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Reduced Cerebral Blood Flow in Older Men with Higher Levels of Blood Pressure

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Abstract

Objective—Examine relations of blood pressure (BP) to single photon emission computed tomography (SPECT)-derived estimates of cerebral blood flow in older men and women.

Methods—Seventy-four stroke and dementia-free, community-dwelling older adults (ages 54–83; 68% men; 91% White) free of major medical, neurological, or psychiatric disease, engaged in a) clinical assessment of resting systolic and diastolic BP; b) magnetic resonance imaging (MRI) rated for brain atrophy; and c) brain SPECT studies with computerized coding of cortical and select subcortical regions of interest (ROIs).

Results—Given significant interactions of BP and sex with respect to multiple SPECT outcomes, sex-stratified multiple regression models were computed. Models were adjusted for age, fasting glucose levels, antihypertensive medication, body mass index, and MRI ratings of brain atrophy. In men ($n = 50$), higher levels of systolic and/or diastolic BP were associated significantly with lower estimates of cerebral perfusion in the right and left frontal, temporal, parietal, and occipital cortex, thalamus, head of caudate and cingulate cortex accounting for up to 28% of the variance in these measures (p 's $< .05$). In women ($n = 24$), higher diastolic BP related marginally to higher levels of perfusion in the right temporal cortex ($p = .05$).

Conclusions—Higher resting systolic or diastolic BP was associated with lower levels of cerebral perfusion in otherwise healthy older men, but not women, in the present sample. Reduced cerebral blood flow may play a pathogenic role in increasing risk for stroke, dementia, and or cognitive decline particularly among older men with high blood pressure.

Keywords

blood pressure; hypertension; cerebral blood flow; cerebral perfusion; brain SPECT

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Introduction

Elevated blood pressure (BP) and hypertension are potent risk factors for stroke [1], silent cerebrovascular disease [2,3], lower levels of cognitive function [4], cognitive decline [5,6], and dementia [7,8]. Hypertension is considered a risk factor for both Alzheimer's disease and vascular dementia; it has been hypothesized that cerebral hypoperfusion associated with hypertension and other cardiovascular risk factors may be a critical factor leading to the pathogenesis of both forms of dementia. [8]. Indeed, cerebral hypoperfusion has been found to precede pathogenic changes in brain morphology by up to two years [9] and may precede the clinical onset of dementia [10].

Prior research has noted lower levels of global or regional cerebral perfusion among hypertensives and spontaneously hypertensive rats [11–14]. Correlations of continuous levels of mean arterial pressure and cerebral perfusion have also been identified [11]. Recent work has demonstrated that hypertensives display greater decreases in regional cerebral blood flow (rCBF) over time in the prefrontal, anterior cingulate, and occipital cortex [15]. To our knowledge, possible sex differences in the relations of blood pressure to rCBF have not been examined explicitly. Because of previously documented sex differences in cerebral perfusion and blood pressure levels [16,17], we examined relations of continuous levels of systolic and diastolic BP to SPECT-derived measures of rCBF in older men and women, the age cohort at greatest risk for stroke and dementia.

Methods

Participants were 74 healthy, community-dwelling older adults [ages 54–83; 68% men; 91% White], with available data to date, enrolled in an ongoing investigation of cardiovascular risk factors, brain, and cognitive function. Participants were recruited for the parent study by newspaper and other local advertisement, from the Geriatric Research Education and Clinical Center at the Baltimore Veterans Affairs Medical Center [B-VAMC], and by general advertisement at the B-VAMC. Exclusionary criteria were history or clinical evidence of cardiovascular disease (other than mild-to-moderate hypertension), diabetes mellitus, other major medical disease (e.g., renal, hepatic, pulmonary), neurologic disease, stroke, known or suspected dementia (Mini-Mental State Examination score < 24), self-reported psychiatric disorder, heavy alcohol use (> 14 drinks per week), severe head injury, or medications affecting central nervous system function. Participants taking antihypertensives had their medications withdrawn for at least two weeks (> five half lives) prior to brain SPECT imaging. Sample characteristics are displayed in Table 1. Women were post-menopausal and 34% were taking hormone therapy. Participants provided written informed consent according to the guidelines of the University of Maryland, Baltimore and University of Maryland, Baltimore County's Institutional Review Boards.

