Quantified duplex augmentation in healthy subjects and patients with venous disease: San Diego population study

Arnost Fronek, MD, PhD,[a] **Julie O. Denenberg, MA,**[b] **Michael H. Criqui, MD, MPH,**[b] and **Robert D. Langer, MD, MPH,**[b] *San Diego, Calif*

Objective: **This study was undertaken to determine the quantitative augmentation response in several veins examined in a cohort assembled to permit comparisons by sex, age, and ethnicity, under normal conditions and in the presence of obstruction, with and without trophic changes.**

Method: **The common femoral vein, superficial femoral vein, sapheno-femoral junction, popliteal vein, sapheno-popliteal junction, and posterior tibial vein were studied with duplex ultrasonographic scanning. Augmentation response was elicited with use of an automated cuff inflator. Mean level of each response was analyzed according to patient sex, age, and ethnicity, each adjusted for the other two. Normal values were compared with those obtained from legs with venous obstructive disease, with or without signs of trophic changes.**

Results: **Decreased augmentation response was noted only in the sapheno-femoral junction and sapheno-popliteal junction, and was smaller in women. Augmentation response was slightly increased in the oldest age group (>70 years) in the common femoral vein, superficial femoral vein, popliteal vein, and posterior tibial vein. The highest augmentation response was found in Asian subjects, in the common and superficial femoral veins and the sapheno-femoral and sapheno-popliteal junctions; and the smallest augmentation response was found in African American subjects, in these same veins and junctions. Differences in vein diameters may explain these findings, ie, smaller diameters in Asians and larger diameters in African Americans. Most important, compared with normal values, augmentation response was decreased in legs with venous obstructive disease only when trophic changes were present.**

Conclusion: **Like quantification of reflux, quantitative evaluation of the augmentation response may help in diagnosis of venous obstructive disease when trophic changes are present. (J Vasc Surg 2003;37:1054-8.)**

Duplex ultrasonographic scanning is standard in diagnosis of venous disease. However, in diagnosing venous obstruction, quantitative evaluation is not fully utilized, though quantification of reflux duration is useful in evaluating venous valvular insufficiency.[1-3] The single publication on quantification of the augmentation response provides information about legs with thrombosis only.[4] The augmentation response provides important information for diagnosing venous obstructive disease. We undertook to quantify the augmentation response in a population that included subjects with and without venous disease, with special reference to sex, age, and four ethnic groups. In addition, the augmentation response was quantitated in a group of subjects with obstructive venous disease diagnosed on the basis of positive results of compression testing and in subjects with cutaneous trophic changes presumed due to chronic venous insufficiency.

From the Departments of Surgery and Bioengineering, VA San Diego Healthcare System,[a] and the Department of Family and Preventive Medicine, University of California, San Diego.[b]

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Reprint requests: Arnost Fronek, MD, PhD, University of California, San Diego, Mail Code 0634, 9500 Gilman Dr, La Jolla, CA 92093-0643 (e-mail: afronek@ucsd.edu).

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METHODS

Subjects were randomly selected from current and retired University of California, San Diego employees, with stratification by sex, age, and ethnicity. Their spouses or significant others were also invited to participate. Women and minority groups were oversampled to attain statistical power for female-specific analyses and comparison according to ethnicity. Four ethnic groups were studied: non-Hispanic white, Hispanic, African American, and Asian. The study was approved by the Human Subjects Committee of the University of California, San Diego.

