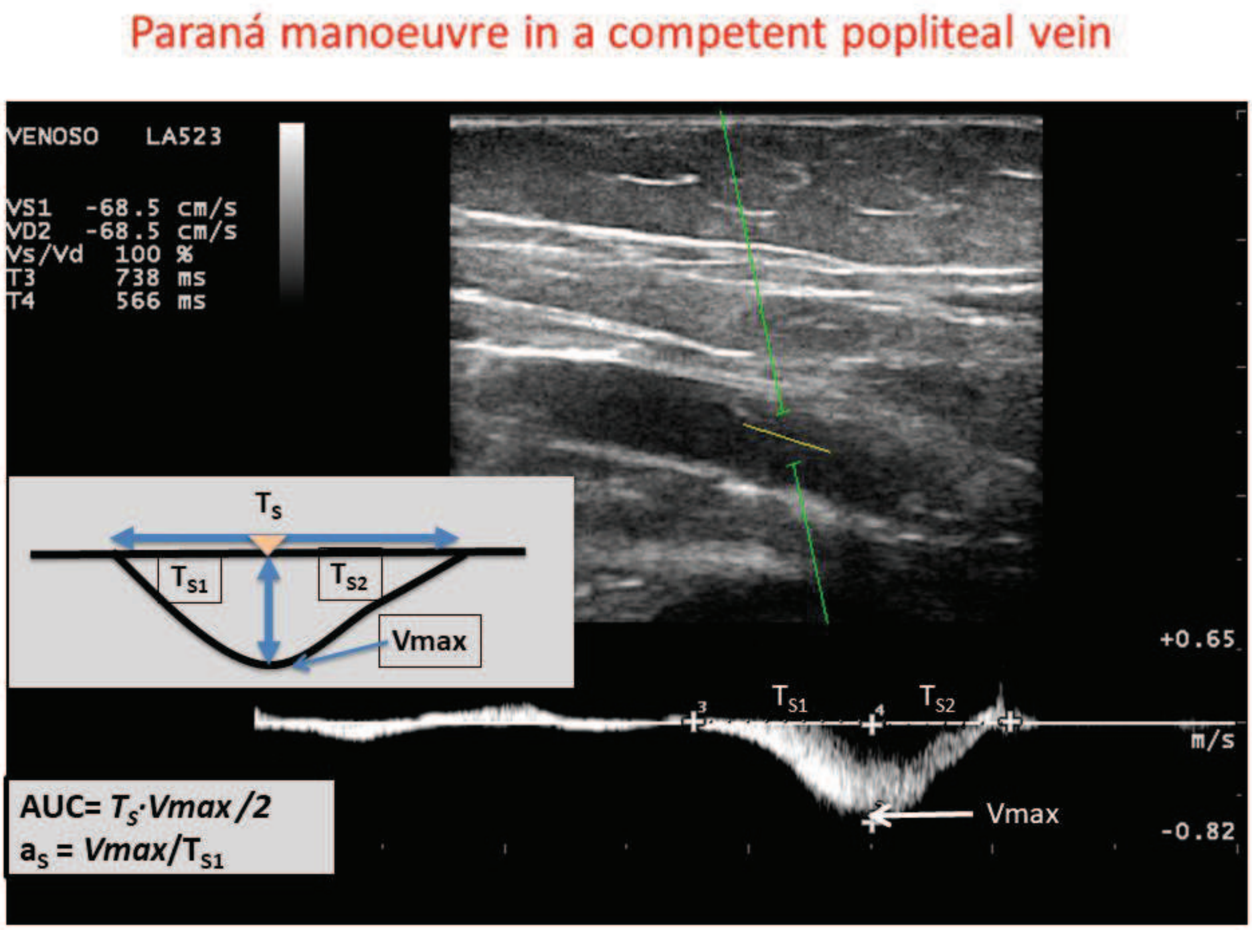

Figure 3 - The Paraná manoeuvre in a competent popliteal vein. The sample volume is adapted to the venous size and the steering line set in the range 30° - 45°. The Doppler angle is adapted according to the vessel direction. T_S systolic ejection time, T_{S1} acceleration time, T_{S2} deceleration time, Vmax max systolic velocity, AUC area under the curve, a_S systolic acceleration.