Biomedical Assessment

Participants underwent a comprehensive medical evaluation that included history, physical examination, blood chemistries, a graded exercise treadmill test, and an oral glucose tolerance test. Resting BP, and fasting lipids and glucose were assessed while participants were taking their routine medications. Total plasma cholesterol and glucose levels were determined enzymatically. Clinical assessment of BP was performed on 2–3 occasions with patients in a seated position using an automated vital signs monitor (Dinamap Model # 1846SX, Critikon, Tampa, FL) and appropriate sized occluding cuff. The readings were averaged to yield an estimate of participants' resting systolic and diastolic BP. Body mass index(BMI) was computed by dividing measured weight (in kg) by measured height (m^2).

Magnetic Resonance Imaging

Magnetic resonance imaging was performed utilizing a Phillips 1.5 Tesla scanner. The imaging protocol consisted of sagittal T1 (TR/TE/thickness/matrix/FOV/averages = 465/14/6 mm/192X256/24/1) axial T1 (600/14/5 mm/192X256/23/2), dual contrast proton density/T2 (3500/16,96/5 mm/192x256/23/2), and fluid attenuated inversion recovery (FLAIR) (TR/TE/TI/thickness/matrix/FOV/averages = 8000/120/2200/5 mm/192x256/21/2) sequences. Images were rated for brain atrophy (sulcal widening, and ventricular enlargement) by a board-certified neuroradiologist (D.M.L.), who was blinded to participant characteristics (including BP), using the following coding scale: 0 = absent; 1 = mild; 2 = moderate; 3 = severe. Ratings were summed to yield a single index of brain atrophy.

Brain SPECT Imaging

Two hours following injection with ^{99m} Technetium (Neurolite), participants engaged in brain SPECT imaging performed using a Picker Prism 3000 triple headed SPECT scanner with a high-resolution fan beam collimator. The acquisition matrix was 128 × 128 pixels with a 360 degree rotation (120 degrees per head). Imaging was acquired in a series of 40 stops per head at 3 degrees per step with a duration of 25 seconds per step. If necessary, an X-Y SPECT motion correction algorithm was used. Reconstruction utilized a standard ramp filter, a 3D post-filter with a 0.76 multiplier, and attenuation correction algorithm using a coefficient of 0.12 and an ellipse fit of one per file.

Computerized coding of the perfusion images was performed using the Cerebral Blood Flow (1999) program developed by Sopha Medical Vision (SMV) America (Twinsburg, OH) on a SMV PowerStation computer. Following oblique reconstruction for anatomic normalization, these images were used to derive relative ratios of blood flow in regions of interest (ROIs). ROIs were predetermined by the research team using anatomic landmarks [18]. These included the right and left frontal, temporal, parietal, and occipital cortex, thalamus, head of caudate, anterior cingulate cortex, and cerebellum. SPECT methodology does not provide interpretable absolute perfusion counts, but rather permits computation of relative ratios of flow in different brain regions such as frontal cortex to cerebellum. Here, mean counts for each ROI were used as numerators to derive relative ratios of blood flow in all defined ROIs. The cerebellum was used as a standard denominator to calculate the relative uptake ratios [19]. Coding was completed using nine 1.3 cm thick transaxial slices such that the top slice corresponded to the first image of the brain's gray-white junction and the ninth image corresponded to the cerebellum. To assess inter-rater reliability of the SPECT coding, all of the SPECT images were coded by two raters (CFT, RJS). Intraclass correlations revealed coefficients greater than 0.90 across all perfusion estimates.