At the study visit, presence or absence of past or current venous disease was determined by means of history and clinical and duplex ultrasound scanning. Of 2408 examined subjects, 1600 had healthy legs, ie, without varicose veins or trophic changes and with normal function at duplex scanning. Altogether, 3549 legs were included in the control group, ie, 3200 healthy legs plus 349 healthy legs from patients with unilateral disease according to findings at history and duplex scanning. A second group consisted of 28 legs in which at least 1 vein yielded positive findings at compression testing,[5-7] corresponding to P_0 according to CEAP classification. A third group comprised 220 legs with at least one sign of trophic changes, eg, hyperpigmentation, lipodermatosclerosis, or healed or active ulcer, correspond-

Table I. Augmentation in 3549 normal control limbs

	CFV	*SFJ*	*SFV*	*POPV*	*SPJ*	*PTV*
Augmentation (cm/s) as function of sex (adjusted for age and ethnicity)						
Male	59.0 ± 31.3	33.4 ± 24.8	66.1 ± 35.3	82.8 ± 35.7	53.9 ± 27.2	37.3 ± 20.3
Female	58.6 ± 30.9	30.7 ± 25.3*	68.8 ± 35.4‡	84.4 ± 36.0	50.7 ± 27.0*	37.4 ± 20.2
Augmentation (cm/s) as function of age (y) (adjusted for sex and ethnicity)						
<50	59.0 ± 30.1	34.3 ± 23.9	68.1 ± 34.3	80.7 ± 35.0	54.8 ± 26.0	37.4 ± 19.4
50-59	57.4 ± 31.4	33.3 ± 24.9	65.3 ± 35.4	77.7 ± 36.1	51.3 ± 27.1†	36.7 ± 20.2
60-69	58.3 ± 31.1	28.9 ± 24.9†	67.4 ± 35.6	87.4 ± 35.9	50.7 ± 26.9†	37.0 ± 20.0
70+	60.8 ± 32.7	29.2 ± 26.7	71.5 ± 37.7‡	91.4 ± 38.0*	49.7 ± 28.3*	38.4 ± 21.0
Augmentation (cm/s) as function of ethnicity (adjusted for sex and age)						
White	58.2 ± 31.6	32.3 ± 25.2	67.3 ± 35.9	81.9 ± 36.4	52.4 ± 26.8	36.8 ± 20.4
Hispanic	60.1 ± 31.4	31.2 ± 25.2	68.5 ± 35.6	87.2 ± 36.1†	50.5 ± 27.4	37.5 ± 20.7
African American	55.0 ± 31.0	28.1 ± 24.7†	64.1 ± 35.3	86.0 ± 35.8†	49.3 ± 27.5†	39.5 ± 20.1†
Asian	64.0 ± 30.9*	33.1 ± 24.9	74.0 ± 35.3†	86.9 ± 35.8	52.7 ± 27.1	37.1 ± 20.1

CFV, Common femoral vein; *SFJ*, sapheno-femoral junction; *SFV*, superficial femoral vein; *POPV*, popliteal vein; *SPJ*, sapheno-popliteal junction; *PTV*, posterior tibial vein.
Values represent mean ± SD.
All significance in relation to first (reference) row.
**P* < .005.
†*P* < .01.
‡*P* < .05.

ing to CEAP classification $C_{4\text{-}6}$. The two patient groups were not mutually exclusive.

An Acuson model 128 duplex scanner (Mountain View, Calif) with a 5 MHz probe was used to examine the common femoral vein, sapheno-femoral junction, superficial femoral vein, popliteal vein, sapheno-popliteal junction, and posterior tibial vein.

Subjects were examined on a tilt table in a reversed 15-degree Trendelenburg position with the legs slightly flexed in minimal external rotation for maximum comfort. The duplex probe was used to determine vein compressibility[5-7] in all examined veins. An automatic cuff inflator (Hokanson, Bellevue, Wash) was connected to cuffs placed at mid-thigh to examine the common femoral vein, superficial femoral vein, and sapheno-femoral junction; at midcalf to examine the popliteal vein and sapheno-popliteal junction; and at foot level to examine the posterior tibial vein. Standard rapid inflation (100 mm Hg) and deflation were performed, and response in the examined veins, ie, augmentation of flow velocity, was determined. Duration of inflation was 3 seconds, and reflux longer than 0.5 seconds was considered a positive result.

