Neurogenic-nitric oxide interactions affecting brachial artery mechanics in humans: roles of vessel distensibility vs. diameter

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Salzer DA, Medeiros PJ, Craen R, Shoemaker JK. Neurogenic-nitric oxide interactions affecting brachial artery mechanics in humans: roles of vessel distensibility vs. diameter. Am J Physiol Regul Integr Comp Physiol 295: R1181–R1187, 2008. First published August 6, 2008; doi:10.1152/ajpregu.90333.2008.—The purpose of this investigation was to assess the interactive influence of sympathetic activation and supplemental nitric oxide (NO) on brachial artery distensibility vs. its diameter. It was hypothesized that 1) sympathetic activation and NO competitively impact muscular conduit artery (brachial artery) mechanics, and 2) neurogenic constrictor input affects conduit vessel stiffness independently of outright changes in conduit vessel diastolic diameter. Lower body negative pressure (LBNP) and a cold pressor stress (CPT) were used to study the changes in conduit vessel mechanics when the increased sympathetic outflow occurred with and without changes in heart rate (LBNP −40 vs. −15 mmHg) and blood pressure (CPT vs. LBNP). These maneuvers were performed in the absence and presence of nitroglycerin. Neither LBNP nor CPT altered brachial artery diastolic diameter; however, distensibility was reduced by 25 to 54% in each reflex (all P < 0.05). This impact of sympathetic activation on brachial artery distensibility was not altered by nitroglycerin supplementation (21–54%; P < 0.05), although baseline diameter was increased by the exogenous NO (P < 0.05). The results indicate that sympathetic excitation can reduce the distensibility of the brachial artery independently of concurrent changes in diastolic diameter, heart rate, and blood pressure. However, exogenous NO did not minimize or reverse brachial stiffening during sympathetic activation. Therefore, sympathetic outflow appears to impact the stiffness of this conduit vessel rather than its diastolic diameter or, by inference, its local resistance to flow. Vascular compliance; ultrasound imaging; lower body negative pressure; conduit vessel mechanics.

Moment-by-moment regulation of vascular contractile state is affected by the interplay between neurogenic constrictor effects and local dilatory influences. Of the constrictor influences, significant vasomotor control is affected through the sympathetic nervous system (SNS) that reflexively increases its constrictor effect during a variety of stimuli, such as orthostatic stress and cold stress (14, 29, 30, 35). In contrast, nitric oxide (NO) is a potent vasodilator (12, 13) that can exert its effect directly through a guaninase-3’,5’-cyclic monophosphate (cGMP) mechanism (24) in smooth muscle or through the degradation of norepinephrine in the neuromuscular cleft (5, 16, 20). Additional vasoactive substances that can potentially affect the contractile state of vascular smooth muscle include the constrictor peptides endothelin and angiotensin II and the endothelial-derived dilator prostacyclin and endothelial-derived hyperpolarizing factor.

While competing effects of vasoactive substances are known to occur at the microvascular level, it is not known whether the upstream muscular conduit vessels undergo similar control. Despite the innervation of muscular conduit arteries by the SNS, evidence of neurogenic control in such vessels is equivocal. In some cases, the reflexive sympathoexcitatory maneuvers of mental or cold stress and the muscle chemoreflex do (2, 6, 8, 26) or do not (6, 18) cause vasoconstriction as interpreted through a reduction in the diameter of the brachial and radial arteries. These conflicting results may depend on what level of conduit vessel is being investigated with the accounts of vasoconstriction being more typical of muscular rather than elastic arteries (8, 9, 11, 18, 25, 26).

In addition to outright changes in diameter, assessment of vascular mechanics during pharmacological or physical inhibition of basal sympathetic outflow has indicated that, in humans, tonic sympathetic nerve activity (SNA) exerts restraint over the distensibility of large- and medium-sized muscular conduit vessels (7, 10). Evidence obtained from an animal model supports the idea that adrenergic outflow augments intrinsic vascular rigidity and further extends this control to conduit vessels of both an elastic and muscular composition (22). Nonetheless, reflexive elevation of sympathetic drive with smoking, cold exposure, and mental stress augment conduit vessel stiffness in some, but not all, reports (8, 18, 25, 31).

