Asymmetric Dimethylarginine in Cerebral Small Vessel Disease

Usman Khan, MRCP; Ahamad Hassan, MRCP; Patrick Vallance, FRCP; Hugh S. Markus, FRCP

Background and Purpose—Endothelial dysfunction may play a causal role in cerebral small vessel disease (SVD). Asymmetric dimethylarginine (ADMA), a circulating endogenous inhibitor of nitric oxide, has been implicated in endothelial dysfunction, particularly in hyperhomocystinemia, a known risk factor for SVD. We determined if ADMA was elevated in SVD, correlated with disease severity, and interacted with homocysteine.

Methods—ADMA and homocysteine levels were determined in 47 consecutive symptomatic SVD patients and 38 controls. SVD was graded by leukoaraiosis severity and number of lacunar infarcts.

Results—Mean (and SD) ADMA was higher in SVD patients compared with controls (0.814 [0.145] versus 0.747 [0.184] μmol/L; P=0.014) after controlling for age, gender, vascular risk factors, and creatinine clearance. Additionally controlling for homocysteine had only a small effect on this relationship (P=0.055). Mean homocysteine was higher in SVD cases compared with controls (15.14 [5.59] versus 12.49 [4.15] μmol/L; P=0.035). Leukoaraiosis grade correlated positively with ADMA (P=0.026) and homocysteine (P=0.003). Lacunar grade correlated with homocysteine (P=0.017), but not ADMA.

Conclusions—ADMA is independently associated with SVD and correlates with leukoaraiosis severity. (Stroke. 2007;38: 000-000.)

Key Words: ADMA ■ endothelial dysfunction ■ homocysteine ■ lacunar ■ leukoaraiosis ■ stroke

Cerebral small vessel disease (SVD) causes both lacunar infarction and more diffuse subcortical ischemic change referred to as leukoaraiosis. The pathogenesis of the underlying arteriopathy is uncertain but studies have implicated both endothelial dysfunction and hyperhomocysteinemia, particularly when lacunar infarction is accompanied by confluent leukoaraiosis.1,2

Asymmetric dimethylarginine (ADMA) is an endogenous inhibitor of endothelial nitric oxide synthase.3 Elevated levels have been reported in cardiovascular disease,4 and it may play a role in mediating endothelial dysfunction seen in hyperhomocysteinemia.5 ADMA is synthesized through arginine methylation by protein arginine methyltransferase, type 1. Protein arginine methyltransferase type 2 generates symmetric dimethylarginine, which has no endothelial nitric oxide synthase inhibitory action. Furthermore, symmetric dimethylarginine is largely eliminated through renal excretion, whereas most ADMA is metabolized by dimethylarginine dimethylaminohydrolase.

We compared ADMA levels between SVD patients and controls to test 2 hypotheses. First, that SVD is associated with elevated ADMA levels that correlate with SVD severity. Second, that there is a significant interaction between ADMA and homocysteine.

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pressure liquid chromatography. Serum homocysteine was measured as described previously. Because ADMA is handled by the kidneys, creatinine clearance was determined in cases and controls.

**Grading of SVD**

MRI was available in 41 cases (87.2%) and CT only in 6 cases (12.8%). Leukoariosis on MRI or CT was graded using a modified Fazekas scale into absent (0), mild (1), early confluent (2), and confluent (3). This method has been previously validated, and a good correlation was found between grading on CT and MRI. Lacunar infarcts (5 to 15 mm) were scored as absent (0), 1 to 2 lesions (1), 3 to 5 lesions (2), and >5 lesions (3). Because only 2 patients had lacunar infarction grade 3, for analysis patients were grouped into 2 categories: lacunar infarct grades 0 to 1 and 2 to 3.

**Statistical Analysis**

All biochemical markers underwent logarithmic transformation to normalize distributions before analysis. Multivariate logistic regression was used to control for age, gender, vascular risk factors, and creatinine clearance. ADMA levels were split into tertiles to enable logistic regression analysis, and odds ratios (ORs) and 95% CIs were calculated. Linear regression analysis was used to assess associations between ADMA, homocysteine, and SVD severity scores.

**Results**

**Subject Characteristics (Table 1)**

Age, gender, or vascular risk factors were well-matched between patients and controls.

**Biochemical Markers in SVD Patients and Controls (Table 2)**

ADMA and homocysteine were increased in SVD patients compared with controls on univariate analysis and multivariate analysis. In contrast, symmetric dimethylarginine levels did not differ. The OR for SVD increased with increasing tertile of ADMA. After controlling for age, OR (95% CI) for the middle compared with the lowest tertile was 3.94 (1.22 to 12.78; \( P = 0.022 \)), and for the upper compared with the lowest tertile 4.80 (1.36 to 16.96; \( P = 0.015 \)). After additionally controlling for gender, vascular risk factors, and creatinine clearance, the ORs were 6.40 (1.20 to 34.16; \( P = 0.030 \)) and 10.04 (1.70 to 59.27; \( P = 0.011 \)), respectively.

