The Ability of Qualitative Assessment of the Common Femoral Doppler Waveform to Screen for Significant Aortoiliac Disease

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Objective: To study the ability of a qualitative assessment of the common femoral Doppler waveform to screen for significant aortoiliac disease.

Design: Prospective, semi-blind study.

Setting: Vascular laboratory, University Hospital.

Methods: A total of 118 aortoiliac segments were studied in 73 patients. Each aortoiliac segment was graded as normal or abnormal from visual interpretation of the common femoral Doppler waveform obtained by colour duplex ultrasound. Full ultrasound assessment of the aortoiliac vessels acted as the “gold standard”. Abnormal aortoiliac segments were defined by the presence of at least one ≥ 50% diameter reducing lesion, whereas vessels considered “normal” included those with disease between 0–49% diameter reduction. An increase in peak systolic velocity of two-fold or greater was used to define a ≥ 50% diameter reducing stenosis. Agreement between common femoral waveform analysis and the duplex scans was measured by the Kappa statistic.

Results: The Kappa value for the agreement between common femoral waveform analysis and duplex scans was 0.74 (95% CI, 0.62–0.86). This represents substantial agreement. Doppler waveform analysis had a sensitivity of 95%, specificity of 80% and accuracy of 87% for the prediction of a significant aortoiliac stenosis seen by ultrasound.

Conclusion: Visual interpretation of the common femoral Doppler waveform is a sensitive and accurate technique for the prediction of significant aortoiliac stenosis. It is of particular value when full ultrasound aortoiliac assessments are not feasible due to time constraints, obesity or the presence of bowel gas.

Key Words: Duplex scanning; Doppler; Arterial disease; Aortoiliac disease.

Introduction

Non-invasive assessment of the aortoiliac segment by evaluation of the common femoral artery Doppler was first reported in the mid-1970s. Various techniques have been described with varying degrees of success, but despite this, feature extraction from common femoral Doppler waveforms remains a controversial area. To date, quantification of the Doppler signal has centred largely around use of the pulsatility index or other waveform parameters such as systolic acceleration and maximum reverse flow and their response to reactive hyperaemia. Mathematical solutions have also been applied, such as Laplace transform or principal component analysis. However, many suggest that the pulsatility index is limited to patients without significant superficial femoral artery (SFA) disease and several of the remaining parameters require more complex calculations and, in certain instances, a degree of “off-line” processing. For these reasons, none of the above techniques has been seen in wide clinical use as a quick screening technique.

Relatively few papers report on the success of aortoiliac evaluation from subjective assessment of the overall common femoral waveform shape and the purpose of the present study was to examine whether visual interpretation of the common femoral waveform can screen for significant aortoiliac disease.

Materials and Methods

A consecutive series of patients referred to a vascular laboratory for full lower limb arterial assessment were included within this study. Prior to a full ultrasound
Fig. 1. An apparently normal, triphasic Doppler waveform, with a sharp systolic element was recorded from the common femoral artery distal to a significant stenosis of the proximal common iliac artery.

assessment, Doppler waveforms were obtained from the common femoral artery using a 5 MHz pulsed wave ultrasound probe and a colour duplex system (Diasonics Spectra or ATL Ultramark IX). Common femoral waveforms were obtained from the centre-stream of the vessel at angles <68°.

Several waveforms from each patient were assessed by one of four vascular technologists who judged the Doppler signals as either normal or abnormal. A sharp systolic uprise and fall, two or three waveform “phases” and an element of reverse flow during diastole were all features of the waveforms considered normal. Abnormal waveforms were characterised by curved systolic upstrokes, increased amplitudes at low frequencies or evidence of disturbed flow in the form of high frequency spikes. In cases of severe aortoiliac
Fig. 2. A severely damped, rounded common femoral Doppler waveform provides evidence of an upstream occlusion.
Fig. 3. The loss of "sharpness" in systole and the lack of a diastolic element produce more subtle changes in the common waveform and indicate the presence of an iliac stenosis.
disease, waveform effects are more marked. Damped, monophasic waveforms, frequently associated with forward flow throughout diastole are seen, creating ill-defined waveform shapes.

