FOOT AND ANKLE

Doppler spectrum analysis

A POTENTIALLY USEFUL DIAGNOSTIC TOOL FOR PLANNING THE TREATMENT OF PATIENTS WITH CHARCOT ARTHROPATHY OF THE FOOT?

T. Wu, P-Y. Chen, C-H. Chen, C-L. Wang

From National Taiwan University Hospital, Taipei City, Taiwan

It is difficult to determine the safe timing of weight-bearing or reconstructive surgery in patients with Charcot arthropathy of the foot and ankle. In this study the Doppler spectrum of the first dorsal metatarsal artery was used to monitor the activity of the disease activity and served as a guideline for management. A total of 15 patients (seven men and eight women) with acute diabetic Charcot arthropathy of the foot and ankle were immobilised in a non-weight-bearing cast. They were followed at two-week intervals and bilateral Doppler spectra of the first dorsal metatarsal arteries were obtained using a 10 MHz linear ultrasound probe. The patients were allowed to start weight-bearing or undergo surgery after the Doppler spectrum had returned to normal pattern. The Doppler spectra in the unaffected limbs were triphasic in pattern, whereas those in limbs with active Charcot arthropathy showed monophasic forward flow. They returned to normal after a mean of 13.6 weeks (6 to 20) of immobilisation. Three patients underwent pan-talar arthrodesis to correct gross instability and deformity.

Doppler spectrum analysis of the foot may reflect the activity of the disease in patients with Charcot arthropathy, and may be used as a guide to begin weight-bearing or undergo reconstructive surgery.

Charcot arthropathy is limb-threatening, destructive and commonly involves the foot and ankle in diabetics with peripheral neuropathy. Its natural progression is from development/fragmentation through coalescence to reconstruction/consolidation, with the duration of each varying from weeks to months.

The goals of treatment are a stable and pliantigrade foot that enables walking with available footwear and orthoses, while avoiding unnecessary immobilisation and inadequate treatment. Apart from clinical signs such as swelling, erythema and warmth, objective measurement of the gradient skin temperature or change in the volume of the limb has been used to assess the progress of the condition. However, these methods are susceptible to environmental and patient factors and may sometimes be impracticable.

The Doppler spectrum of the first dorsal metatarsal artery has been used to evaluate blood flow in the foot and may indicate the underlying inflammatory activity, and in this study we used it to guide the treatment of patients with Charcot arthropathy.

Patients and Methods

Between July 2001 and December 2009, 15 patients presented at our clinic with acute diabetic Charcot arthropathy of the foot and ankle (grossly visible erythema, oedema and/or heat, having undergone no previous evaluation or treatment). There were seven men and eight women, with a mean age of 55.6 years (28 to 76). Four had type 1 diabetes and 11 had type 2, with a mean diabetic history of 22.2 years (13 to 34). All had loss of protective sensation to the 10 g Semmes–Weinstein monofilament and an abnormal Doppler spectrum pattern, but none had ulcers in the affected foot and ankle. According to the modified Brodsky classification6 (Fig. 1), six patients were type 1, four were type 2, two were type 3A, one was type 3B and two were type 4 (Table I). None had undergone previous surgery to the foot and ankle.

The patients were immobilised in a well-padded bivalved cast and kept non-weight-bearing until the Doppler spectrum pattern returned to normal. The patients were followed at two-week intervals. In addition to skin inspection and cast check-up, Doppler spectra of the first dorsal metatarsal arteries in both feet were obtained using a 10 MHz linear ultrasound probe (ATL HDI3000 or HDI5000; ATL, Bothel, Washington). Swelling, warmth and erythema of the feet were recorded and radiographs obtained every
four weeks. After the Doppler spectrum analysis in the affected limb had returned to a normal pattern the patients were allowed either to start protected weight-bearing with footwear (pneumatic controlled-ankle-motion brace) or to undergo pan-talar arthrodesis. The use of walking aids varied and the patients decided when to discard them. They were followed up for at least six months after mobilisation or reconstructive surgery.

**Results**

The Doppler spectrum of the unaffected limbs was triphasic in pattern, with an initial forward flow in systole followed by a short period of reverse flow and further forward flow in diastole (Fig. 2a). In limbs with active Charcot arthropathy the Doppler spectrum showed continuous forward flow with loss of the triphasic pattern (Fig. 2b); decrease of the pulsatility index (PI) and resistance index (RI) were noted. The Doppler spectrum returned to the normal pattern after a mean of 13.6 weeks (6 to 20) of treatment. None of the limbs showed any residual swelling, erythema or warmth at that time, and the skin creases of the ankle could be seen. Their radiological staging showed only four patients in the coalescence stage by the time a triphasic pattern was observed (Fig. 3). Calcification of the dorsalis pedis artery was seen radiologically in five patients, but this did not interfere with the Doppler spectrum measurement.

Three patients (two Brodsky type 3A, one type 2; Table I) underwent pan-talar arthrodesis to correct gross instability.