In contrast to the constrictor impact of SNA, NO acts to relax vascular smooth muscle cells, thereby increasing luminal diameter. Pharmacologic blockade of NO synthase reduced elasticity of both elastic and muscular conduit arteries (15, 28, 38, 39), confirming an important role of endogenous NO in maintaining a level of elasticity in these vessels. Whether this effect is maximized under baseline conditions is not known. Provision of exogenous NO altered pulse wave velocity and arterial pulse contours in a way that is consistent with improved elasticity (15, 28, 39). However, these latter effects may be related to changes in central elastic arteries or the impact of heart rate on pulse wave amplification (36) with minimal impact from the peripheral muscular conduit vessels. It is noteworthy that while several studies have examined the manner in which isolated systems of vascular control (SNS, NO) influence arterial stiffness, the combined impact of these systems on muscular conduit vessel mechanics has not been explored.

An additional concern is that reliance on a change in vessel diameter, which is usually assessed in diastole, is an incom...
ple index of vascular contractile state, omitting a change in the stiffness of the vessel, or its distensibility during systole. Previous data from our laboratory (40) indicate that the resistance and compliance of the downstream vascular tree can be differentiated and studied independently; such changes in conduit vessel mechanics have not been evaluated.

Therefore, the purpose of this investigation was to test the hypothesis that sympathetic activation and NO competitively impact muscular conduit artery (brachial artery) mechanics. Second, we tested the hypothesis that neurogenic constrictor input affects conduit vessel stiffness independently of outright changes in conduit vessel diastolic diameter. Our approach was to quantify the impact of reflex sympathetic activation on brachial artery mechanical properties both with and without exogenous NO [supplementation of nitroglycerin (NG)] while the central and forearm hemodynamics were measured.

METHODS

Participants. Ten healthy adults volunteered for participation in the present study (4 female, 6 male). The participants were 27 ± 2 years of age (mean ± SD) and had average heights and weights of 175 ± 8 cm and 73 ± 12 kg, respectively. By self-report, all participants were nonsmoking individuals who were free of cardiovascular and neurological disease. Participants reported to the laboratory following a 6-h fast and having abstained from caffeine, alcohol, and exercise for a minimum of 12 h. Preceding experimentation, participants were encouraged to maintain typical water consumption and sleeping behaviors. While the menstrual phase was not assessed, it was consistent for each female between the two consecutive study days. Each participant provided informed written consent to the experimental protocols, which were approved by The University of Western Ontario Health Sciences Research Ethics Board.

Experimental design. There is a challenge in coordinating the interactive effects of two types of sympathetic activation, both with and without changes in blood pressure, along with NG administration, due to the transient effect of NG and the need to avoid multiple doses of NG on a single day. Therefore, two experimental protocols were conducted on consecutive days in random fashion (Fig. 1). Each protocol was designed to assess brachial artery distensibility during sympathoexcitatory maneuvers in the presence and absence of supplemental NO. In addition, in consideration of the fact that vascular distensibility may change due to sympathetic activation and/or to changes in blood pressure alone, two types of sympathoexcitatory maneuvers were used that did [cold pressor test (CPT)] and did not (LBNP) affect blood pressure. Also, to account for earlier concerns that changes in heart rate may independently affect measures of vascular stiffness (37), two levels of LBNP were used that did (−40 mmHg) or did not (−15 mmHg) affect HR.

Protocol 1: lower body negative pressure protocol and NG. Data collection for each test commenced following 15 min of undisturbed rest in the supine position. An initial baseline collection period (Table 1) was followed by lower body negative pressure (LBNP) at either −15 mmHg or −40 mmHg, the order of which varied across participants. Exposure to each LBNP stimulus lasted for 5 min and was followed by 5 min of rest at atmospheric pressure.