After categorising the common femoral waveform and its documentation by a second observer, a full ultrasound assessment of the aortoiliac tract was performed using the same ultrasound system and 3.5 MHz curved-array probe. Patients were examined supine as the common femoral artery was identified and followed along the iliac vessels to the level of the distal aorta. Areas of flow disturbance, pinpointed either by colour-flow changes or differences in spectral Doppler recordings, were investigated further for changes in peak systolic velocity. In accordance with previous work, a two-fold increase in peak systolic velocity across a stenosis as compared with the corresponding proximal peak systolic velocity was used to represent a significant 50% diameter reducing lesion. Where no flow could be detected, the vessel was considered occluded. Results of the aortoiliac ultrasound scan, including any areas of velocity increase, were recorded onto a diagrammatic proforma. Abnormal aortoiliac segments were indicated by the presence of at least one 50% diameter reducing lesion.

For the purpose of comparison, the aortoiliac scan was considered to be the “gold standard” and the ability of common femoral artery waveforms to screen for aortoiliac disease was determined by sensitivity, specificity and the Kappa statistic. Kappa varies from <0, indicating agreement less than that given by chance to 1, indicating perfect agreement. Inaccuracies of the common femoral Doppler waveform in the presence of distal disease have previously been reported and we therefore examined the ability of the common femoral waveform to detect significant aortoiliac disease for the subgroup of patients with and without superficial femoral artery occlusions.

Results

A total of 118 limbs from 73 patients were available for comparison, 45 having bilateral examinations. This comprised 48 males and 25 females with a median (range) age of 70 (41–96) years. A satisfactory common femoral Doppler signal and full aortoiliac ultrasound assessment was obtained from all patients.

Results comparing waveform analysis to the full ultrasound examination are given in Table 1, both in the form of a two-way contingency table (Table 1a) and in terms of sensitivity, specificity, positive and negative predictive values (Table 1b). It can be seen that visual interpretation of the common femoral waveform successfully predicted the presence of significant aortoiliac disease in the majority of cases. False positives occurred approximately three times more frequently than false negatives to produce a high sensitivity level of 95%. Specificity was 80%, overall accuracy 87% and an overall Kappa value of 0.74 (0.62–0.86) denoting substantial agreement was obtained.

On closer study, each of the twelve falsely-positive common femoral waveforms related to iliac vessels with slight disease (i.e. <50% diameter reduction). Of the three cases where common femoral waveforms mistakenly identified corresponding aortoiliac segments as normal, one accounted to a patient with a distal aortic stenosis, and the remaining two to patients with common iliac stenoses. The latter two patients also had long superficial femoral artery occlusions.

Results from the subgroup of patients, with and without proximal superficial femoral artery occlusions, are displayed in Tables 2a and 2b. Common femoral Doppler signals in the presence of multi-level disease proved 89% sensitive and 76% specific. The corresponding figures for patients without occlusive disease in the proximal superficial femoral artery were 97% and 81%, respectively. Kappa values were not significantly different between the two groups, both achieving levels of substantial agreement.

Discussion

In the setting of a busy vascular laboratory, common femoral waveform analysis would allow colour duplex examinations of the lower limb to become less time-consuming if their qualitative assessment could be used to reliably and quickly screen for significant proximal disease. In the current study, visual interpretation of the common femoral Doppler waveforms proved 95% sensitive and 80% specific for upstream disease. Substantial overall agreement was obtained with a Kappa value of 0.74 (0.62–0.86). This is comparable to the levels of agreement attained by previous studies. Walton et al. and Cossman et al. both assessed visual interpretation of the common femoral Doppler waveform against arteriography, reporting values of sensitivity in excess of 80% with associated specificities in the order of 90%. In a similar manner, Baxter et al. achieved an overall accuracy of 91% in comparison to aortoiliac arteriograms. Interestingly, the more quantitative approach taken by Currie et al. and Van Asten et al. in assessing multiple parameters from Doppler spectra both at rest and...
after hyperaemia, proved less sensitive, 86% and 74%, respectively, in contrast to hyperaemic intra-arterial pressure measurements.

Twelve cases of insignificant aortoiliac disease associated with abnormal common femoral waveforms were found in the present study. However, without exception, each related to slight upstream abnormalities, rather than completely “disease-free” vessels. Walton et al. also reported difficulties in distinguishing disease graded just below the 50% cut-off mark, although for screening purposes, sensitivity is considerably more important than specificity. Of the small number of false negatives found in our study, all related to very proximal lesions of either the aorta or common iliac artery, reinforcing the view that, given a sufficient distance downstream, Doppler waveforms have the ability to recover, allowing short, proximal lesions to go undetected.

The common femoral waveform of one of the false negative cases is presented in Fig. 1. This apparently normal, triphasic waveform with sharp acceleration in systole displays no evidence of the three-fold increase in velocity sighted at the common iliac origin. A further 10 single site common iliac lesions were cor-

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Table 1a. A comparison of aortoiliac disease seen on colour duplex ultrasound and Doppler waveform grading from the common femoral artery. Both modalities grading the aortoiliac arteries either as normal (0–49%) or significantly diseased (50–100%).