Data Analyses

Initial multiple regression models, conducted with the entire sample of 74 participants, included age, sex, use of antihypertensive medication (yes/no), fasting plasma glucose levels, BMI, brain atrophy, systolic BP, and the interaction of sex and systolic BP. Models were then re-computed with diastolic BP. Sex-stratified models were then examined for each ROI as a function of systolic then diastolic BP.. Adjustment variables were included on the basis of theoretical associations with predictors or outcomes, in addition to significant empirical relations across multiple variables in the present data. Following an analysis of residuals, data from one outlier was removed from the analyses.. Otherwise, the residuals were homoscedastic and normally distributed. With the exception of newly attained significant for systolic BP and both left occipital cortex and left head of caudate, results remained identical with the outlier included.

Results

Results revealed significant interactions of sex and diastolic BP for the following ROIs: right frontal cortex, left and right temporal cortex, left and right occipital cortex, and right thalamus (p 's < .05). Significant interactions of sex and systolic BP were found for the left and right occipital cortex (p 's < .05). Marginally significant relations of the sex and diastolic BP interaction (p 's < .10) were noted for the left frontal cortex, and for the sex and systolic BP interaction for the left and right occipital cortex.

To clarify the numerous interactions of sex and BP, sex-stratified multiple regression models (see Table 2) were next computed and included age, antihypertensive medications, fasting plasma glucose levels, BMI, and brain atrophy as adjustment variables. Systolic and diastolic BP levels were modeled in separate analyses. Results indicated significant relations of diastolic BP to lower levels of perfusion in the following ROIs in men: left and right frontal cortex, left and right temporal cortex, right and left parietal cortex, right occipital cortex, and right and left thalamus, right and left head of caudate, and left cingulate (marginal). In men, with the exception or right and left head of caudate, systolic BP was associated significantly with lower perfusion estimates in the same regions plus the left cingulate cortex.. In women, the only relation that approached significance (p = .05) was noted for diastolic BP was with perfusion in the left temporal cortex (see Figure 1). Brain atrophy was a potent predictor of rCBF in the right and left frontal cortex in women (p 's < .05) explaining 20% and 32% of the variance in perfusion, respectively.

Correlations were computed between rCBF and MMSE scores for the entire sample. These ranged from .01 to .20, and none was significant. Associations with more extensive neurocognitive testing will be examined following further data collection.

Discussion

To our knowledge, this was the first investigation to examine explicitly the interaction of BP and sex with respect to cerebral perfusion. Results indicated that SPECT-derived estimates of CBF were reduced in the majority of cortical (i.e., frontal, temporal, parietal, occipital) and select subcortical (i.e., thalamus, head of caudate, cingulate) regions in men, with higher levels of systolic or diastolic BP explaining a substantial proportion of variance (i.e., up to 28%) in these measures. The magnitude of these associations is particularly striking given that the upper range of BP did not exceed mild to the lower end of moderate hypertension. However, minimal associations were noted in women, with a relation of diastolic BP to perfusion only approaching significance in the right temporal cortex. Despite the power limitations associated with the small sample of women, all but one association noted in women was in the opposite direction from the men – higher levels of BP were associated with greater rCBF.

Prior research has demonstrated reduced resting global or regional cerebral perfusion among hypertensives [11–14], in addition to perfusional decline over time [15]. Pattern of decreases have varied across studies, but often include the frontal, temporal, and occipital cortex, “watershed” regions, areas of the basal ganglia, and the anterior cingulate cortex [11–15]. The present pattern of findings in men is quite similar. Differences in the patterns of rCBF findings across studies may be due, in part, to striking differences in study methodologies including sample size, characteristics, and exclusions; technology used to estimate CBF; type of statistical analyses employed; and use of pertinent adjustment variables. With respect to the latter point, a number of critically important confounding variables such as age and co-morbidities that could affect CBF were not evaluated in all prior work. Further, few studies have examined the linear relations of BP levels to cerebral perfusion. Such assessment is

important particularly given Joint National Committee 7 BP classifications that include a pre-hypertensive category at systolic BP ranging from 120 – 139 mm Hg [17]