After the control LBNP trials, sublingual NG (0.4 mg/metered dose Nitrolingual Pumpspray; Aventis) was administered to deliver exogenous NO. The effects of NG were studied between 2 and 10 min following its application. Beginning at 2 min post-NG administration, a baseline measurement was made (2 min) reflecting changes due to NG. Immediately following this measurement, LBNP was initiated at a level of either −15 mmHg or −40 mmHg (4 min); again the order of LBNP level varied between participants but only one level was used in this test due to the transient effect of NG administration. The timing of LBNP and CPT protocols was designed so that the peak reflex response occurred with the maximal NO effect, which is between 4 and 6 min postadministration [Bressler et al., (3)]. Upon return to atmospheric pressure, participants were allowed a 2-min recovery, after which an additional period of baseline NG data collection was conducted.

Protocol 2: cold pressor test and NG. On the different day, and following 15 min of supine rest, baseline data were collected. Subsequently, data were collected for 5 min during which the participant’s foot was immersed in an ice-water bath (4°C), a CPT. This 5-min CPT was followed by a 30-min period of quiet supine rest for recovery. After having reestablished baseline conditions, sublingual NG was administered as in protocol 1. The application of this second NG dose was simultaneously combined with the application of LBNP, at the level that had not been tested in combination with NG during the earlier protocol (either −15 mmHg or −40 mmHg). Two minutes of adaptation to the LBNP was provided prior to data collection. Upon termination of LBNP, and immediately following return to atmospheric pressure, the participant’s foot was again submerged in an ice-water bath to examine the combined effects of NG and CPT.

Data acquisition: brachial artery images. Brachial artery ultrasound images were acquired from the antecubital region of the right arm by utilizing a 10-MHz linear array transducer (System 5; GE/Vingmed, Horten, Norway). M-mode images were initially obtained at a frame rate of ~24 frames/s from two-dimensional brachial images. Anatomical landmarks were documented to ensure the acquisition of images from the identical location during the separate recording sessions. Each M-mode image encompassed four cardiac cycles. Edge tracking software (32) determined the diameter over 2 to 4 cardiac cycles using the media-to-media distances. The peak and minimum values were extracted as the systolic and diastolic diameters, respectively. While accurate in determining diameter changes and reducing observer variability, this edge tracking approach tends to overestimate the luminal diameter by ~3%, as it depends on particular contrast values and is calibrated based on the voxel dimensions (Shoemaker JK, unpublished observations).

For each experimental condition, a minimum of five M-mode images were recorded and stored online for later analysis. Specifically, during both control and NG-combined with LBNP (NG-LBMP) trials, images were obtained following a 2-min period of adaptation to the given level of negative pressure. During control and NG-combined with CPT (NG-CPT), images were obtained 1 min following the onset of ice-water submersion. NG baseline images were collected 2 min

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**Fig. 1.** Outline of experimental protocols. Protocols A (A) and B (B) were completed on consecutive days. LBNP, lower body negative pressure; NG, sublingual nitroglycerin; CPT, cold pressor test.
following drug administration, and additionally after 2 min of rest at atmospheric pressure following NG-LBNP. In all instances, the precise time of image acquisition was documented to ensure correspondence with simultaneously collected brachial pressure values, as required for calculation of distensibility.

**Hemodynamic variables.** Analog signals for hemodynamic variables were sampled at 1,000 Hz and collected with an online data acquisition and analysis package (Powerlab; ADInstruments). HR was determined by standard three-lead electrocardiogram techniques. Arterial blood pressure was continuously monitored from the finger of the left hand by photoplethysmographic methods from which pulsatile brachial pressure was determined via waveform reconstitution and regression equations (Finometer; Finapres Medical Systems; Amsterdam, The Netherlands). To determine stroke volume velocity (SVV), the ascending aortic peak velocity envelope, was recorded using a 2-MHz Doppler ultrasound probe positioned at the suprasternal notch (model CFM750; GE/Vingmed, Horten, Norway). An insonation angle of 20 degrees was assumed for the ascending aortic velocity calculations. In conjunction with SVV, the aortic root diameter was determined for future calculation of cardiac output (Q). This dimension was quantified once at the study onset along the parasternal long axis utilizing two-dimensional B-mode ultrasound and a 3.5-MHz sector probe (System 5; GE/Vingmed). Brachial artery mean blood flow velocity (BFV) was obtained with a 4-MHz pulsed wave transducer positioned in the antecubital region of the right arm (GE/Vingmed System 5). In all experimental conditions, BFV was collected immediately following the period of brachial artery M-mode image acquisition.

