Duplex Scanning and Effect of Multisegmental Arterial Disease on its Accuracy in Lower Limb Arteries

S. Aly*, M. P. Jenkins, F. H. Zaidi, P. D. Coleridge Smith and C. C. Bishop

Department of Surgery, University College London and Medical School, London, UK

Aim: to assess the accuracy of duplex in assessment of peripheral arterial disease and determine the effect of multisegmental disease on the accuracy duplex as opposed to single lesion

Patients and methods: one hundred and seventy-seven lower limbs were examined in 90 patients who presented with lower limb arterial disease, (59 male, 31 female, median age 68 years - 81 with intermittent claudication, eight rest pain, one ulceration). Patients were examined with duplex US, and arteriography (IA DSA). Two radiologists and two technologists were involved in this double-blind study. Patients were classified into five groups, groups with single stenotic lesions, single occlusions, multiple stenotic lesions or occlusions, and multiple mixed disease. Duplex accuracy was determined in each group

Results: duplex was able to differentiate between normal and disease arterial segment with a sensitivity of 92%, specificity 99%, PPV 91%, and NPV 100% and Kappa 0.87. Sixty-six limbs were found to have single lesions, and 68 multisegmental disease. Duplex showed accuracy with a sensitivity of 87%, and specificity of 99%, for single stenotic lesion and 95%, 96% respectively for multisegmental. For single occlusions duplex accuracy showed sensitivity 92% and specificity 100%, and for multisegmental occlusions, sensitivity 97%, and specificity 99% For mixed multisegmental pathology (stenosis and occlusion), sensitivity 94% and specificity 97%

Conclusion: duplex is an accurate tool in diagnosis of lower limb arterial disease and multisegmental pathology does not adversely effect this accuracy

Key Words: Duplex; Multisegmental, Peripheral arterial disease.

Introduction

Atherosclerosis by its very nature tends to be a multilevel disease. Arteriography has always regarded as the "gold standard" investigation for peripheral arterial disease. However, vascular reconstruction demands both functional, and anatomical data. Peak systolic velocity ratio (PSVR) across an arterial lesion has an important role in determining the degree of arterial stenosis.1-14

It has been postulated that the accuracy of duplex scanning based on the peak systolic velocity ratio can be altered in the case of multisegmental disease due to low reading of peak systolic velocity at the distal sites.2-14

The aim of this study, was to assess the accuracy of duplex scanning in evaluation of lower limbs arteries and to determine any change in such accuracy in the case of multisegmental arterial disease.

Methods

By using duplex ultrasound scanning, peripheral arteries of lower limb were evaluated in 90 patients (177 lower limbs, 59 male, 31 female, median age 68) This group of patients was referred to the vascular outpatient clinic at University College London Hospitals NHS Trust, London with peripheral arterial disease. To assess the accuracy of duplex scanning intra-arterial digital subtraction arteriography (IA DSA) was performed. The complaint in 81 patients was intermittent claudication, one with ischaemic ulceration, and eight with rest pain. Ethical committee approval for this study was obtained from UCL Medical School Ethical Committee and patients gave their written consent.

An Acuson ultrasound machine 128XP/10v (Acuson
1220 Charleston Road, Mountain View, CA94039 (U.S.A.) was used with a 2.5MHz, and 7.0MHz linear array probe to examine the pelvic and the infragenual vessels respectively. The scanning was done by two trained vascular technologists.

To minimize the presence of bowel gases and enhance the visualisation of pelvic vessels, patients were fasted for 6h prior to scanning.

The aorta distal to the renal vessels was scanned routinely with the patient lying in a supine position and the scanning proceeded to the ankle vessels. Colour-flow was used to outline arterial lesion and the peak systolic velocity was obtained for each arterial segment.

The peak systolic velocity ratio (PSVR) of any stenosis was obtained for each arterial segment by comparing the peak systolic velocity (PSV) at the stenotic area to the peak systolic velocity of the pre- or post-stenotic area. A peak systolic velocity ratio of 2.0 was used prospectively to differentiate between significant stenoses with more than 50% reduction in the diameter and the insignificant stenoses with less than 50% reduction in the diameter. The arterial tree of lower limb was divided into main four regions (aortoiliac, femoral, femoropopliteal, and run-off vessels), and each was subdivided into their anatomical branches (aorta, common iliac, external iliac, internal iliac, common femoral, superficial femoral at origin, mid femoral, distal femoral, proximal popliteal, distal popliteal, three calf run-off and three ankle run-off vessels. All these segments were routinely examined, and the degree of arterial stenoses were obtained.