Statistics. All analyses were cross-sectional. Analysis of covariance was used to compare mean results according to gender, age, and ethnicity. Results for age were adjusted for sex and ethnicity; results for sex differences were adjusted for age and ethnicity; and results by ethnic group were adjusted for age and gender. All analyses were performed with SAS statistical software (version 6.12 for Windows; SAS Institute, Cary, NC).

RESULTS

Analysis according to sex, age, and ethnicity was restricted to 3549 healthy legs.

Augmentation response according to sex. Augmentation response in 3 veins, ie, common femoral vein, popliteal vein, and posterior tibial vein, were the same for both sexes (Table I, *A*). In women, the response was smaller in the sapheno-femoral junction and sapheno-popliteal junction, but was greater in the superficial femoral vein.

Augmentation response according to age. Augmentation response increased slightly with increasing age in the sapheno-femoral vein and the popliteal vein, but decreased with age in the sapheno-femoral junction and sapheno-popliteal junction (Table I, *B*).

Augmentation response according to ethnicity. Augmentation response in the four ethnic groups is summarized in Table I, *C*. In the Asian group, a significantly higher response was observed in the common femoral vein and sapheno-popliteal junction, and in the African American group in the popliteal vein and posterior tibial vein. However, in the African American group, response was significantly lower in the sapheno-femoral junction and sapheno-popliteal junction. In the Hispanic group, augmentation response was significantly higher in the popliteal vein.

Venous obstructive disease and augmentation. Augmentation responses in healthy veins, adjusted for sex, age, and ethnicity, are presented in Table II (row 1). The highest response was obtained in the popliteal vein (83.7 cm/s), and the lowest was recorded in the posterior tibial vein (37.2 cm/s).

Augmentation response in specific veins in which obstruction was identified, with and without trophic changes, is shown in Table II (rows 2 and 3, respectively). Although the numbers are small, augmentation response was lower

Table II. Augmentation as function of obstruction and trophic changes

	CFV		*SFJ*		*SFV*		*POPV*		*SPJ*		*PTV*		*Total*	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Normal legs (n = 3549)	58.3	29.8	31.3	24.4	67.2	34.0	83.7	34.6	52.5	27.4	37.2	20.3	329.4	108.4
Obstruction in specific veins, with trophic changes	32.0	29.8	15.9	24.0	41.6	33.7	43.7*	34.2	24.9‡	26.8	24.0	22.2	—	—
n	4		3		4		8		4		6			
Obstruction in specific veins, without trophic changes	36.2	29.7	—	—	45.9	33.7	71.6	34.2	38.0	26.8	43.8	21.5	—	—
n	2		0		6		3		2		9			
Obstruction anywhere, with trophic changes (n = 10)	33.6†	29.7	26.4	26.8	44.3‡	33.7	50.9†	34.2	29.3‡	26.7	28.0	21.4	205.2*	124.9
Obstruction anywhere, without trophic changes (n = 18)	55.3	29.7	31.1	24.0	62.3	33.7	62.5‡	35.2	49.0	28.3	40.7	21.5	311.8	118.5
No obstruction, with trophic changes and reflux (n = 162)	55.4	30.3	30.5	26.1	62.3	34.5	76.5‡	34.9	47.3‡	27.8	38.3	20.8	313.4	117.2
No obstruction, with trophic changes and reflux (n = 58)	51.6	30.1	25.9	24.5	67.2	34.4	82.9	34.6	53.1	27.5	42.0	21.3	324.6	115.0

CFV, Common femoral vein; *SFJ*, sapheno-femoral junction; *SFV*, superficial femoral vein; *POPV*, popliteal vein; *SPJ*, sapheno-popliteal junction; *PTV*, posterior tibial vein.
All significance in relation to first row (normal legs).
*$P < .005$.
†$P < .01$.
‡$P < .05$.

than in healthy veins, and somewhat more so if obstruction was associated with trophic changes.