**Data analysis: distensibility.** Continuous arterial diameters were determined over three of the four cardiac cycles in which the pulsatile wall motion in the M-Mode image was consistent and similar to the pressure waveform. The diameter data were obtained using a semi-automated edge tracking analysis (17, 32, 34). These data were averaged over the consecutive cardiac cycles to produce the single representation of the pulsatile diameter for each condition. Blood pressure waveforms obtained during the same time as brachial arterial images were also averaged to produce a single pressure waveform. The number of data points that composed the average diameter and pressure waveforms were matched by an in-house MATLAB program. Corresponding averages of the pulsatile diameter and pressure waveforms were plotted, and the resultant loop was fit with a best-fit regression. With the use of regression coefficients, the pressure-diameter curve was reconstructed and normalized to a pulse pressure range (0 to 40 mmHg), which was used across all subjects so that the data could be averaged. Distensibility was calculated according to the equation \[ \text{distensibility} = \frac{[D_s - D_d]}{P_s - P_d} \cdot \frac{D_d}{P_s} \] where \( D_s \) and \( D_d \) are systolic and diastolic diameter and \( P_s \) and \( P_d \) are systolic and diastolic pressures, respectively. In the calculation of average distensibility \( (D_s, D_d) \), distensibility was determined for each 5-mmHg pulse pressure increment along the normalized curve and subsequently averaged. This method of analysis considers the change in distensibility that can occur as pressure increases from end diastole to peak systole, due to the curvilinear nature of the pressure-diameter response. Furthermore, distensibility at various pressures along the pressure-diameter curve can be calculated. Thus, peak distensibility \( (D_s) \) was calculated as the distensibility that occurred in the lowest pulse pressure interval (0–5 mmHg).

**Data analysis: hemodynamic variables.** Analog signals for ECG, blood pressure, SVV, and BFV were sampled at 1 KHz and collected with an online data acquisition and analysis package (Powerlab, ADInstruments). Sixty seconds of data were selected between 2 and 4 min of LBNP and after 60 s of CPT (in both control and NG conditions). Data for NG alone (NG baseline) were selected 3 min after drug administration. Brachial pulse pressure was calculated as systolic minus diastolic brachial blood pressure. Stroke volume (SV) was calculated as the product of aortic cross-sectional area and SVV. Forearm blood flow (FBF) was calculated as brachial cross-sectional area \( \times \) BFV \( \times 60 \). Cardiac output (Q) was calculated as SV \( \times 60/1,000 \). Total peripheral resistance (TPR) was calculated as MAP/Q. Systemic vascular conductance (SVC) was calculated as Q/MAP, where MAP is mean arterial pressure.

**Statistical method.** The effect of the different testing days on baseline hemodynamic data was tested with a repeated-measures one-way ANOVA [Statistical Analysis System (SAS) version 9.1; SAS Institute, Cary, NC]. The effect of LBNP and CPT, both with and without supplemental NG, was assessed using a repeated-measures two-way ANOVA. Tukey’s post hoc test was used to address significant interactions. The statistical level of probability was set at \( P < 0.05 \). Data are expressed as means \( \pm \) SD.

**RESULTS**

**Baseline analysis.** Baseline \( D_s \) and \( D_d \) were equivalent on each experimental day; therefore, corresponding values were pooled. Furthermore, baseline hemodynamic measures were not different between experimental days or between subsequent baseline periods in the same protocol. The only exception to this observation was an elevation in systolic blood pressure in the baseline period prior to the control CPT compared with baseline systolic blood pressure measured in protocol 1.

**Hemodynamic results.** The hemodynamic responses to LBNP and CPT stimuli, with and without NG, are presented in Table 2. Compared with the control (non-NG) condition, HR was elevated during NG (main effect; \( P < 0.0001 \)). Similarly, HR was elevated during the LBNP \(-40 \text{ mmHg}\) and CPT (\( P < 0.0001 \)). Heart rate did not increase above baseline during LBNP \(-15 \text{ mmHg}\).