Competent popliteal veins

	ST	P
Systolic T_{S1} (ms)	380±20	590±40
Systolic T_{S2} (ms)	350±14	550±30
Max Systolic Speed ($cm \cdot s^{-1}$)	68±5	72±7
Systolic AUC (cm)	25±2	42±4

AUC = (T_{S1} + T_{S2})·Max Systolic Speed/2000 - Systolic AUC P/ST = 1.68, p=0.00014**

Table II - Systolic blood volume ejected in 20 competent popliteal veins.
T_{S1} systolic acceleration time, T_{S2} systolic deceleration time, AUC area under the curve, P Paraná, ST Squeezing Test. Mean ± standard error of the mean.

Results

Systolic Popliteal flow

The systolic acceleration measured in the competent popliteal veins (Figure 3) showed a smaller average value of 0.13 $cm{\cdot}s^{-2}$ for P and 0.19 $cm{\cdot}s^{-2}$ for ST ($p=0.014^{**}$) but P moved 68% more blood volume ($p=0.00014^{***}$) (Table II). In addition, the popliteal AUC in systole was systematically greater than the AUC in any other superficial vein. The comparison was possible only in systole and not in diastole, as all investigated popliteal veins were competent.

Time length of the diastolic phase

In incompetent superficial veins, the diastolic phase of P, compared to ST, was 2.52 times longer in the incompetent SFJ ($p=0.00003^{***}$) (Table III), 1.83 times longer in the incompetent GSV trunk ($p=0.0015^{**}$) (Table IV) and 3.27 times longer in the re-entry perforating veins (p=0.07 n.s.) (Table V), though this ratio was not enough to reach the significance.

Incompetent SFJ - systolic and diastolic flows

Terminal valves were incompetent in all examined SFJ. P produced a slightly greater systolic ejection volume 1.21 times than ST (p=0.19 n.s.). In addition, P gave a consecutive diastolic reflux volume 3.77 times greater ($p=0.009^{**}$) (Table III).

Incompetent GSV- systolic and diastolic flows

In the incompetent GSV trunk (Figure 3), P produced a slightly greater systolic ejection volume 1.42 times than ST (p=0.59 n.s.). In addition, P gave a consecutive diastolic reflux volume 2,0 times greater ($p=0.02^{*}$). (Table IV).

Re-entry perforator - systolic and diastolic flows

In the re-entry perforating veins, P produced a slightly greater systolic outward reflux volume 1.62 times than ST (p=0.08 n.s.), in addition providing a diastolic inward volume 4.84 times greater ($p=0.009^{**}$) (Table V).

Systolic acceleration

The systolic acceleration was slightly smaller for P vs. ST in the competent popliteal vein ($p=0.014^{*}$) and in the incompetent SFJ ($p=0.008^{**}$) (Table VI), while in the other veins differences were negligible. The standard deviation of the systolic acceleration for ST was greater in the incompetent SFJ ($p=0.0002^{***}$) and smaller in the incompetent GSV ($p=0.0000001^{***}$), while in the other veins differences were negligible. Our data regarding the systolic acceleration were somewhat contradictory, suggesting that no unique interpretation about accuracy could be formulated in this patients' series.

Discussion

It should be noted that we performed all measurements in longitudinal section more fit to quantitative research. In daily clinics instead the Paraná manoeuvre is generally used with both longitudinal and transverse oblique sections (Figure 1).

Intra-observer differences were not investigated. Our data demonstrated that P caused greater flow variations than a conventional ST. Greater volume shifts were observed and therefore it could be inferred that P is a better test than ST in the evaluation and quantification of reflux.

Incompetent SFJs

		ST	P
Systolic events			
	Systolic T_S (ms)	750±60	1140±80
	Max Systolic Speed S ($cm{\cdot}s^{-1}$)	45±6	34±4
	Systolic AUC (cm)	16±2	19±3
Diastolic events			
	Diastolic T_D (ms)	2300±200	5800±600
	Max Diastolic Speed D ($cm{\cdot}s^{-1}$)	43±9	70±20
	Diastolic AUC (cm)	49±13	185±40

Systolic AUC P/ST = 1.21, p=0.19(n.s.), Diastolic AUC P/ST = 3.77, $p=0.009^{**}$ Diastolic TD P/ST = 2.52, $p=0.00003^{***}$

Table III - Analysis of the Paraná Manoeuvre and Squeezing Test in 13 incompetent SFJ.
SFJ saphenous femoral junction, T_S systolic ejection time, T_D diastolic refluxing time, AUC area under the curve, P Paraná, ST Squeezing Test. Mean ± standard error of the mean.

