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The use of automated strain gauge plethysmography in the diagnosis of deep vein thrombosis

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Abstract. The venometer is a nurse- or technician-operated machine that uses automated strain gauge plethysmography to detect deep vein thrombosis (DVT). We compared the venometer with contrast venography to determine its accuracy, and also used it to triage patients between admission with subsequent anticoagulation and out-patient investigation without anticoagulation. We enrolled 307 consecutive patients presenting to the medical admissions unit with suspected DVT, of whom 270 underwent both plethysmography and venography. Plethysmography produced a negative predictive value (NPV) of 97% and a sensitivity of 90% for proximal DVT. It also produced a false negative rate of 10% for proximal DVT, For distal DVT, sensitivity was 66%, specificity 80%, positive predictive value 36% and NPV 93%. We conclude that the automated venometer report is a quick, non-invasive and easy to use initial screening test. However, it is not sufficiently accurate in a medical admissions unit to be a definitive diagnostic test for DVT and may, therefore, be best used in combination with clinical risk assessment and D-dimer assay with more definitive radiological investigations as necessary.

Deep vein thrombosis (DVT) is a common clinical condition and accounts for 2.5 million cases per year in the US, of which approximately 20% will develop pulmonary embolism [1]. It is one of the most common reasons for acute referral to physicians in the UK and costs the NHS an estimated £240 million per year [2].

Contrast venography is a standard method for diagnosing the presence of DVT [3, 4]. However, it is invasive, not always technically possible to perform and carries a small risk of causing venous thrombosis [5]. In view of these limitations, compression ultrasound has emerged, in many centres, as the non-invasive method of choice for the evaluation of patients with suspected DVT. This is largely because of its accuracy in detecting DVT, patient tolerability and the non-invasive nature of the test [6–8]. In our hospital, venograms and ultrasound are only available 9am–5pm, Monday to Friday.

Although low molecular weight heparin is often used in patients with suspected DVT as out-patient treatment whilst awaiting a definitive test, at the time of this study it was not routinely available. Therefore, patients with suspected DVT who were unable to undergo venogram or ultrasound at the time of admission would be admitted and given heparin until a venogram could be performed. This might mean patients admitted on a Friday evening would undergo 72 h of anticoagulation before a definitive test could be performed. A significant proportion of patients are therefore admitted and anticoagulated unnecessarily, with its associated risks and costs.

The most important adverse effect of heparin therapy for DVT is major haemorrhage. This has been shown to occur in 4% of cases, with one in six of these being fatal [9]. O'Shaughnessy et al's study had a similar major haemorrhage rate with the addition of minor haemorrhage in 3.2% of patients, and a rethrombosis rate of 6.9% [10].

Strain gauge plethysmography has been used diagnostically for several decades [11–12]. It measures changes in calf dimensions whilst venous outflow is occluded by a cuff placed around the thigh. The rate of decrease in calf diameter when the cuff is deflated gives a measure of venous outflow. However, the calculations involved were laborious, which made its use unappealing. Computer-assisted strain gauge plethysmography (AMT Ltd, Belfast, UK) using a technician-operated portable machine is quick and simple to use. Venous capacitance and venous outflow are automatically calculated and plotted against a computer determined discrimant line giving an immediate and objective measure of the presence or absence of DVT [13–15].

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AMT Ltd, Belfast provided a grant for venometer tests.

Figure 1. The venometer and correct patient positioning.

We compared this with contrast venography and evaluated its accuracy in detecting both above and below knee DVT in a District General Hospital Medical Admissions Unit.

Methods

All patients admitted to the Acute Medical Unit at Gloucestershire Royal Hospital over a 24 month period (November 1997–October 1999) with suspected DVT were screened using computer-assisted strain gauge plethysmography.

This venometer scan was performed within 3 h of admission. The patients leg was elevated with the knee flexed at 30° and the heel supported in a custom made rest. Maximum calf circumference was measured and recorded and the strain gauge then applied to the calf at this level. A standard thigh cuff is inflated automatically when the computer programme is started [13, 16]. The venometer and position the patient has to adopt is shown in Figure 1. The computer clearly displays the result as positive or negative for a proximal DVT (Figure 2).

Scans were performed by one of several nurses trained to use this equipment. If a venogram could be arranged on the day of admission, this was performed. If this was not possible, and the venometer was negative, the patient was discharged without anticoagulation but with an out-patient venogram booked for the next list.

All venograms were reported blind of the venometer result. Thrombosis involving popliteal, femoral or iliac veins was defined as proximal (or above knee), whilst thrombosis below the popliteal vein was defined as distal (or below knee).

Statistical analysis

Data were entered into a spreadsheet and the statistical programme SPSS (version 7.5.1) (SPSS Inc., Chicago, IL). Diagnostic data were summarized using sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV).

Exclusions

37 patients referred for investigation of possible DVT were excluded. Four of these did not have a venometer test; one was too obese for the venometer cuff to fit, two patients were not able to keep still for long enough and one patient was unable to bend their leg owing to a recent orthopaedic procedure.

The remaining 33 patients underwent a venometer test on arrival at the Medical Admissions ward, but in 21 cases venogram was not performed because another clinical diagnosis was made by the admitting medical team (Table 1).