Intra-arterial digital subtraction arteriography (IA DSA) was performed within a week of the duplex scanning. IA DSA was performed by a consultant radiologist using the Seldinger technique. Local anaesthetic (lignocaine 2.0%) routinely infiltrated subcutaneously and a sheath with an internal diameter of 7-French was introduced through the common femoral artery. A catheter with an external diameter of 5F then introduced transfemorally through the sheath to the aorta and contrast medium was injected while a uniplanar view of X-ray film was obtained for each case. Intra-arterial pressure measurements were not done routinely.

Percentage of stenosis on the IA DSA was obtained by dividing the actual diameter at of the artery at the stenosis by the diameter of the nearest normal segment. Five grades were described by the radiologist (1 = normal diameter, 2 = less than 20% reduction, 3 = 20% less than 50% reduction, 4 = 50-99% reduction, and 5 = 100% reduction in the diameter). All the IA DSA films were reviewed and classified with two consultant radiologists. For the purposes of assessment, patients in this study were classified into five groups:

1. Patients with single vessel stenotic lesions.
2. Patients with single vessel occlusions.
3. Patients with multisegmental stenoses.
4. Patients with multisegmental occlusions.
5. Patients with multisegmental mixed disease (stenosis and occlusion).

The accuracy of duplex scanning in each of these groups was determined.

**Statistical Analysis**

The sensitivity and specificity of duplex scanning compared to arteriography in detecting a non-significant (<50%), and a significant lesion (>50%) or occlusion were detected.

The kappa statistic was computed to measure the level of the agreement between the radiologists and technologists. For agreement by chance alone the k value is 0, and for perfect agreement, the k value is 1. The 95% confidence interval (95% CI) was also obtained.

**Results**

In this group of patients, 3108 arterial segments of 177 lower limbs (630 aortoiliac segment, 531 femoral, 885 femoropopliteal, and 1062 run-off vessels in both calf, and ankle) were examined. While 466 arterial lesions were identified on IA DSA, 451 lesions were identified on duplex scanning (Table 1, 2). Table 3 summarises the duplex accuracy compared to the IA DSA for both significant stenoses and occlusion disease. 570 arterial segments (out of 630) were normal on both duplex and arteriography in the aortoiliac region. Bowel gas

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**Table 1. Distribution of the arterial disease as described by radiologists on background of IA DSA.**

<table>
<thead>
<tr>
<th>% of stenosis</th>
<th>AI</th>
<th>FA</th>
<th>FP</th>
<th>ROF</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;20%</td>
<td>6</td>
<td>3</td>
<td>6</td>
<td>0</td>
<td>15</td>
</tr>
<tr>
<td>20-49%</td>
<td>6</td>
<td>2</td>
<td>5</td>
<td>0</td>
<td>13</td>
</tr>
<tr>
<td>50-99%</td>
<td>23</td>
<td>13</td>
<td>55</td>
<td>45</td>
<td>136</td>
</tr>
<tr>
<td>Occlusion</td>
<td>22</td>
<td>27</td>
<td>170</td>
<td>83</td>
<td>302</td>
</tr>
<tr>
<td>Total</td>
<td>57</td>
<td>45</td>
<td>236</td>
<td>128</td>
<td>466</td>
</tr>
</tbody>
</table>
Multisegmental Arterial Disease and Duplex US Accuracy

Table 2. Distribution of the arterial disease as described by duplex scanning.

<table>
<thead>
<tr>
<th>Duplex (PSVR)</th>
<th>AI</th>
<th>FA</th>
<th>FP</th>
<th>ROF</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1.5</td>
<td>2</td>
<td>1</td>
<td>8</td>
<td>0</td>
<td>11</td>
</tr>
<tr>
<td>&gt;1.5</td>
<td>2</td>
<td>1</td>
<td>6</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>&gt;2.0</td>
<td>27</td>
<td>14</td>
<td>60</td>
<td>45</td>
<td>146</td>
</tr>
<tr>
<td>No pulse</td>
<td>19</td>
<td>28</td>
<td>159</td>
<td>79</td>
<td>285</td>
</tr>
<tr>
<td>Total</td>
<td>50</td>
<td>44</td>
<td>233</td>
<td>124</td>
<td>451</td>
</tr>
</tbody>
</table>

Table 3. Demonstrates the overall duplex accuracy.