Some prior research has demonstrated sex differences in CBF such that women have greater levels of perfusion than men [16]. However, to our knowledge, sex differences in the relation of blood pressure to rCBF have not been examined. Meyer and colleagues [20] have previously reported that male sex and hypertension are risk factors for decline in cerebral perfusion, but the interaction of these variables was not examined explicitly. Our findings, if replicated, suggest the utility of evaluating whether somewhat different biological mechanisms may underlie relations of blood pressure (or hypertension) to rCBF and perhaps also cognitive difficulties, dementia, and/or stroke in men and women, or if older age cohorts are affected differently than younger age cohorts. For example, in the present sample, variability in rCBF in the frontal cortex in women was largely explained by brain atrophy whereas BP was the most potent predictor in men. It is also possible that the identified sex differences, in part, reflect the well-known earlier manifestations of cardiovascular disease in men than in women. In addition, it is notable that about one-third of the women in this study were taking hormone therapy which may have contributed to the noted sex differences. Further, possible sex difference in cerebral vessel diameter may influence the present findings.

It has been suggested that even very slight reductions in CBF in hypertension may place the cerebral circulation at risk for infarction [21]. Cerebral hypoperfusion is also thought to be particularly important to the ultimate development of dementia. De la Torre has suggested that a critically attained threshold of cerebral hypoperfusion triggers a series of cerebrovascular changes that include increased oxidative stress and impaired nitric oxide activity, pathogenic processes that then promote Alzheimer's disease and vascular dementia [8]. Hypertension has indeed been associated with increased oxidative stress in the brain [22]. Interestingly, male rats exhibit higher levels of oxidative protein damage than same-aged females [23]. In humans, men show a higher oxidative stress index than women [24]. Further, males may also show greater oxidative stress in a hypertensive rat model [25]. It is conceivable that these sex differences could, in part, underlie the differential associations of BP to rCBF noted here. Hypertension has also been associated with impaired endothelial function including diminished endothelium-dependent relations of the cerebral blood vessels possibly due to insufficient nitric oxide activity [26], although sex differences have not been noted.

The present investigation had several limitations. The first is use of a cross-sectional design. It is critical to determine the prognostic significance of BP-related reductions in CBF to clinical outcomes, and whether these relations differ as a function of sex. Second, the small, relatively homogeneous, and non-representative sample limits the generalizability of these findings. Further, there were about half as many women as men. Thus, power was a particular concern for detecting significant associations among women. Yet, it is notable that all relations between BP and rCBF in women were either flat or showed a slightly positive association which is opposite to the relation noted in men. Furthermore, post-hoc power analyses revealed that, with the exception of the right temporal cortex, between 158 to 876 female participants would have been needed to achieve statistical significance given the present effect sizes. This suggests that any effects present in the current sample are unlikely to be clinically meaningful. Third, because only those with mild to moderate hypertension were admitted to the protocol due to safety concerns about medication withdrawal, associations of BP to rCBF are likely underestimated in the present analyses. Fourth, history of, and adherence to, antihypertensive medication is unknown. Plus, it is possible that rCBF per se may influence BP response to antihypertensives (27). Fifth, the small sample size limits our statistical power. Use of a larger sample would also permit the evaluation of possible threshold effects with respect to systolic and diastolic BP. Sixth, use of brain SPECT imaging confers limited ability to estimate perfusion in subcortical ROIs and generally provides less spatial resolution than positron emission tomography.

To conclude, results of the present study demonstrate for the first time interactive relations of sex and continuous levels of BP with respect to cerebral perfusion. Sex-specific analyses revealed that men with higher BP showed lowered levels of perfusion in almost all cortical and subcortical regions accounting for a substantial proportion of variance in many of these measures. Such lowered levels of perfusion may confer risk for future cognitive decline, dementia, and stroke. Potential sex differences in these associations require further examination.

