Graded compression stockings in elective orthopaedic surgery

AN ASSESSMENT OF THE IN VIVO PERFORMANCE OF
COMMERCIALLY AVAILABLE STOCKINGS IN PATIENTS
HAVING HIP AND KNEE ARTHROPLASTY

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We recruited 89 patients who had hip or knee replacements to assess the performance of below-knee graded compression stockings. The pressure gradients generated by the stockings were measured and all patients had venography of the ipsilateral leg.

We found that 98% of stockings failed to produce the 'ideal' pressure gradient ($\pm 20\%$) of 18, 14 and 8 mmHg from the ankle to the knee, while 54% produced a 'reversed gradient' on at least one occasion during the course of the study. The overall rate of deep-venous thrombosis was 16.7%. Stockings which produced reversed gradients were associated with a significantly higher incidence of deep-venous thrombosis ($p = 0.026$) than those with the correct gradient (25.6% v 6.1%). This suggests that the performance of graded compression stockings can be improved if reversed pressure gradients are detected and prevented.

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Graded compression stockings (GCS) are commonly used for patients who have total hip (THR) and knee replacements (TKR). Surveys suggest that between 68% and 73% of orthopaedic surgeons use them routinely for the prophylaxis of deep-venous thrombosis (DVT).^{1,2} It is estimated

that the NHS spends over two million pounds on such products each year.³ They are presumed to work by increasing the velocity of venous flow thus preventing venous stagnation in patients who are not walking. This effect is best achieved by graded compression of 18 mmHg at the ankle, 14 mmHg at the calf and 8 mmHg at the knee.⁴ High levels of compression (>30 mmHg) can impede venous blood flow whereas non-graduated or low levels of compression do not adequately increase it.^{4,5} There is little information on the pressures achieved by stockings in a clinical setting and no study has yet related this performance to the subsequent formation of DVT. Many clinical trials support the use of GCS in general surgery⁶ but their efficacy is in doubt in elective orthopaedic surgery.^{7,8} It is known that the stockings perform poorly even when examined on the industry's own hosiery tester,³ but more recently their ability to produce the correct levels of graded compression in the clinical setting has been questioned.⁹⁻¹² In healthy volunteers three commonly used stockings, Anti-Em (Biersdorf UK Ltd, Milton Keynes, UK), TED (Kendall, Basingstoke, UK) and Tx (Brevet, Oldham, UK) all failed to produce the ideal gradient in up to 75% of cases. Anti-Em stockings proved to be slightly more reliable than Tx, while TED stockings were clearly inferior.¹³ This disparity between the gradients claimed to be produced by stockings and those observed in vivo led us to investigate whether stockings produce the correct pressure profiles in patients having joint replacements and to determine the effect of adverse pressure gradients on the subsequent formation of DVT.

Patients and Methods

We enrolled 89 consecutive patients who had been admitted to Glenfield General Hospital for either primary THR or TKR. We excluded those who had iodine sensitivity, peripheral vascular disease, a proven history of thromboembolism, or were having bilateral or revision surgery. The approval of the Ethical Committee was obtained and all patients who were recruited gave written informed consent.

On the day of admission patients were measured for the appropriately-sized below-knee Biersdorf stockings. In a previous study these had been shown to give the best

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pressure profiles.^{9,13} The pressures generated by the GCS were measured in mmHg by air cells beneath the stockings, connected to an Oxford Pressure Monitor MK II (Talley Medical Group Ltd, Romsey, UK). Measurements were taken from 1 cm above and anterior to the medial malleolus, the mid-calf half way between the medial femoral epicondyle and the medial malleolus, and under the elasticated band at the top of the stocking at the popliteal fossa. The stockings were removed for the duration of the operation, but replaced immediately afterwards. In patients who had knee replacements the stockings were worn under a Robert-Jones bandage which was removed on the second postoperative day when the patient was mobilised and knee flexion begun. The stockings were worn continuously until venography was carried out.

Three measurements were taken from each site and the mean value calculated to give a pressure gradient for each stocking. Further measurements were made on the second, fourth and sixth days after operation. Ipsilateral ascending venography was carried out on the sixth day. The venograms were assessed by an independent radiologist who was blinded to the pressure measurements. A reverse gradient was defined as a pressure of greater than 4 mmHg generated at a more proximal part of the stocking.^{9,13}

For the reasons given in Table I, 17 patients were withdrawn from the study. These did not have complete pressure studies and therefore venography was not undertaken. This left 72 patients who completed the study. No other form of thromboprophylaxis was given and all were mobilised routinely, usually on the second postoperative day except for one who was delayed until the fourth day because of confusion. Of those who completed the study 52 had THR; 34 Charnley (De Puy International Ltd, Leeds, UK), eight Elite (De Puy International) and ten hybrid prostheses. The remainder had TKR with the Press-Fit Condylar prosthesis (Johnson & Johnson, Rayham, Massachusetts) of which 13 were cemented.