---

<table>
<thead>
<tr>
<th>Patient/Gender</th>
<th>Age (yrs)</th>
<th>Brodsky classification</th>
<th>Duration of total contact casting (wks)</th>
<th>Arthrodesis</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 / F / 61</td>
<td>1</td>
<td>10</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>2 / M / 55</td>
<td>2</td>
<td>10</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>3 / F / 41</td>
<td>3B</td>
<td>18</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>4 / M / 63</td>
<td>4</td>
<td>16</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>5 / F / 73</td>
<td>2</td>
<td>6</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>6 / F / 57</td>
<td>1</td>
<td>12</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>7 / M / 36</td>
<td>3A</td>
<td>12</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>8 / M / 52</td>
<td>2</td>
<td>14</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>9 / F / 28</td>
<td>1</td>
<td>10</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>10 / M / 65</td>
<td>4</td>
<td>12</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>11 / F / 57</td>
<td>3A</td>
<td>14</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>12 / M / 76</td>
<td>1</td>
<td>16</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>13 / F / 68</td>
<td>2</td>
<td>14</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>14 / F / 58</td>
<td>2</td>
<td>20</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>15 / M / 46</td>
<td>1</td>
<td>18</td>
<td>No</td>
<td></td>
</tr>
</tbody>
</table>
and deformity after the Doppler spectrum pattern had returned to normal. All were fixed internally with screws and achieved uncomplicated bony union (Figs 4 and 5).

One patient (type 3A) reported a ‘twisting injury’ of the ankle seven weeks after removal of the cast, with recurrence of pain and swelling. The Doppler spectrum showed the reappearance of a monophasic flow pattern. The affected leg was put into a non-weight-bearing cast for another six weeks until the Doppler spectrum became normal again.

Discussion
The mainstays of treatment of the Charcot foot are off-loading and immobilisation of the affected foot and ankle. The safe timing of weight-bearing or bony reconstruction depends critically on the activity of the disease. Efforts have been made to allow earlier weight-bearing to ease patient care and hasten the return of function. However, weight-bearing before adequate bone healing may risk the progression of deformity and prolong the course of the disease. Likewise, although successful early arthrodesis has been reported in stage I tarsometatarsal Charcot arthropathy, the weakened bone and swollen soft tissues may jeopardise fixation and wound healing. The Eichenholtz staging, which is largely radiological, provides a good understanding of the natural history of Charcot arthropathy, but it lacks clear-cut distinctions between different stages and is not sensitive enough to indicate the level of disease activity.

This study showed that the Doppler spectrum of the first dorsal metatarsal artery changed with the course of the disease. Continuous forward flow with loss of the triphasic pattern suggests reduced resistance and arteriovenous shunting, reflecting the inflammatory activity. Recovery of the normal pattern indicates decreased inflammatory and reparative responses. Using these as criteria to discontinue casting and begin weight-bearing seems reasonable, theoretically. The mean duration of casting in our study was 13.6 weeks, compared with other reports of 18.5 weeks and 87 days. These results suggest that the return to a normal pattern may be used as a simple and clear indicator to begin weight-bearing. As well as the changes in the Doppler spectrum pattern, several parameters such as vessel pulsatility and resistance indices may potentially be used to depict more subtle changes in the healing process.

The measurement of skin temperature has been used to monitor disease activity and guide the management of...
Armstrong et al\textsuperscript{15} converted total-contact casts to a removable walking cast when skin temperature gradients were within 1°C for two consecutive weeks at the affected site compared with the contralateral site. The mean duration of total-contact casting was 18.5 weeks (SD 10.6) (4 to 56) and progression to prescription footwear took a mean of 28.3 weeks (SD 14.5). Seven of the 50 unilaterally involved patients had a recurrent increase in temperature gradient within one month and were treated with total-contact casting for a mean of 2.9 weeks (SD 1.2) until skin temperature normalised.\textsuperscript{3} Although the measurement of skin temperature gradient is inexpensive and may reflect the activity of the disease, the results are susceptible to ambient and patient factors. The environment must be carefully controlled to minimise these influences.\textsuperscript{15} Moreover, it is not uncommon to encounter patients with bilateral involvement (in 9% to 35% of cases)\textsuperscript{2,3} or pre-existing disease in the contralateral limb, thereby making comparison between limbs unreliable or impossible. Our study only observed the presence of gross warmth to touch and did not record the skin temperature. A future study would be to compare the Doppler flow pattern with skin temperature.

The Doppler spectrum has been used to evaluate blood flow in the diabetic neuropathic foot. Edmonds, Roberts and Watkins\textsuperscript{5} reported abnormal patterns in patients with severe diabetic neuropathy, including continuous forward flow with loss of triphasic pattern and a reduced pulsatility index. However, this cross-sectional study did not describe the entire chronological change of the Doppler spectrum: blood flow abnormalities were recognised as parts of established neuropathy and vasculopathy instead of transient changes in the disease course of the arthropathy. In all our patients return of a normal triphasic flow pattern was observed after off-loading and immobilisation, along with decreased warmth, erythema and swelling. No symptoms or signs of acute inflammation were observed by the time the Doppler spectrum had reverted to a triphasic pattern. The recovery of normal blood flow does not support the neurovascular theory of the aetiology of Charcot arthropathy,\textsuperscript{16} Nevertheless, there might be subtle blood flow changes that cannot readily be displayed by the Doppler spectrum, and neurovascular abnormalities may still play a role in the exaggerated inflammatory responses during the fragmentation stage.\textsuperscript{16-19}

In conclusion, Doppler spectrum analysis of the first dorsal metatarsal artery may reflect the activity of Charcot arthropathy. Although our study involved relatively few patients, the results suggest that this investigation might be an additional marker of disease activity to aid therapeutic decision-making. However, further research is needed to confirm these findings, incorporating other indicators of disease activity, such as skin temperature.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

References