Comparison of duplex ultrasonography and venography in the diagnosis of deep venous thrombosis

Sixty-five patients with suspected deep venous thrombosis (DVT) in 68 limbs were entered consecutively into a study to compare venography with duplex ultrasonography scanning. Both tests were performed on 64 limbs, venography being contraindicated in four. Overall, duplex scanning correctly identified 86 per cent of DVTs diagnosed on venography and correctly excluded 80 per cent with negative venograms. Nearly all errors arose in the diagnosis of calf DVT. In the femoral vein duplex scanning had a specificity of 100 per cent and a sensitivity of 88 per cent. In addition, duplex scanning provided data on the limb not undergoing venography. Of 55 limbs that underwent bilateral duplex scanning, five had thrombus in the femoropopliteal segment and a negative contralateral venogram. In addition, three Baker’s cysts were diagnosed. Duplex scanning can be used in patients in whom venography is contraindicated and may also provide information about the contralateral limb. We regard femoropopliteal duplex scanning as sufficiently accurate that treatment can be initiated on the basis of the scan. Duplex scanning should replace venography as the standard method of diagnosing femoropopliteal DVT; radiographic studies should now be required only when the scan result is in doubt.

Patients and methods

A consecutive series of 65 patients was studied. Patients were entered into the study by the referring physician on the suspicion of DVT. Patients underwent both venography and duplex scanning within 24 h. The staff performing each test were unaware of the results of the other investigation. Venography was carried out using a standard protocol. In the semierect position with the leg under examination non-weight bearing and a tourniquet around the ankle, between 50 and 70 ml of low osmolar radiological contrast medium was injected into a dorsal foot vein. Three views were taken of the calf and two views of the popliteal vein. After this the patient was gradually lowered into the supine position and views of the femoral and iliac veins were obtained. Further views were taken as necessary. Following completion of the examination, the venous system was flushed clear with physiological saline and this was checked fluoroscopically.

All venograms were reported ‘blind’ by a single consultant radiologist (I.B.N.) for the presence or absence of thrombus in the calf, popliteal, femoral or iliac veins according to the criteria of Williams. If the result was equivocal, the films were re-examined after an interval of 2 weeks and regraded. This final report was used for the eventual analysis.

Duplex scanning was performed using a 5 MHz linear array transducer (Acuson, Mountain View, California, USA) coupled to an Acuson 128 scanner. The femoral veins were imaged with the patient supine, and the popliteal veins with the patient sitting. If the patient was unable to sit up, the popliteal fossa was scanned with the patient in the lateral position or prone. The following features were specifically sought in all patients: (1) a clear lumen with no filling defects; (2) compressibility by gentle probe pressure (imaged in transverse section); (3) a normal spontaneous phasic flow with respiration; (4) flow surge on calf compression; (5) no reflux on calf release; and (6) normal valve cusp movement (when identified).

Duplex scans were reported by the scanning technician at the time of scanning on a specially designed pro forma. Thrombus was graded as present or absent in the calf, popliteal or femoral veins. Proximal extension of thrombus into the external iliac vein was assessed routinely, but consistent images of the common iliac vein proved difficult and
findings at this level have not been included in the results. If thrombus
was identified, it was further classified into occlusive or non-occlusive,
depending on whether any flow signal could be obtained from the
involved vein. Scans were recorded on to videotape and kept for
subsequent review. The initial report was used for comparison with
venography.

Results

There were no contraindications to duplex scanning, but four
of the 68 limbs did not undergo venography. This was due to
failure of vein cannalization in two cases and to contrast allergy
in one case. In the fourth case venography was contraindicated
by severe arterial disease with digital sepsis. All four limbs had
negative duplex scans and the patients were not anticoagulated,
with no adverse sequelae.

In the remaining 64 limbs, both venogram and duplex results
were available. Overall there were 29 positive venograms out
of 64 examinations (45 per cent), and duplex scanning correctly
identified 25 giving an overall sensitivity of 86 per cent. Of the
35 negative venograms, duplex scanning identified 28 correctly
giving a specificity of 80 per cent. Most of the errors were due
to interpretation of calf and popliteal thrombosis (Table 1). If
duplex scanning was compared with venography for all except
isolated calf thrombosis it identified 23 of 24 positive venograms
(sensitivity 96 per cent) and 28 of 33 negative venograms
(specificity 85 per cent), giving a diagnostic accuracy of
81 per cent.