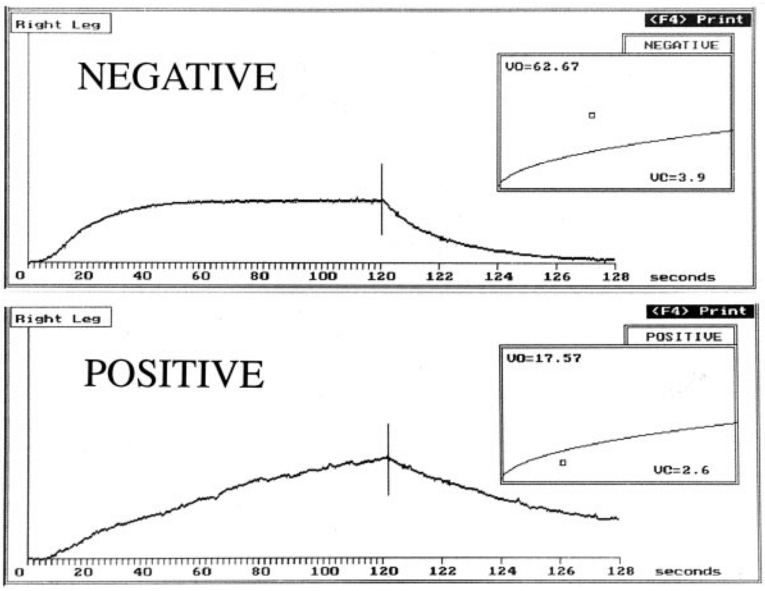

Figure 2. Computer printout of positive and negative venometer tests.

Table 1. Medical diagnosis, other than deep vein thrombosis, made at time of admission

Diagnosis	No. of patients
Cellulitis	9
Biventricular failure	3
Ruptured Baker's cyst	2
Reactive knee effusion	2
Achilles tendonitis	2
Superficial thrombophlebitis	2
Fracture of lateral malleolus	1

The remaining 12 patients did not undergo venography because of technical difficulties such as failure to cannulate a suitable vein owing to local swelling. Most of these patients underwent compression ultrasound.

Results

307 consecutive patients, with a mean age of 57.9 years (range 18–95 years), underwent automated strain gauge plethysmography. 195 patients were female and 112 male. 37 of 307 patients were excluded from subsequent analysis. 270 patients had both venometer test and venogram. Venography showed 82 of these patients to have DVT (50 proximal, 32 distal).

Plethysmography detected 45 of these 50 proximal DVTs and 21 of these 32 distal DVTs (Table 2). Automated strain gauge plethysmography had a 97% NPV for proximal DVT together with a sensitivity of 90% (Table 3). Plethysmography gave 38 false positive results giving a false positive rate of 20%. This meant that these patients were treated unnecessarily whilst awaiting a venogram. Plethysmography also had a false negative rate of 10% for proximal DVT.

In total, 166 patients produced a negative venometer result. Of these, 59 produced a negative venogram the same day. 107 patients with a negative venometer underwent venography on a subsequent day, with the potential to save 118 days of anticoagulation.

Discussion

In this study, automated strain gauge plethysmography performed in 270 consecutive patients with suspected DVT had a sensitivity of 90% for the detection of proximal DVT. Although a high figure, this is not as good as published data on a selected group of orthopaedic patients [13, 16]. Possible explanations include non-occulsive proximal thrombosis, procedural errors on a busy admission ward, different staff members performing the test, occasional poor fitting of the cuff or strain gauge errors, as well as unobserved patient movement during the test [17–19]. Results are, however, comparable to two previously published smaller studies that showed the test to have sensitivities of 95% and 94%, respectively [13, 20].

There were five false negative results for proximal DVT, with a clot shown on the venogram. On reviewing these scans, four of the five cases had a clot extending as far as the popliteal vein only, with free flow in the femoral and iliac veins. As these patients had a delay ranging from 1–3 days between venometer test and venography, it is possible that an initial distal DVT may have propagated between the time of venometer and subsequent venogram. It has been shown that up to 20% of distal DVTs will propagate with time [1]. This may be another reason for the slightly lower sensitivity of 90% in our series compared with other studies using computer-assisted strain gauge plethysmography [18, 20]. Plethysmography has a poor sensitivity (66%) for calf DVT, failing to detect 11 of 32 DVTs in our study. Therefore, the venometer is not a reliable test for diagnosing or excluding distal DVT on its own. D-dimer testing has been used with great success as an adjunct to radiological investigations for DVT [19]. It may, therefore, have a use in combination with venometer testing and clinical

Table 3. Sensitivity, specificity, negative predictive value (NPV) and positive predictive value (PPV) using the venometer

	Sensitivity (%)	Specificity (%)	NPV (%)	PPV (%)
Proximal DVT	90	73	97	43
Distal DVT	66	80	93	36
Proximal and/or distal DVT	80	80	90	63

DVT, deep vein thrombosis.

Table 2. Venography and venometer results in 270 patients

	Venography positive for DVT	Venography positive showing proximal DVT	Venography positive showing only a distal DVT	Venography normal
Venometer				
Positive	66	45	21	38
Negative	16	5	11	150
Total	82	50	32	188

DVT, deep vein thrombosis.

score assessment, an additional advantage being the 24 h availablitiy of these tests in most UK hospitals.

In summary, the venometer should not be used as a definitive test to exclude DVT because of its high false negative rate. In this study it failed to detect 10% of above knee DVTs and one third of distal thrombi that may later propagate.

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