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References

1. Lewington S, Clarke R, Qizilbash N, Peto R, Collins R. Prospective Studies Collaboration. Age-specific relevance of usual blood pressure to vascular mortality: a meta-analysis of individual data for one million adults in 61 prospective studies. *Lancet* 2002;360:1903–1913. [PubMed: 12493255]
2. Liao D, Cooper L, Cai J, Toole JF, Bryan NR, Hutchinson RG, Tyroler HA. Presence and severity of cerebral white matter lesions and hypertension, its treatment, and its control. The ARIC study. *Stroke* 1996;27:2262–70. [PubMed: 8969791]
3. Hougaku H, Matsumoto M, Kitagawa K, et al. Silent cerebral infarction as a form of hypertensive target organ damage in the brain. *Hypertension* 1992;20:816–20. [PubMed: 1452297]
4. Waldstein SR, Katzel LI. Hypertension and cognitive function. In: Waldstein SR, Elias MF, editors. *Neuropsychology of Cardiovascular Disease*. Mahwah, NJ: Lawrence Erlbaum Associates; 2001. p. 15–36.
5. Elias PK, Elias MF, Robbins MA, Budge MM. Blood pressure-related cognitive decline: does age make a difference? *Hypertension* 2004;44:631–636. [PubMed: 15466661]
6. Waldstein SR, Giggey PP, Thayer JF, Zonderman AB. Nonlinear relations of blood pressure to cognitive function: the Baltimore Longitudinal Study of Aging. *Hypertension* 2005;45:374–397. [PubMed: 15699446]
7. Meyer JS, Rauch GM, Rauch RA, Anwarul H, Crawford K. Cardiovascular and other risk factors for Alzheimer's Disease and vascular dementia. *Ann NY Acad Sci* 2000;903:411–423. [PubMed: 10818532]
8. De La Torre JC. Vascular basis of Alzheimer's pathogenesis. *Ann NY Acad Sci* 2002;977:196–215. [PubMed: 12480752]
9. Meyer JS, Rogers RL, Mortel KF. Progressive cerebral ischemia antedates cerebrovascular symptoms by two years. *Ann Neurol* 1984;16:314–320. [PubMed: 6486737]
10. Ruitenberg A, den Heijer T, Bakker SL, van Swieten JC, Koudstaal PJ, Hofman A, Breteler MM. Cerebral hypoperfusion and clinical onset of dementia: the Rotterdam Study. *Ann Neurol* 2005;57:789–794. [PubMed: 15929050]
11. Rodriguez G, Arvigo F, Marengo S, Nobili F, Romano P, Sandini G, Rosadini G. Regional cerebral blood flow in essential hypertension: data evaluation by a mapping system. *Stroke* 1987;18:13–20. [PubMed: 3810745]
12. Nobili F, Rodriguez G, Marengo S, et al. Regional cerebral blood flow in chronic hypertension. A correlative study. *Stroke* 1993;24:1148–1153. [PubMed: 8342188]
13. Salerno JA, Grady C, Mentis M, Gonzalez-Aviles A, Wagner E, Schapiro MB, Rapoport SI. Brain metabolic function in older men with chronic essential hypertension. *Journal of Gerontology: Medical Sciences* 1995;50A:M147–M154.
14. Fujishima M, Ibayashi S, Fujii K, Mori S. Cerebral blood flow and brain function in hypertension. *Hypertens Res* 1995;18:111–117. [PubMed: 7584916]