<table>
<thead>
<tr>
<th>CF waveform</th>
<th>Normal Al</th>
<th>Significant AI disease</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>48</td>
<td>3</td>
<td>51</td>
</tr>
<tr>
<td>Abnormal</td>
<td>12</td>
<td>55</td>
<td>67</td>
</tr>
<tr>
<td>Total</td>
<td>60</td>
<td>58</td>
<td>118</td>
</tr>
</tbody>
</table>

$k = 0.74$ (95% CI 0.62–0.86). Substantial agreement.

Table 1b. The sensitivity, specificity, negative and positive predictive values of visual interpretation of the common femoral Doppler waveform in detecting significant (50–100%) aortoiliac disease.

<table>
<thead>
<tr>
<th></th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
<th>PPV (%)</th>
<th>NPV (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual interpretation of the CF waveform</td>
<td>95</td>
<td>80</td>
<td>82</td>
<td>94</td>
</tr>
</tbody>
</table>

PPV – positive predictive value.
NPV – negative predictive value.
CF – common femoral.

Table 2. Comparison of aortoiliac disease on colour duplex ultrasound and Doppler waveform grading from the common femoral artery. Both modalities grading the aortoiliac arteries as either normal (0–49%) or significantly diseased (50–100%).

a. Patients with a proximal superficial femoral artery occlusion.

<table>
<thead>
<tr>
<th>CF waveform</th>
<th>Normal Al</th>
<th>Significant AI disease</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>13</td>
<td>2</td>
<td>15</td>
</tr>
<tr>
<td>Abnormal</td>
<td>4</td>
<td>17</td>
<td>21</td>
</tr>
<tr>
<td>Total</td>
<td>17</td>
<td>19</td>
<td>36</td>
</tr>
</tbody>
</table>

$k = 0.66$ (95% CI 0.53–0.79). Substantial agreement.

b. Patients without a proximal superficial femoral artery occlusion.

<table>
<thead>
<tr>
<th>CF waveform grade</th>
<th>Normal Al</th>
<th>Significant AI disease</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>35</td>
<td>1</td>
<td>36</td>
</tr>
<tr>
<td>Abnormal</td>
<td>8</td>
<td>38</td>
<td>46</td>
</tr>
<tr>
<td>Total</td>
<td>43</td>
<td>39</td>
<td>82</td>
</tr>
</tbody>
</table>

$k = 0.78$ (95% CI 0.64–0.92). Substantial agreement.
rectly diagnosed by common femoral waveform analysis, although, incidentally, none had the disease pattern of the two false negatives described previously.

The majority of previous reports state that superficial femoral artery occlusions create abnormal common femoral waveforms even in the absence of aortoiliac disease, although this can be associated more with a prolonged systolic deceleration than with the prolonged acceleration phase commonly found in patients with aortoiliac disease. The presence of proximal superficial femoral artery occlusive disease, however, did not appear to have any major adverse effects on our results. Sensitivity fell from 97% to 89% for patients with superficial femoral artery occlusions, but overall agreement remained substantial and not statistically different between the two groups.

Doppler waveform analysis from the common femoral artery appears successful, particularly in distinguishing normal from severely diseased aortoiliac vessels. Well defined, triphasic waveforms with a sharp acceleration phase are good indicators of normal proximal vessels, whereas occlusive disease propagates severely damped, monophasic waveforms many diameters downstream allowing detection at common femoral level (Fig. 2). Discriminating slight from significant aortoiliac disease poses greater problems, however, as waveform effects are less dramatic. The stenotic lesion of Fig. 3, for example, creates a common femoral waveform that simply lacks sharpness and an element of reverse diastolic flow. Using criteria similar to that of Walton et al., we found identifying waveforms, in particular with abnormal systolic elements, such as a curved acceleration phase yielded a high sensitivity to iliac disease. This appeared a more useful indicator than a lack of reverse flow focused on in earlier studies.

In our study, three (5%) aortoiliac lesions from a total of 58 were missed. Considering that angiographic underestimation has been reported to miss as many as 40% of all aortoiliac lesions, this figure is acceptable, particularly in circumstances where full aortoiliac assessments are not feasible due to time constraints, obesity or the presence of overriding bowel gas.

In conclusion, assessment of the aortoiliac segment by subjective grading of the common femoral waveform is a very sensitive, accurate method and one not significantly influenced by the presence of downstream disease.

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References

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