<table>
<thead>
<tr>
<th>Artery</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>PPV</th>
<th>NPV</th>
<th>K (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AI</td>
<td>89%</td>
<td>99%</td>
<td>92%</td>
<td>99%</td>
<td>0.81 (0.11)</td>
</tr>
<tr>
<td>FA</td>
<td>100%</td>
<td>99%</td>
<td>95%</td>
<td>100%</td>
<td>0.94 (0.05)</td>
</tr>
<tr>
<td>FP</td>
<td>95%</td>
<td>99%</td>
<td>94%</td>
<td>99%</td>
<td>0.92 (0.02)</td>
</tr>
<tr>
<td>ROF</td>
<td>82%</td>
<td>99%</td>
<td>82%</td>
<td>100%</td>
<td>0.81 (0.06)</td>
</tr>
<tr>
<td>Overall</td>
<td>92%</td>
<td>99%</td>
<td>91%</td>
<td>100%</td>
<td>0.87 (0.06)</td>
</tr>
</tbody>
</table>

Summary of statistical assessment of duplex examination compared to IA DSA, for all arterial segments
AI = aortoiliac, FA = femoral artery, FP = femoropopliteal region and ROF = run-off vessels, PPV = positive predictive value, NPV = negative predictive value, K = kappa statistic

and obesity were the main reasons for poor visualisation of iliac arteries. Out of 90 patients, in two, iliac scanning was described as difficult. Duplex scanning showed a sensitivity of 100% and specificity of 99.6% in identifying significant lesions; positive predictive value (PPV) 96%, and negative predictive value (NPV) 100%. For aortoiliac occlusion the sensitivity and specificity were 89% and 99% respectively. For occlusions in this area the sensitivity and specificity were 93% and 99%, respectively, and PPV and NPV were 90% and 99%, respectively. K statistic was 0.88 (95% CI 0.07).

Table 3. Demonstrates the overall duplex accuracy.

In the femoral artery 485 of 531 arterial segments were normal on both duplex and arteriography. Duplex was able to identify significant stenoses in femoral arterial segment with a sensitivity and specificity of 100% and 99%, respectively, and PPV and NPV 94%, and of 99%, respectively. For occlusions in this area the sensitivity and specificity were 93% and 99%, respectively, and PPV and NPV were 90% and 99%, respectively. K statistic was 0.88 (95% CI 0.08).

Six hundred and forty-eight segments were normal by both modalities in the femoropopliteal region. Duplex was able to recognise significant stenoses with a sensitivity and specificity 98% and 99%, respectively and PPV and NPV 92%, and 99%, respectively. For occlusions, duplex showed a sensitivity and specificity 91% and 99%, respectively, and PPV and NPV 97% and 99%, respectively. K statistics was 0.86 (95% CI 0.02). While in the run-off vessels 915 of 1062 segments were normal. Thirty-seven significant stenoses were identified by both modalities. Duplex was able to recognise significant stenosis with a sensitivity and specificity of 100%, and 100%, respectively, and with PPV and NPV and 100%, and 100%. Duplex was able to detect occlusive disease with a sensitivity and a specificity 89%, and 99% and PPV and NPV 81%, 99%, respectively and kappa with k statistics of 0.88 (95% CI 0.05).

Duplex accuracy in single and multisegmental pathology

Out of 177 limbs, 66 were found with a single lesion, and 68 limbs with multiple lesions. In the case of a single significant stenosis (using the IA DSA as the "gold standard") duplex showed an accuracy with a sensitivity of 87%, specificity 99%, PPV 92%, and NPV 99%. While in multisegmental significant stenosis, the duplex accuracy was 95%, 96%, 83%, 99% respectively.

In the case of the single occlusion, duplex showed an accuracy with a sensitivity, specificity, PPV, NPV of 92%, 100%, 100%, 99% respectively, which in the case of multisegmental occlusion were 97%, 99%, 99%, 99% respectively. In mixed multisegmental disease (stenosis and occlusion) they were 94%, 97%, 91%, 98% respectively (Table 4).