Augmentation response in the 6 examined veins in a given leg in which obstruction was identified anywhere in the leg is shown in Table II (rows 4 and 5, respectively). In legs with trophic changes, obstruction anywhere in the limb was associated with generally decreased response. In contrast, response in legs without trophic changes was generally normal.

A significant difference was observed when comparing total summarized augmentation responses from all examined veins (Table II; Figure). Total augmentation response in the control group was 329.4 cm/s; in legs in which obstruction was combined with trophic changes, response was significantly smaller (205.2 cm/s; $P < .005$), whereas in legs with obstruction but no trophic changes, response was similar to that in control legs (Figure).

We also evaluated legs with trophic changes in which no obstruction could be identified, both with and without reflux (Table II, rows 6 and 7, respectively). Despite trophic changes, in the absence of obstructive disease the augmentation response was normal, whether reflux was present or not.

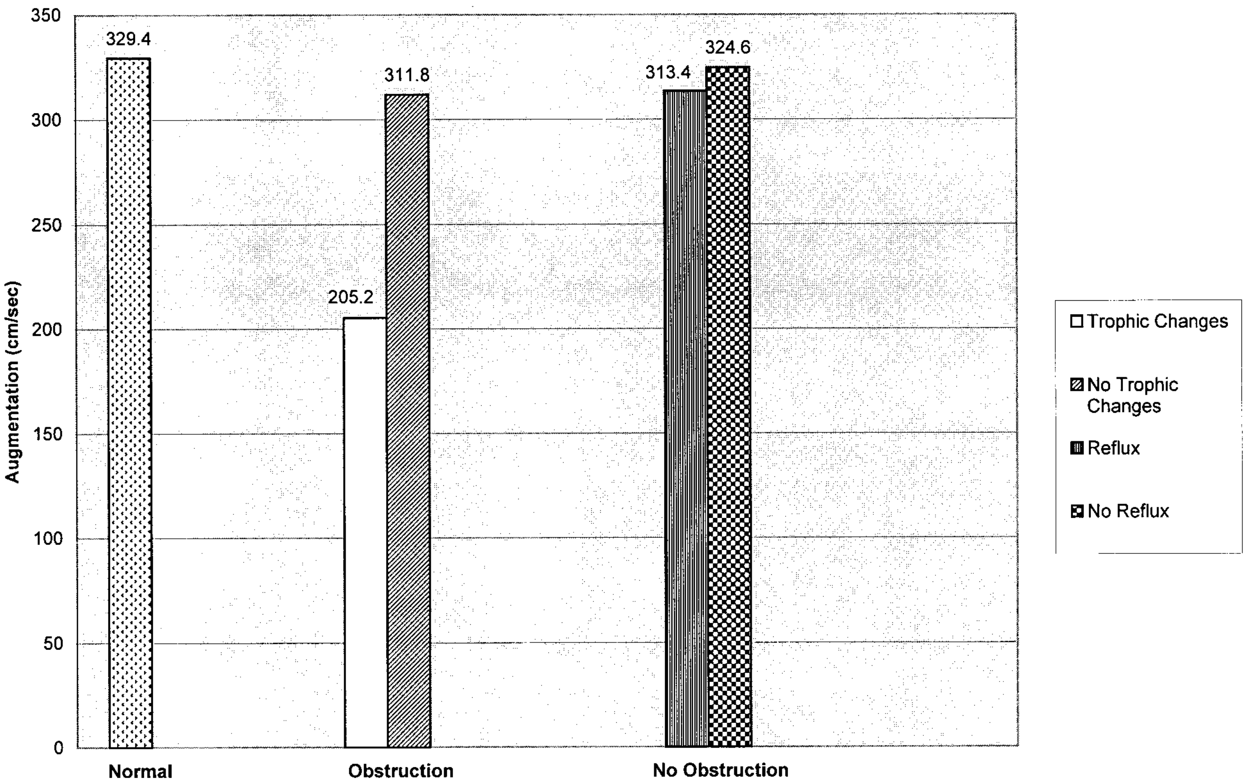
DISCUSSION

Although duration of reflux is an important factor in diagnosis of venous valvular insufficiency,[1-3] augmentation response is mainly used qualitatively, not much differently from in the era of continuous wave Doppler scanning.[8-10]