- Compared with baseline, MAP, systolic blood pressure, and diastolic blood pressure were unchanged during LBNP but increased during CPT (\( P < 0.0001 \)). The blood pressure response to CPT was the same during the control and NG trials. Compared with baseline, pulse pressure was reduced during LBNP. However, pulse pressure increased during both the control and NG-CPT trials (\( P < 0.05 \)) (Table 2).
- Compared with baseline, FBF was reduced during both levels of LBNP (main effect, \( P < 0.005 \)). This LBNP-induced fall in FBF was not affected by supplemental NG. SV and Q displayed similar alterations in the control and NG trials. LBNP at \(-40 \text{ mmHg}\) produced consistent reductions in both SV and Q (main effect, \( P < 0.005 \) ; Table 2). Additionally, LBNP at \(-40 \text{ mmHg}\) reduced SVC (main effect, \( P < 0.005 \)) and elevated TPR (main effect, \( P < 0.05 \)) relative to baseline. The CPT had little systematic effect on SV, Q, TPR, or SVC either with or without NG (Table 2).

**Brachial artery diameter.** Compared with baseline, diastolic and systolic brachial diameters remained unchanged during the
application of LBNP and CPT in the control session (Fig. 2). The individual responses in diastolic diameter to LBNP −40 mmHg were somewhat variable and unrelated to gender (Fig. 3). Following NG administration a main effect of drug was evident (P < 0.0001), such that diastolic and systolic diameters were increased compared with corresponding control conditions. This translated to an average increase in diastolic diameter of 12% during NG baseline, 11% during NG-LBNP (P < 0.05), and 17% during NG-CPT. Systolic diameter responded similarly, with a dilation of 12% during NG baseline, 10% during NG-LBNP (P < 0.05), and 17% during NG-CPT. Reflex sympathetic activation with LBNP and the CPT caused a general reduction in the pulsatile diameter change (systolic-diastolic diameter) of the brachial artery (P < 0.05; Table 2). This effect was not modified by NG.

Brachial artery distensibility. Reflex sympathetic activation initiated by LBNP (−15, −40 mmHg) and the CPT resulted in a reduction of both DA and DP in the brachial artery (Fig. 4). Compared with baseline, LBNP at levels of −15 mmHg and −40 mmHg resulted in a 25% and 31% reduction in DA, respectively, while CPT caused a 54% decline (P < 0.05). Moreover, the reduction in DA was greater in the CPT vs. LBNP trials (P < 0.05). Similarly, DP was decreased by 31%, 29%, and 53% in the respective conditions (Fig. 4) (P < 0.05). The individual responses of DA to LBNP (P < 0.05). Similarly, DP was decreased by 31%, 29%, and 53% in the respective conditions (Fig. 4) (P < 0.05). The individual responses of DA to LBNP −40 are shown in Fig. 5, demonstrating a reduction from baseline in all participants.

Following NG, DA and DP during LBNP were still reduced relative to corresponding control conditions (main effect; P < 0.05) (Fig. 3). In detail, compared with NG baseline, DA was lowered by 21%, 30%, and 54% during NG-LBNP −15 mmHg (not significant), NG-LBNP −40 mmHg (P < 0.05), and NG-CPT (P < 0.001) conditions, respectively. Similarly, DP declined by 24%, 37%, and 60% during NG-LBNP −15 mmHg (not significant), NG-LBNP −40 mmHg (P = 0.05), and NG-CPT (P < 0.001), respectfully. For each reflex protocol, the reduction in DA and DP was similar with or without NG (Table 3).
DISCUSSION

The major findings of this study were 1) LBNP and CPT both caused a reduction in brachial artery distensibility without changes in diastolic diameter, and 2) reflexive reductions in brachial distensibility were not reduced by NG. Therefore, these data argue against the hypothesis that exogenous NO can inhibit sympathetically-mediated changes in conduit vessel mechanics. Evidence that this stiffening of the brachial artery occurred during both levels of LBNP as well as during CPT suggest that it was the sympathetic stimulus causing the constriction rather than changes in heart rate or blood pressure per se. Therefore, these data do support the second purpose of the study with evidence that conduit vessel distensibility may be an important conduit vessel response to sympathetic activation, rather than a more generalized constriction that is typically detected during diastole.