The accuracy of duplex scanning was also examined segment
by segment (Table 2). In the femoral segment, duplex identified
21 of 22 positive venograms (95 per cent) and all 42 negative
venograms (100 per cent). The solitary error was in a patient
with popliteal and distal femoral thrombosis extending just
proximal to the adductor hiatus. The duplex scan correctly
identified the popliteal thrombosis, but missed the thrombus in
the lower femoral vein.

Iliac extension of femoral DVT was routinely sought and
was identified by duplex scanning in all cases diagnosed
venographically. In no case did the thrombus extend further
than the distal external iliac vein.

In the popliteal segment, accuracy was lower, with duplex
scanning identifying 21 of 23 positive venograms (91 per cent)
and 34 of 41 negative venograms (83 per cent). Review of the scans
identified slow flow and the appearance of clumps of rolling
cells (which we term 'rouleaux') as the predominant cause of
false positive diagnosis. The other cause of false positive
diagnosis was difficulty in compressing the vein behind a
swollen knee. These errors were partly due to the learning curve in
interpreting duplex findings. We found that few of these errors
occurred towards the end of the study.

Blind review of these scans was carried out at the end of
the study and resulted in the regrading of six out of the seven
initially positive duplex scans as negative due to rouleaux
behind the knee, giving a revised sensitivity of 91 per cent and
a revised specificity of 98 per cent.

Analysis of the accuracy of calf duplex scanning is more
difficult. We did not routinely examine the calf if thrombus
was detected in the femoral or popliteal segments. There were 49
limbs in which the calf vessels were examined by both
venography and duplex scan. Duplex scan correctly identified
34 of 41 negative venograms (83 per cent). Review of the scans
identified slow flow and the appearance of clumps of rolling

<table>
<thead>
<tr>
<th>Test site</th>
<th>Venogram</th>
<th>Duplex</th>
<th>Duplex sensitivity (%)</th>
<th>Duplex specificity (%)</th>
<th>Diagnostic accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Femoral</td>
<td>22</td>
<td>21</td>
<td>95</td>
<td>100</td>
<td>96</td>
</tr>
<tr>
<td>Popliteal</td>
<td>23</td>
<td>21</td>
<td>91</td>
<td>83 (98)</td>
<td>74 (89)</td>
</tr>
<tr>
<td>Calf</td>
<td>21</td>
<td>17</td>
<td>81</td>
<td>89</td>
<td>70</td>
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</tbody>
</table>

Figures in parentheses are those obtained following review of the popliteal duplex scans.

Table 2 Numbers of limbs with positive or negative studies by segment studied

<table>
<thead>
<tr>
<th>Venogram</th>
<th>Duplex</th>
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<tbody>
<tr>
<td>+ve</td>
<td>+ve</td>
</tr>
<tr>
<td>21</td>
<td>0</td>
</tr>
<tr>
<td>21</td>
<td>7 (1)</td>
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<tr>
<td>17</td>
<td>3</td>
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</tbody>
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Figures in parentheses are those obtained following review of the popliteal duplex scans.

17 of 21 positive venograms (81 per cent) and 25 of 28 negative
venograms (89 per cent).

Duplex scanning provided the diagnosis of Baker's cyst in
three limbs thought to have a DVT on clinical grounds. This
advocates duplex scanning as a test of choice for diagnosing
venography. This technique is useful for detecting pathology
squatting on clinical grounds. This demonstrates that duplex scanning can detect pathology
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Discussion

The variety of tests reported in the literature illustrate that, so
far, no single test has proved superior to venography. The main
limitations are accuracy and the availability of experienced staff
to apply the tests in a reproducible manner.

Thermography seeks to diagnose DVT by detecting a rise
in temperature in association with the thrombosed vein
segment. The recent introduction of portable equipment using
liquid crystals has opened the way for more widespread
application of the technique. It has a number of major
limitations, the most important being that it is not applicable
to individuals who have suffered trauma to their lower limbs,
or who have significant peripheral vascular disease. This limits
its application in high risk groups such as patients undergoing
joint replacement.

