Evaluation of Vascular Function in Hemodialysis Patients: Small Artery Elasticity Index (SAE) Correlates with Pulse Wave Velocity (PWV)

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Introduction

Arteriosclerosis is a major cause of cardiovascular disease and mortality in end-stage renal disease (ESRD) [1-6]. Arteriosclerosis is characterized by arterial stiffening, with high arterial systolic and pulse pressures [1-6]. Changes follow from the loss of dampening function of arteries, which causes an increase in pulse wave velocity. In a normal vascular circuit, arterial pulse waves are reflected back from the periphery and branch points, and these reflected waves augment diastolic pressure, thereby enhancing coronary perfusion. However, pulse waves travel more quickly in a stiff artery. Thus, reflected waves may return during systole, thereby augmenting systolic pressure and reducing diastolic pressure. This helps explain enhanced cardiovascular mortality in ESRD [7-10]. Thus, measurement of pulse wave velocity (PWV) is considered the gold standard for evaluating arterial stiffness and vascular function.

A second method of measuring vascular health is flow mediated dilatation (FMD). FMD measures reactive dilatation of the brachial artery following release of nitric oxide. Stiff arteries generally demonstrate poor dilatation in response to nitric oxide [11,12]. This technique can be used to detect vascular dysfunction, but requires a highly trained sonographer and is difficult to perform. Although PWV and FMD can be used to evaluate cardiovascular disease in ESRD, these tests may not be fast and easy enough for widespread use. Measurement of arterial elasticity may meet this need since the test is quick and requires no significant training to perform. Additionally, small artery elasticity index (SAE) has been shown to correlate with clinical outcomes in both ESRD and non-ESRD patients [13,14]. In this project, we compared these three tests of vascular function to determine the relation between SAE and the two established measures of vascular function: PWV and FMD.

Materials and Methods

Twenty-five stable hemodialysis patients were studied. Subjects were evaluated for vascular function with 3 methods: PWV, FMD and SAE. In addition, arterial blood pressure and heart rate were measured.

Cardio-femoral pulse wave velocity was measured noninvasively with application tonometry (Sphygmocor Pulse Wave Velocity Vx System). In this method, a probe was applied over the carotid and femoral arteries to detect the arterial pulse wave. The timing of pulse wave arrival was used to calculate PWV, which is high in stiff arteries.

Flow Mediated Dilatation (FMD)

A blood pressure cuff was inflated for 4 minutes (causing ischemia) and then suddenly released, causing an increase in blood flow and reactive release of nitric oxide, an arterial vasodilator. The diameter of the brachial artery was measured by ultrasound before and after occlusion of the brachial artery, and percentage increase in arterial diameter was computed.

Results

Simple Regression Analysis

- SAE negatively correlated with PWV (R² = 0.29, P = 0.009)
- SAE did not correlate with FMD (P = 0.81)
- SAE negatively correlated with mean arterial pressure (R² = 0.242, P = 0.013)
- SAE negatively correlated with systolic pressure (R² = 0.191, P = 0.029)
- SAE positively correlated with body mass index (R² = 0.337, P = 0.002)

Multiple Regression Analysis

- SAE correlated with PWV, pulse pressure, body mass index, and mean arterial pressure (R² = 0.701, all P < 0.022)

Table 1: Patient demographics and mean values for vascular testing. Values are consistent with arterial dysfunction: high systolic & pulse pressure, low SAE, high PWV, low FMD.

<table>
<thead>
<tr>
<th>Patient characteristic (n = 25)</th>
<th>Mean ± SD</th>
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<tbody>
<tr>
<td>Patient age (yrs)</td>
<td>46.68</td>
</tr>
<tr>
<td>Female (%)</td>
<td>8</td>
</tr>
<tr>
<td>African American (%)</td>
<td>92</td>
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<tr>
<td>Body mass index (kg/m²)</td>
<td>28.01</td>
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<tr>
<td>Diabetes Mellitus (%)</td>
<td>32</td>
</tr>
<tr>
<td>Cardiovascular disease (%)</td>
<td>52</td>
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<tr>
<td>Systolic blood pressure (mmHg)</td>
<td>144.12</td>
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<tr>
<td>Diastolic blood pressure (mmHg)</td>
<td>81.47</td>
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<tr>
<td>Mean arterial pressure (mmHg)</td>
<td>105.77</td>
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<tr>
<td>Pulse pressure (mmHg)</td>
<td>62.65</td>
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<tr>
<td>Small artery elasticity index (mmHg x 100)</td>
<td>5.69</td>
</tr>
<tr>
<td>Pulse wave velocity (m/s)</td>
<td>9.49</td>
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<tr>
<td>Flow mediated dilatation (%)</td>
<td>6.18</td>
</tr>
</tbody>
</table>

Figure 1: Lower SAE was associated with higher PWV.

Figure 2: Lower SAE was associated with higher systolic blood pressure.

Figure 3: Higher SAE was associated with higher body mass index (BMI).

Discussion

This study supports the utility of small artery elasticity index as a measure of arterial stiffness and vascular function in ESRD. In both simple and multiple regression analyses, SAE correlated with various vascular indicators, including PWV, systolic pressure, and mean arterial pressure. While SAE did not correlate with FMD, FMD did not correlate with any measures of vascular function (data not shown). This suggests that FMD may not be an optimal method of measuring vascular health in ESRD.

An unexpected finding was the positive correlation between body mass index (BMI) and SAE. A previous study found the same relationship and suggested it might be due to the improved vascular function found at higher BMIs within the non-obese range [15].

Summary

- Measurements in this cohort of ESRD patients were generally consistent with arterial stiffness and dysfunction (high systolic and pulse pressures, high PWV, low SAE, and low FMD).
- Lower SAE was associated with higher PWV.
- There was no correlation between SAE and FMD.
- Over 70% of SAE variation is explained by its association with PWV, pulse pressure, body mass index, and mean arterial pressure.

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References