In designing the study we anticipated two groups of patients, one with appropriate pressure profiles and one without. The initial results after 44 patients indicated a sixfold difference in the rates of DVT (4.7% v 30.4%). A statistical power of 80% could be reached with sample sizes of 42 and 38 in each group, respectively. We undertook statistical analysis using the chi-squared test (Epi-info statistical package, Centres for Disease Control and Prevention, Atlanta, Georgia).

Results

Of the 12 patients who developed DVT (16.6%), seven had a THR (13.5%) and five a TKR (25%). Seven were major proximal or femoral thrombi; in the calf there were four minor (<5 cm) and one major (>5 cm) DVTs.

The ideal pressure gradient of 18.0, 14.0 and 8.0 mmHg $\pm$ 20%¹³ was noted only twice throughout the study (0.7% of measurements). Quite often the stockings produced low

Table I. Reasons for withdrawal of 17 patients from study

Reason for withdrawal	Number
Stockings not replaced postoperatively	4
Stockings removed by patient/nurses	9
Failed/refused venogram	3
Cardiac arrest	1

readings under the elasticated band around the calf. Allowing for this, the desired gradient was still produced on only six occasions (2.1% of measurements). The mean profiles (SD) produced in this study were 9.4 ± 4.6 mmHg at the ankle, 9.1 ± 3.9 mmHg at the mid-calf point and 3.0 ± 3.5 mmHg at the knee.

We observed two groups of patients, those with no reversed gradients throughout the course of the study (45.8%) and those with at least one reversed gradient (54.2%). In the 33 patients with no reversed gradients there were two DVTs (one proximal and one minor below the knee), while in the 39 patients with reversed pressure gradients there were ten DVTs (six proximal, one major and three minor below the knee). The difference was statistically significant using the chi-squared test ($p = 0.026$).

Despite the use of below-knee stockings the withdrawal rate was high (Table I), most often because patients found them uncomfortable to wear and requested their removal.

Discussion

Compression stockings are designed to give graded compression with 18 mmHg at the ankle and 8 mmHg at the knee. This has been shown to produce the maximum increase in velocity of venous flow, thus preventing venous stasis in patients who are not walking.⁴ It is presumed that this increase in venous velocity will reduce the incidence of DVT. It was not known whether this compression is actually achieved in the clinical setting and what effect, if any, such compression has on the postoperative formation of DVT. Our study has assessed how commercially available compression stockings perform in patients after arthroplasty and if this relates to the rate of DVT after operation.

Our results showed that the commercially-available graded compression stockings which had previously performed best in a normal control group¹³ seldom produced the 'optimal' pressure gradient in patients after arthroplasty. In over half the patients, the pressure gradient was reversed on at least one measurement. This produced distal venous congestion and predisposed to the increased formation of DVT. The rate of DVT of 25.6% in those patients with reversed pressure gradients is significantly higher than the 6.1% in patients with 'normal' gradients ($p = 0.026$).

The levels of compression achieved were low (9.4 mmHg at the ankle). Despite this, the overall rate of DVT was low, 16.7%, in comparison with historical rates^{1,2} and rates seen previously in the same unit.⁷ A study by Ibegbuna, Delis and Nicolaides¹⁴ showed that lightweight compression was sufficient to produce a significant effect

on venous haemodynamics. This suggests that stockings could be effective in preventing DVT with lower levels of compression, as long as reversed pressure gradients are avoided. They may be more comfortable to wear and patient compliance may be improved.

Below-knee stockings are as effective as their above-knee counterparts.¹⁵⁻¹⁷ Above-knee stockings are more uncomfortable for the patient and may produce band-like constrictions at the knee during flexion.¹³ They are more expensive than below-knee stockings and do not appear to be any more effective in preventing DVT. Their use in patients undergoing arthroplasty should be discouraged.⁷

Our study has shown that below-knee graded compression stockings could potentially be a very effective method of mechanical thromboprophylaxis. Current commercial brands, however, produce inconsistent and, sometimes, reversed pressure gradients. Further research to redefine the optimum level of compression and modifications, including a simple method of detecting reversed pressure gradients, are required to improve their performance.

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