Discussion

Arteriography has long been the definitive test for evaluation of lower limb arterial pathology. Beside the failure of arteriography to provide any functional data; it is also associated with both a morbidity and mortality risk12,14 (mortality of 0.01%, and morbidity of 1%). Due to the fact that most atherosclerotic plaques are eccentric, the angiographic appearance may be misleading, especially if only uniplanar views are obtained. Measurements of the pressure gradients are the only useful and accepted methods to obtain the haemodynamic information of the arterial lesion; which is not practical or always possible.12-14

Peak systolic velocity ratio (PSVR) across the arterial lesion has been reported as the most useful parameter to determine the nature of the arterial lesion.1-14

Jager1 in his study established a peripheral arterial disease classification based on duplex findings and PSVR. PSVR of 2.0 was used by most of the reported studies to differentiate between significant and insignificant stenosis.1-2-13,14 We used a PSVR of 2.0 prospectively and it showed a sensitivity of 92% and specificity of 99% in quantifying arterial stenosis in lower limbs. A PSVR of 2.5 was also used in certain
Table 4. Demonstrates duplex accuracy in multisegmental disease compared to single lesion disease.

<table>
<thead>
<tr>
<th>Accuracy</th>
<th>Single</th>
<th>Multisegmental</th>
<th>Mixed</th>
</tr>
</thead>
<tbody>
<tr>
<td>No of limbs</td>
<td></td>
<td></td>
<td>27</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>87%</td>
<td>95%</td>
<td>94%</td>
</tr>
<tr>
<td>Specificity</td>
<td>92%</td>
<td>96%</td>
<td>97%</td>
</tr>
<tr>
<td>PPV</td>
<td>92%</td>
<td>93%</td>
<td>99%</td>
</tr>
<tr>
<td>NPV</td>
<td>99%</td>
<td>99%</td>
<td>98%</td>
</tr>
<tr>
<td>Kappa (95% CI)</td>
<td>0.81 (0.08)</td>
<td>0.91 (0.02)</td>
<td>0.89 (0.05)</td>
</tr>
</tbody>
</table>

Demonstrates the accuracy of duplex in both single and multisegmental lesions

studies which was associated with a sensitivity of 84% and specificity of 96%. Retrospective assessment of our data by using receiver-operating curve statistics (ROC) showed that a PSVR of 1.8 (98%, 97%) was more sensitive than PSVR of 2.0 (92%, 98%) and this was supported by Baxter et al.19

Our current study showed that duplex was able to determine significant disease with an overall sensitivity of 92% and specificity of 98%, positive predictive value of 91%, negative predictive value of 100%, while kappa with k 0.87 (95% CI 0.06).

Reduction in the peak systolic velocity distal to occlusion or tight stenosis has been reported by some authors to alter the duplex accuracy.21,34 Accuracy of femoropopliteal reduced between the distal segment of SFA, proximal segment of popliteal artery especially when short lesion exist (double checking was used). Also the accuracy of duplex scanning was also reduced in the run-off in both calf and ankle vessels. The peroneal vessels were most difficult to identify and their lesions to be assessed.

Multisegmental arterial disease is characterised by high incidence of ischaemic ulceration or gangrene and the method of the therapeutic intervention has to be based on an accurate modality of investigation.14,17

Kohler reported a difficult in determining the nature of the arterial disease using a PSVR reading if that lesion is near to a total occlusion and also stated that duplex ultrasound scanning is not reliable in quantifying lesions in multiple arterial disease. He also reported that the overall accuracy of duplex ultrasound scanning was with a sensitivity of 82%, specificity of 92%, PPV of 80%, NPV of 93% with a kappa statistics of 0.55.

Bergamini et al.15 also reported that there was a significant reduction in duplex accuracy in the case of single arterial lesions of the lower limb compared to its accuracy in the multisegmental disease. This was also supported by Polak et al. in which he stated that out of 17 patients recruited to the study; seven patients with significant stenosis were missed by duplex scanning. In two of these patients, the lesion was distal to an occluded segment and in the other two, the lesion was distal to a tight stenosis, while the other three were heavily calcified. The explanation of the findings in these studies could be due to the fact that some of them used a black and white coded-duplex machine12 or they reported such findings in small selected groups of patients.13,14 Great advances in both technical skill and ultrasound equipment have occurred since

Kalomy in his recent meta-analysis reported that multisegmental disease of lower limbs arteries has no significant effect on duplex accuracy. This was also supported by Pemberton et al.17 in his recent review.

In our study we classified patients with lower limb arterial pathology into five groups to determine effect of multisegmental arterial disease on duplex accuracy (Table 4), but did not find any significant difference between the accuracy for single lesions compared with multisegmental disease.

Conclusion

We conclude from this study and the previous reports that duplex can be used safely in assessment of peripheral arterial disease of lower limbs specifying the arterial pathology accurately in both single and multisegmental arterial disease. These criteria make duplex ultrasound scanning a less invasive, but are an accurate alternative to arteriography in the assessment of lower limb artery.

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