Sympathetic vascular control of arterial mechanics. The present data are consistent with previous reports that sympathetic excitation has limited effect on medium-sized conduit vessel diameter (6), even though it is innervated and equipped with adrenergic receptors that respond to sympathetic activation (33). Nonetheless, some reports indicate that this vessel can constrict, but this effect appears to be observed in a reflex-specific manner (6, 26). Additionally, variations in the duration and intensity of the sympathetic stimulus could affect the results. Furthermore, the heterogeneous responses among individuals may underlay between-study inconsistencies (see Fig. 2).

Despite the inconsistent and minimal effect on brachial artery diastolic diameter change, both LBNP and CPT were effective in reducing both peak and average brachial distensibility across all individuals. The $D_A$ measure is representative of the relative pressure-diameter relationship over the entire normalized cardiac cycle, whereas $D_P$ assesses distensibility at the onset of systole, when pressure is lowest. Reductions in both values suggest a generalized stiffening of the vascular tissue.

The important element of these observations is that a stiffening of the vascular system may occur without detectable changes in the caliber (or diameter) of the vessel in question. A similar stiffening of the forearm vascular tree without consistent change in its vascular resistance was demonstrated previously in our laboratory (40). This type of response is also present in the data provided by Boutouyrie et al. (2) who examined the radial artery and observed an increased stiffness during smoking and mental stress without change in the mean diameter. Moreover, in both the current and previous studies, the reflexive change in vasomotor stiffness was consistent across participants, in contrast to the heterogeneous changes in vascular resistance or conduit artery diameter. Thus, we speculate that the stiffness of the vascular tree, at least in skeletal muscle beds, is an important regulatory target of neurogenic input. The mechanism of this control feature is beyond the current study but must include the interaction of the contractile and elastic elements of the vessel wall. While the benefit of such a control feature requires further analysis, it is expected to include a modification of flow transit time through the vascular bed and back to the heart.

NG administration during sympathetic challenge. This stiffening of the brachial artery was graded with the level of LBNP in a manner that is consistent with the incremental increase in SNA (14). Whether this trend continued into the CPT cannot be determined with certainty because, although the reduction in distensibility with the CPT was greater than during both levels of LBNP, the muscle sympathetic nerve responses to $-40$ mmHg LBNP and a CPT are quite similar (30). Rather, it is possible that the CPT interferes with endothelial function (6), thereby reducing an effect of endogenous dilators on conduit vessel distensibility. If so, then a further item for investigation is the role of endogenous vs. exogenous NO (that is added to existing endogenous activity) in counteracting neurogenic changes in conduit vessel mechanics.

Previous lines of evidence suggest that NO can modulate sympathetic control at multiple levels of the neurovascular...
system, including direct relaxation of arterial smooth muscle, metabolism of NE in the neurovascular space, and inhibition of sympathetic outflow in postganglionic sympathetic neurons and the central nervous system (16, 27, 41). Previously, NG provided by intravenous infusion (1) or sublingual oral presentation (15) increased brachial artery elasticity under baseline conditions. This effect was not observed in the current study and the reasons for the disparity are not clear, but may be related to the short duration of baseline NG measures that were necessary in this study (see below). Nonetheless, the effectiveness of NG administration was evident in the expected dilation of the brachial artery (3) and the elevation in HR. However, in contrast to the hypothesis, the reduction in brachial artery distensibility with LBNP and CPT was unaltered with NG.

Additional methodological considerations. As mentioned briefly above, a possible limitation of the NG component of this study includes the timing of the various measurements to coordinate baseline and peak response periods with the transient impact of NG. Specifically, it was necessary to obtain NG baseline measurements after only 2 min, whereas maximal dilation usually requires ~4–6 min (3). The current investigation was designed so that its maximal vascular effects occurred simultaneously with the sympathetic perturbations at the possible expense of baseline effects of NG. Thus, while NG effects on baseline conduit vessel mechanics may suffer from suboptimal timing, the impact of this intervention during sympathetic activation was optimized.