15. Beason-Held LL, Moghekar A, Zonderman AB, Kraut MA, Resnick SM. Longitudinal changes in cerebral blood flow in the older hypertensive brain. *Stroke* 2007;38:1766–1773. [PubMed: 17510458]
16. Gur RC, Gur RE, Obrist WD, et al. Sex and handedness differences in cerebral blood flow during rest and cognitive activity. *Science* 1982;217:659–661. [PubMed: 7089587]
17. Chobanian AV, Bakris GL, Black HR, et al. The Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure: the JNC 7 report. *JAMA* 2003;289:2560–2572. [PubMed: 12748199]
18. Nolte, J.; Angevine, JB. The human brain: In photographs and diagrams. St. Louis, MO: Mosby Year Book Inc; 1995.
19. Schmitt FA, Shih WJ, Dekosky ST. Neuropsychological correlates of single photon emission computed tomography (SPECT) in Alzheimer's disease. *Neuropsychology* 1992;6:159–171.
20. Meyer JS, Rauch G, Rauch RA, Haque A. Risk factors for cerebral hypoperfusion, mild cognitive impairment, and dementia. *Neurobiol Aging* 2000;21:161–169. [PubMed: 10867201]
21. Dickinson CJ. Cerebral oxidative metabolism in essential hypertension: a meta-analysis. *J Hypertension* 1995;13:653–658.
22. Poulet R, Gentile MT, Vecchione C, et al. Acute hypertension induces oxidative stress in brain tissues. *Journal of Cerebral Blood Flow & Metabolism* 2006;26:253–262. [PubMed: 16079792]
23. Kayali R, Cakatay V, Tekeli F. Male rats exhibit higher oxidative protein damage than females of the same chronological age. *Mech Ageing Dev* 2007;128:365–369. [PubMed: 17451787]
24. Veglia F, Cighetti G, De Franceschi M, Zingaro L, Boccotti L, Tremoli E, Cavalca V. Age- and gender-related oxidative status determined in healthy subjects by means of OXY-SCORE, a potential new comprehensive index. *Biomarkers* 2006;11:562–573. [PubMed: 17056475]
25. Banos G, Medina-Camps ON, Maldonado PD, Zamora J, Perez I, Pavon N, Pedraza-Chaverri J. Antioxidant enzymes in hypertensive and hypertriglyceridemic rats: effect of gender. *Clin Exp Hypertens* 2005;27:45–57. [PubMed: 15773229]
26. Cosentino F, Volpe M. Hypertension, stroke, and endothelium. *Current Hypertension Reports* 2005;7:68–71. [PubMed: 15683589]
27. Jennings JR, Muldoon MF, Whyte EM, Scanlon J, Price J, Meltzer CC. Brain imaging findings predict blood pressure response to pharmacological treatment. *Hypertens* 2008;52:1113–1119.

Figure 1.
Relations of Diastolic Blood Pressure to Perfusion in the Right Temporal Cortex in Men and Women

Table 1

Sample Characteristics

	Men (N=50)		Women (N=24)		Total (N = 74)	
	Mean or %	SD	Mean or %	SD	Mean or %	SD
Age (yrs)	67.29	6.65	64.65	6.19	66.33	6.59
Education (yrs)	16.41	3.10	15.92	2.59	16.23	2.93
Sex	--	--	--	--	68%	--
Race (%White)	94	--	83	--	91	--
Brain Atrophy	2.39	1.17	1.35	0.90	2.01	1.18
Systolic BP (mmHg)	135.28	17.29	126.71	17.96	132.14	17.96
Diastolic BP (mmHg)	76.92	7.96	71.96	9.74	75.11	8.94
Prior Hypertension Diagnosis (%)	34	--	29	--	36	--
Antihypertensives (%)	22	--	21	--	22	--
Glucose (mg/dl)	99.15	14.01	91.19	8.11	96.29	12.77
Total Cholesterol (mg/dl)	187.85	29.63	214.01	29.54	197.49	32.09
Body Mass Index (kg/m ²)	27.69	4.01	27.14	5.41	27.48	4.56
Smoking (%ever)	50	--	57	--	53	--