Similarly, as in a previous analysis of common femoral vein dimension and hemodynamics,[12] we determined the normal augmentation response in a randomly selected population cohort, searching for possible differences due to sex, age, and ethnicity. In addition, we compared the quantitative augmentation response in legs with obstructive venous disease with control values.

Only limited information regarding quantitative augmentation could be found in the literature.[4] In that report, normal peak velocity in the superficial femoral vein was 142.8 cm/s, twice the velocity we found (67.2 cm/s). On the other hand, we are reporting average velocity of 83.7 cm/s in the popliteal vein, compared with 35.7 cm/s in the quoted report. Though the examination conditions were slightly different, ie, standing vs reversed Trendelenburg position, this does not seem to explain the differences. On the contrary, increased hydrostatic pressure in the standing position could, to some extent, reduce peak augmentation response.

Sex-related differences were found mainly in the sapheno-femoral junction and sapheno-popliteal junction, in both cases yielding a smaller response in women. There were no major age-related differences except for increased response in the popliteal vein and decreased response in the sapheno-popliteal junction. The highest augmentation response was found in the Asian group, in the common femoral vein and the sapheno-femoral junction. The underlying factor may be smaller vein diameter in this ethnic group.[12] The augmentation response was higher in all veins except the posterior tibial vein in the Asian group compared with the African American group. Again, this increased response may be related to smaller vein diam-



Total augmentation response. *Bar 1,* Normal; *bar 2,* obstruction with trophic changes; *bar 3,* obstruction without trophic changes; *bar 4,* no obstruction, trophic changes, with reflux; *bar 5,* no obstruction, trophic changes, without reflux.

eter in the Asian group compared with the African American group.

Obstruction and trophic changes. As expected, the augmentation response was decreased in specific veins, with or without trophic changes, although the numbers were too small for statistical significance. In legs with obstruction and trophic changes, the augmentation response was similarly reduced. In contrast, legs with obstruction but without trophic changes were statistically indistinguishable from control legs, indicating that severity of obstruction may influence development of trophic changes. The only exception was in the popliteal vein, with lower augmentation response (62.5 cm/s) compared with that in control legs (83.7 cm/s) but still higher than in the group with obstruction and trophic changes (50.9 cm/s) (Table II).

The slightly reduced augmentation response in some legs with trophic changes and reflux but no obstruction, noted mainly in the popliteal vein and sapheno-popliteal junction, suggests that some degree of obstruction may have been below the diagnostic sensitivity of ultrasonography.

Trophic changes were found in some legs without signs of obstruction or reflux. Augmentation values in these legs, including the summarized response, were close to results obtained in control legs. The presence of trophic changes in the absence of obstruction as well as reflux suggests nonvascular origins (in view of normal ankle/brachial artery pressure ratios), eg,chronic dermatitis or congestive heart failure.[13]

In summary, quantitative augmentation response is reported in a control group stratified according to sex, age, and ethnicity. Adjusted normal values are 58.3 cm/s for the common femoral vein, 31.3 cm/s for the sapheno-femoral junction, 67.2 cm/s for the superficial femoral vein, 83.7 cm/s for the popliteal vein, 52.5 cm/s for the sapheno-popliteal junction, and 37.2 cm/s for the posterior tibial vein. The summarized, normal total response for all examined veins was 329.4 cm/s. In addition, augmentation responses are given for each vein in which obstruction was diagnosed. The response was generally lower if venous obstruction was accompanied by trophic changes.

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