Additionally, as NG dilated the brachial artery, the effect of exogenous NO on distensibility could be masked by the artery moving to the end of the diameter-pressure relationship. Stated differently, a fully dilated artery may be unable to distend further during systole. However, Dp was assessed at low pressure where a limitation of wall distension should not have occurred. The reductions in both average and Dp indicate a neurogenically-mediated reduction in brachial artery elasticity that affected the entire pressure-diameter relationship.

Finally, it should be recognized that neurogenic factors may not be the only constrictors at work during reflex sympathetic activation. There is some evidence that the renin-angiotensin-aldosterone system and vasopressin may be involved in the hormonal response to LBNP, although this is unlikely during the brief durations used in the current study (Sander-Jensen et al., 26a; Mohanty et al., 22a). Additionally, during cold stress the release of vasoconstrictor factors such as angiotensin II, endothelin, and prostaglandins has been reported (Velasco et al., 34a). Based on these reports, these vasoactive agents oppose the vascular effect of NO, and some have been shown to antagonize NO production. The possibility for interaction between NO and these various constrictor factors was not addressed in the current study.

**Perspectives and Significance**

The vasculature provides the means by which blood supply to skeletal muscle is regulated. The current view of this regulation is that it is achieved by a change in the diameter of resistance vessels that, in turn, produces a change of resistance to flow. While this view deals adequately with the steady component of blood flow, it is incomplete when dealing with the full pulsatile character of the flow. In pulsatile flow, the compliance of blood vessels plays an important role in the mechanics of the flow.

A change in the elasticity of the vessel wall provides an additional mechanism for control of flow through a vessel. In turn, vasomotor control is complex and involves multiple neurogenic, endocrine, and paracrine regulators. This study examined the concurrent influence of sympathetic activation and supplemental NO on the local stiffness and diameter of the brachial conduit vessel. The results suggest that conduit vessel stiffness is an important neurogenic target during baroreflex unloading. Neural control and regulation of blood supply to skeletal muscle is thus seen to consist of not only a change of

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**Table 3. Comparison of brachial distensibility and pulsatile diameter between experimental conditions**

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<th>Control</th>
<th>Nitroglycerin</th>
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<tr>
<td></td>
<td>Baseline</td>
<td>LBNP, 15 mmHg</td>
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<tr>
<td>ΔD&lt;sub&gt;a&lt;/sub&gt;, 10&lt;sup&gt;-3&lt;/sup&gt;</td>
<td>0.77±0.27</td>
<td>0.59±0.28*</td>
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<tr>
<td>ΔΔD&lt;sub&gt;a&lt;/sub&gt;, 10&lt;sup&gt;-3&lt;/sup&gt;</td>
<td>NA</td>
<td>-0.18±0.13</td>
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<tr>
<td>D&lt;sub&gt;p&lt;/sub&gt;, 10&lt;sup&gt;-3&lt;/sup&gt;</td>
<td>1.08±0.55</td>
<td>0.73±0.38*</td>
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<tr>
<td>ΔΔD&lt;sub&gt;p&lt;/sub&gt;, 10&lt;sup&gt;-3&lt;/sup&gt;</td>
<td>NA</td>
<td>-0.34±0.31</td>
</tr>
<tr>
<td>Diam</td>
<td>0.20±0.06</td>
<td>0.16±0.06</td>
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Values are means±SD. ΔD<sub>a</sub>, average distensibility (mmHg<sup>-1</sup>); ΔΔD<sub>a</sub>, change in average distensibility from baseline (mmHg<sup>-1</sup>); D<sub>p</sub>, peak distensibility (mmHg<sup>-1</sup>); ΔΔD<sub>p</sub>, change in peak distensibility from baseline (mmHg<sup>-1</sup>); Diam, systolic/diastolic diameter (mm); NA, not applicable. *Significantly different from control baseline; †significantly different from nitroglycerin baseline; ‡significantly different from LBNP, 15 mmHg and LBNP, 40 mmHg (P < 0.05). 

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vessel caliber to affect a change of resistance to the steady component of the flow, but also a change in the elasticity of the vessel wall to affect a change of impedance to the oscillatory component of flow.

**GRANT**

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**REFERENCES**