	M	SD	M	SD	M	SD
R Frontal	0.92	0.12	0.92	0.09	.92	.10
L Frontal	0.91	0.10	0.91	0.10	.91	.10
R Temporal	0.98	0.14	0.99	0.08	.98	.12
L Temporal	0.95	0.11	0.97	0.09	.96	.10
R Parietal	0.98	0.13	0.96	0.09	.98	.12
L Parietal	0.98	0.12	0.96	0.09	.98	.11
R Occipital	0.93	0.11	0.97	0.08	.95	.11
L Occipital	0.93	0.11	0.96	0.09	.94	.10
R Thalamus	0.61	0.09	0.57	0.06	.60	.08
L Thalamus	0.62	0.09	0.57	0.07	.61	.09
R HOC	0.56	0.08	0.55	0.06	.56	.07
L HOC	0.56	0.09	0.56	0.05	.56	.08

	M	SD	M	SD	M	SD	M	SD
R Cingulate	1.04	0.13	1.05	0.10	1.04	0.11	1.03	.12
L Cingulate	1.02	0.13	1.04	0.11	1.03	0.11	1.03	.12

R= Right; L = Left

Table 2

Relations of SBP or DBP to rCBF in Men and Women

ROI	Predictor	MEN				WOMEN			
		Beta	r ² *	t	p	Beta	r ²	F	p
R Frontal	SBP	-.003	.11	-2.34	.02	.001	.05	1.21	.24
	DBP	-.006	.16	-3.02	.004	.002	.03	.97	.35
L Frontal	SBP	-.003	.12	-2.50	.02	.001	.03	1.05	.31
	DBP	-.005	.15	-2.80	.008	.001	.01	.59	.56
R Temporal	SBP	-.003	.15	-2.86	.007	.001	.04	1.00	.33
	DBP	-.009	.28	-4.32	.0001	.004	.15	2.10	.05
L Temporal	SBP	-.003	.15	-2.84	.007	.001	.01	.52	.61
	DBP	-.007	.26	-4.06	.0001	.003	.05	1.05	.31
R Parietal	SBP	-.003	.09	-2.19	.03	.001	.03	1.02	.32
	DBP	-.005	.11	-2.34	.02	.002	.01	.62	.54
R Occipital	SBP	-.003	.14	-2.74	.009	.002	.10	1.53	.14
	DBP	-.005	.16	-2.92	.006	.004	.13	1.79	.09
L Occipital	SBP	-.002	.06	-1.73	.09	.002	.06	1.21	.24
	DBP	-.003	.07	-1.84	.07	.003	.06	1.23	.24
R Thalamus	SBP	-.003	.19	-3.29	.002	.002	.09	1.47	.16
	DBP	-.006	.28	-4.37	.0001	-.001	.01	.61	.55
L Thalamus	SBP	-.002	.09	-2.19	.03	.001	.05	1.05	.31
	DBP	-.004	.14	-2.85	.007	-.001	.02	.63	.54
R HOC	SBP	-.001	.04	-1.53	.13	.000	.00	-.02	.99
	DBP	-.003	.10	-2.33	.03	-.001	.03	-.82	.42
L HOC	SBP	-.002	.07	-1.91	.06	.000	.000	-.05	.96
	DBP	-.003	.09	-2.20	.03	-.001	.03	-.80	.43
R Cingulate	SBP	-.002	.03	-1.23	.22	.002	.09	1.56	.14
	DBP	-.003	.03	-1.24	.22	.003	.05	1.15	.27
L Cingulate	SBP	-.003	.10	-2.30	.03	.002	.07	1.27	.22
	DBP	-.005	.08	-2.02	.05	.002	.02	.72	.48

* r² = the squared semi-partial correlation coefficient which reflects the unique variance explained by SBP or DBP term after statistical adjustment for all other variables in the multiple regression model

R = right; L = left; SBP = systolic blood pressure; DBP = diastolic blood pressure; HOC = head of caudate