Incompetent GSV trunks

		ST	P
Systolic events			
	Systolic T_S (ms)	500±40	570±140
	Max Systolic Speed S ($cm \cdot s^{-1}$)	30±6	26±5
	Systolic AUC (cm)	7,7±1,1	10±4
Diastolic events			
	Diastolic T_D (ms)	4300±700	7900±1100
	Max Diastolic Speed D ($cm \cdot s^{-1}$)	35±5	41±9
	Diastolic AUC (cm)	70±10	140±30

Systolic AUC P/ST = 1.42, p=0.59(n.s.), Diastolic AUC P/ST = 2.0, p=0.02* Diastolic TD P/ST = 1.83, p=0.0015**

Table IV - Analysis of the Paraná Manoeuvre and Squeezing Test in 13 incompetent GSV trunks.
GSV greater saphenous vein, T_S systolic ejection time, T_D diastolic refluxing time, AUC area under the curve, P Paraná, ST Squeezing Test. Mean ± standard error of the mean.

Re-Entry Perforating veins

		ST	P
Systolic events			
	Systolic T_S (ms)	470±40	760±120
	Max Systolic Speed S ($cm \cdot s^{-1}$)	28±5	26±3
	Systolic AUC (cm)	6,6±1,3	10,7±2,5
Diastolic events			
	Diastolic T_D (ms)	1500±300	4900±1600
	Max Diastolic Speed D ($cm \cdot s^{-1}$)	23±4	46±8
	Diastolic AUC (cm)	19±5	92±22

Systolic AUC P/ST = 1.62, p=0.08(n.s.), Diastolic AUC P/ST = 4.84, p=0.009** Diastolic TD P/ST = 3.27, p=0.07 n.s.

Table V - Analysis of the Paraná Manoeuvre and Squeezing Test in 11 Re-Entry Perforating veins.
T_S systolic ejection time, T_D diastolic refluxing time, AUC area under the curve, P Paraná, ST Squeezing Test. Mean ± standard error of the mean.

As an easier detectable reflux provides a more reliable DUS as well as plethysmography, the quantitative advantages of P could be of paramount clinical importance in improving diagnostics in venous diseases.

In addition, P does not rely on the size of the operator's hand or the size of the patient's calf. In this paper we compared P to a manually performed ST, as this is the modality ST is generally performed in almost all vascular labs, while the standardized pneumatic compression by means of a cuff is rarely executed, being also time consuming.

Furthermore, as posture adjustments are spontaneously performed daily and in countless ways, P provides invaluable information about a condition which is almost near to the physiological posture balance. On the contrary, ST is based on external compression and relaxation, which are completely artificial operations.

This paper could also serve to encourage and to give more recognition to diagnostic manoeuvres which explore better physiological conditions.

Conclusions

In competent popliteal veins P moved 40% more blood volume than ST. The diastolic phase of P compared to ST lasted more than 3 times longer in the incompetent SFJ, more than 2 times longer in the incompetent GSV trunk, and more than 3 times longer in the re-entry Perforating veins. No significant difference in the standard deviation of the acceleration was detected between P and ST.

ST is widely practiced in most vascular labs, though nowadays several old and new manoeuvres have shown that ST is not the best choice to elicit the venous reflux[8-12]. In addition, P is undoubtedly an easy and safe manoeuvre, causing physiological changes which occur in balance adjustments in the standing position. P is actually practised since 20 y in many vascular labs and we hope that our results will support an increased utilization in the assessment of the function of the venous system.

Systolic acceleration

Acceleration Unit: $cm \cdot s^{-2}$	Average (two-tailed paired T test)			σ (two-tailed F test)		
	p	Squeezing	Paraná	p	Squeezing	Paraná
Competent Popliteal veins	0,014*	0.19	0.13	0.8 (n.s.)	0.06	0.07
Incompetent SFJ	0.008**	0.07	0.03	0.0002***	0.04	0.01
Incompetent GSV	0.21 (n.s.)	0.06	0.11	$1 \cdot 10^{-7}$ ***	0.02	0.14
Re-Entry Perforators	0.08 (n.s.)	0.06	0.04	0.10 (n.s.)	0.04	0.02

Table VI - Analysis of the standard deviation of systolic acceleration.
SFJ saphenous femoral junction, GSV greater saphenous vein, p statistical significance, σ standard deviation.

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Author contributions

Conception and design: SE, Data collection: SE, Statistics: FP, Literature review: MC, Writing the article: SE FP, Critical revision of the article: SE FP MC CF, Supervision: CF.

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