Radioisotopic fibrinogen scanning has an established place
in the detection of DVT. The labelled fibrinogen is incorporated
into developing clot and therefore has to be given before the
development of the thrombus. This technique is useful for
screening, but unsuitable for diagnosing DVT. When used to
screen, there is a tendency to overdiagnose, especially in
the calf. The accuracy of this method decreases in the thigh
and it will not readily detect non-occlusive thrombi. Coupled
with this, fibrinogen is obtained from pooled plasma which
makes it both expensive and a potential infection risk.

Tests that indirectly measure altered flow, such as impedance
plethysmography, while good at excluding thrombosis, are of

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variable sensitivity and require considerable experience to obtain reproducible results. A disadvantage is that calf thrombi are not readily detected, but more importantly, non-occlusive thrombi in the proximal veins may also be overlooked.

Ultrasonography is able to recognize occlusive thrombus by detecting non-compressible veins and it has been used to improve the selection of cases for venography. A high degree of accuracy has been demonstrated using compression thrombosis, but most studies avoided assessment of the iliac or calf veins. When calf veins are included, the accuracy of the test is lower. The hand-held Doppler flow probe can also be used to test for DVT, but it is of limited accuracy because it cannot detect non-occlusive thrombus and has difficulty in picking up signals from the smaller calf veins.

The combination of B-mode scanning and Doppler shift data from the duplex scanner have advanced the accuracy of these tests in the few series reported to date, although Cronan et al. concluded that Doppler analysis improved confidence in the result of ultrasound compression studies rather than the accuracy of diagnosis of DVT. Most studies have concentrated on diagnosis in the femoropopliteal segment. In the absence of proximal thrombus, calf vein thrombosis should be excluded by direct examination. Treatment may not need to be started in the face of isolated calf vein thrombosis, but as propagation may occur in up to 10 per cent of cases, the condition should be followed with repeat examinations.

There are a number of important points which emerge from this study. In common with other groups, we have found that diagnostic accuracy is lowest in the calf and that calf vein thrombus was not invariably present when the duplex identified more proximal thrombosis. Isolated calf vein thrombosis is difficult to detect, but the specificity of scanning in the calf allows a high level of confidence in a negative scan which identifies normal veins.

Initial assessment of the popliteal fossa yielded a number of false positive results, most of which occurred early in the study. Blind review of the scans was undertaken some weeks after the study closed to try to identify errors in scan interpretation. Review of the scans reveals that most of the false positive diagnoses were made in patients with sluggish flow and clumping of cells. With increasing experience improved quality of diagnosis can be expected. The other feature of note was that compression of the vein was found to be difficult on a few occasions. This may be related to our technique of examining the patient in the sitting position. One group has commented that this can make it difficult to collapse the popliteal vein with probe pressure.

In the femoral segment accuracy was high, the one error being a patient who had limited extension of thrombus from the popliteal into the distal femoral veins. The scan had correctly identified the popliteal thrombus. Scanning in the region of the adductor hiatus is known to be a source of inaccuracy as it is difficult to visualize the vein over a few centimetres at this level. Increasing experience and improved technique have allowed us to improve our visualization of this area, although isolated thrombus at this location would be one instance of proximal thrombosis where error might be expected.

In summary, we have demonstrated that duplex scanning can identify DVT with a high degree of accuracy in the proximal venous tree of the lower limb. Diagnostic accuracy is lower as one proceeds distally, a factor that should be remembered when interpreting the results of duplex scanning. Isolated calf thromboses are not associated with an adverse outcome unless they propagate. Further study of the ability of duplex scanning to detect such thromboses is warranted to define the optimum diagnostic parameters and to assess the rate of propagation. At present we feel that if reliance is to be placed on duplex scanning, a negative scan should be repeated after an interval of 2 or 3 days. We believe that the duplex scanner has an important role to play in the diagnosis of DVT, and it is our policy to exclude major vein thrombosis with duplex scanning. The use of the duplex scanner should reduce the requirement for venography. It should also allow more accurate follow-up and assessment of the response to treatment, as well as providing alternative diagnoses and information on the opposite limb. Venography is required when the scan result is doubtful and clinical suspicion is strong.

References