**Associations Between ADMA and Homocysteine**

There was no correlation between ADMA and homocysteine \( (R=0.114, P=0.329). \) The positive association between ADMA and SVD on multivariate analysis \( (P=0.014) \) was only slightly attenuated after additionally controlling for homocysteine \( (P=0.055). \) Similarly, the association between homocysteine and SVD \( (P=0.035) \) was attenuated slightly after additionally controlling for ADMA \( (P=0.055). \)

**Differences in ADMA and Homocysteine Between Cerebral SVD Subtypes (Figure)**

Leukoariosis grade correlated positively with both ADMA \( (R=0.324, P=0.026) \) and homocysteine \( (R=0.433, P=0.003). \) There was no correlation between the lacunar grade and ADMA \( (R=0.029, P=0.849) \), but a positive correlation with homocysteine \( (R=0.362, P=0.017). \)

**Discussion**

We found ADMA was elevated in SVD after controlling for vascular risk factors and correlated with leukoariosis severity but not lacunar grade. Homocysteine was also elevated in SVD, and in contrast was correlated with both leukoariosis severity and lacunar grade. These findings may be consistent with ADMA mediating smaller perforator damage, contributing to leukoariosis, and homocysteine acting on both smaller and larger perforators additionally contributing to lacunes. A role for ADMA in mediating endothelial dysfunction in hyperhomocysteinemia has been proposed, but we failed to demonstrate significant interaction between these two biomarkers.

The association of ADMA with atherosclerosis may offer an alternative explanation for the elevation of ADMA seen in SVD. Undetected atherosclerosis elsewhere in the vascular tree could result in high ADMA levels. However, several factors argue against this. SVD patients and controls were well-matched for vascular risk factors. Thirty-nine of 47 SVD patients had no evidence of plaque on extracranial vessel imaging. Eight patients had minimal plaque (10% to 30% stenosis). None of the patients who had echocardiography had evidence of a cardiac or aortic atherosclerosis. Of the 47 SVD patients, only 1 had a history of myocardial infarction and 2 had symptomatic peripheral vascular disease.

Our findings demonstrate an association between SVD and ADMA and are consistent with, but do not prove, a

**TABLE 1. Demographics of Cerebral SVD and Control Groups**

<table>
<thead>
<tr>
<th>Clinical Characteristic</th>
<th>Controls</th>
<th>SVD</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>66.5 (8.2)</td>
<td>65.3 (10.4)</td>
<td>0.543</td>
</tr>
<tr>
<td>Male</td>
<td>20 (52.6)</td>
<td>31 (66.0)</td>
<td>0.212</td>
</tr>
<tr>
<td>Hypertension</td>
<td>30 (78.9)</td>
<td>37 (78.7)</td>
<td>0.980</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>0 (0)</td>
<td>4 (8.5)</td>
<td>0.999</td>
</tr>
<tr>
<td>Hypercholesterolemia</td>
<td>24 (63.2)</td>
<td>32 (68.1)</td>
<td>0.634</td>
</tr>
<tr>
<td>Smoking</td>
<td>28 (73.7)</td>
<td>38 (80.9)</td>
<td>0.430</td>
</tr>
</tbody>
</table>

Mean (SD) for continuous variables and numbers (%) for categorical variables.

**TABLE 2. ADMA, SDMA, and homocysteine in SVD Cases and Controls**

<table>
<thead>
<tr>
<th></th>
<th>Controls</th>
<th>SVD</th>
<th>Univariate ( P ) Value</th>
<th>Multivariate ( P ) Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADMA (( \mu )mol/L)</td>
<td>0.747 (0.185)</td>
<td>0.814 (0.145)</td>
<td>0.040</td>
<td>0.014</td>
</tr>
<tr>
<td>SDMA (( \mu )mol/L)</td>
<td>0.859 (0.260)</td>
<td>0.881 (0.190)</td>
<td>0.388</td>
<td>0.206</td>
</tr>
<tr>
<td>Homocysteine (( \mu )mol/L)</td>
<td>12.49 (4.15)</td>
<td>15.14 (5.59)</td>
<td>0.029</td>
<td>0.035</td>
</tr>
</tbody>
</table>

Mean (SD) provided. Multivariate analysis controlled for age, gender, vascular risk factors, and creatinine clearance.
role in disease pathogenesis. Our findings need to be replicated in a larger sample and in a prospective study to examine causality.

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Disclosures
None.

References
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