Br. J. Surg. 1991, Vol. 78, June, 724–726

Deep vein thrombosis: effect of graduated compression stockings on distension of the deep veins of the calf

The mechanisms by which graduated compression stockings prevent deep vein thrombosis are not completely understood. Recent work has suggested that venous distension plays a role in initiating the process. Our previous work has shown that the deep veins of the lower limb distend in patients undergoing surgical procedures. We have investigated 40 patients receiving surgical treatment on the abdomen or neck. A medial gastrocnemius vein was studied using ultrasound imaging during the operations. In half the patients a graduated compression anti-embolism stocking was applied to the limb under study at the start of the operation, immediately after initial measurements of vein diameter. The median vein diameter in both groups was the same at the start of the operative procedures (*control, 2·6 mm, interquartile range 2·1–3·3 mm; stocking, 2·6 mm, interquartile range 2·1–3·7 mm*). *After application of a stocking the median diameter in this group fell to 1·6 mm* (*interquartile range 1·3–2·8 mm*) *and then decreased slightly at the end of the operation. In the control group the vein diameter increased to 2·9 mm* (*interquartile range 2·3–4·0 mm*) *during the operative procedure.*

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Deep vein thrombosis remains a common cause of death in hospital patients in the UK although the diagnosis may only be suspected in a very small proportion of these patients[1]. Deep vein thrombosis is a hazard for surgical patients in many specialities as well as those being treated in medical wards for common conditions such as myocardial infarction and strokes[2–4]. The means of reducing the hazard to hospital patients are well known and their efficacy has been tested[5,6]. Subcutaneous injections of heparin are effective but may cause patient discomfort and occasionally severe haemorrhage[7]. Anti-embolism stockings also reduce the risk of deep vein thrombosis and do not carry an associated risk of haemorrhage or cause discomfort to the patient[8].

The efficacy of heparin probably lies in its ability to promote antithrombin III activity, which along with the other inhibitors of thrombosis tends to decline in activity during surgical procedures and times of stress[9]. The means by which stockings achieve their effect remains to be fully explained. It has been shown that they increase the flow velocity in the femoral vein[10] but this may not be their only mechanism of action. Certainly, the compression gradient is essential since inadequatly designed stockings may be ineffective[11]. Recently it has been shown that there is an association between venous distension in the upper limb and subsequent deep vein thrombosis of the lower limb[12]. It has been suggested that the mechanism which results in the development of deep vein thrombosis is the production of subliminal endothelial damage, produced by stretching of the vein. Our own observations have confirmed that venous distension occurs in lower limb veins during the course of surgical procedures[13].

This investigation was designed to determine whether graduated compression stockings prevent the venous distension we had seen previously.

Patients and methods

A total of 41 patients undergoing a variety of surgical procedures were investigated (*Table 1*). After induction of anaesthesia, images of the medial gastrocnemius veins were obtained using the 7 MHz linear array transducer of an Acuston 128 ultrasound scanner (Acuson, Mountain View, California, USA) with the patient supine on the operating table. When a suitable vein was identified, the transducer was held in place using a clamp firmly attached to the operating table. Care was taken to ensure that the transducer exerted no compression on the limb under investigation, a factor which might result in alteration of the vein diameter. This was achieved by clamping the transducer 1–3 mm from the skin and filling the gap with acoustic scanning jelly. Patients were randomly allocated to receive a TED stocking (Kendall Healthcare Products Company, Mansfield, Massachusetts, USA) or no additional prophylaxis. The stocking was applied to the limb under study by slight abduction away from the transducer during the application process. The limb was then replaced in contact wth the transducer to regain a view of the gastrocnemius vein, after application of a suitable quantity of acoustic scanning jelly. Subsequently, the vein under study was maintained in constant view and the diameter noted at 5-min intervals until the operative procedure was completed. All patients received appropriate alternative prophylactic measures to prevent deep vein thrombosis where indicated, usually in the form of low-dose subcutaneous heparin.

The flow velocities in the gastrocnemius veins could not be measured accurately even using the low flow velocity measuring capability of the ultrasound machine which indicates velocities of 5 mm or greater and is satisfactory in the assessment of axial veins such as the popliteal or posterior tibial vessels. Clearly the flow rates in these veins were very low during anaesthesia so flow velocity data have not been considered further in this study.

Table 1 *Patients studied and operations performed*

	Controls	TED stocking
Number of patients	20	21
Men	5	9
Women	15	12
Mean age (range) (years)	46 (17–73)	55 (26–74)
Operations		
Laparotomy	5	6
Head and neck procedures	5	4
Herniorrhaphy	4	6
Vascular access	6	5

Patients gave their informed consent to inclusion in the study. Data were analysed using the Wilcoxon matched-pairs signed-rank test for within-subject comparison.

Results

Details of the patients and of the operative procedures carried out are shown in *Table 1*. The changes in diameter during the course of the operation are shown in *Figure 1* in which the stocking and control groups are compared. Initially, the diameter of gastrocnemius veins was the same in the control and stocking groups after induction of anaesthesia but before the start of the operative procedure (control: median, 2·6 mm; interquartile range (IQR) 2·1–3·3 mm; stocking: median, 2·6 mm; IQR, 2·1–3·7 mm). In the stocking group there was an immediate reduction in vein diameter in response to application of the garment which applies 18 mmHg compression at the ankle and 8 mmHg at the upper calf. The median vein diameter fell to 1·6 mm (IQR, 1·3–2·8 mm), a median reduction of 32 per cent (IQR, 19–49 per cent) which is highly statistically significant ($P=0{\cdot}0001$, Wilcoxon). During the course of the operative procedure there was a further decrease in vein diameter to 1·5 mm (IQR, 1·0–2·2 mm) which represents a decrease of 5·5 per cent (IQR, 0–15 per cent) compared with that immediately after the application of the stockings, $P=0{\cdot}026$ (Wilcoxon). The total reduction in vein diameter seen in this group was 48 per cent (IQR, 26–53 per cent) between induction of anaesthesia and the end of the operation.

The patients in the control group showed the same capability to undergo distension of the gastrocnemius veins during surgical procedures that we have previously observed[13]. The median distension seen during this study between induction of anaesthesia and the end of the operation was 19 per cent (IQR, 6·9–29 per cent) to 2·9 mm (interquartile range 2·3–4·0 mm), $P=0{\cdot}0005$ (Wilcoxon).

Discussion

Previous investigations into the mode of action of graduated compression stockings in preventing deep vein thrombosis have shown that, using an appropriate compression profile, a substantial increase in femoral vein velocity measured by Doppler ultrasound can be obtained[14]. These data suggest that venous emptying of the calf can be optimized by this method of prophylaxis. This has been confirmed in studies using radioisotope clearance which have shown that graduated compression stockings achieve much greater efficiency of emptying than limbs without support in recumbent subjects[15]. The flow velocity in veins of the lower limb during recumbency has been estimated to be in the range of 2–5 cm/s from isotope injections into dorsal foot veins when blood is directed into the deep veins by an ankle tourniquet[15]. By comparison, radiological studies have shown persistance of contrast medium for 10–30 min in the deep veins of the leg following injection[15,16]. The effect of graduated compression stockings is substantially to decrease the time taken to clear the contrast. The reasons for the discrepancy in isotope transit time and contrast clearance are not clear. This may be due to the high density of the radiographic contrast media used which are consequently rather difficult for the slow venous circulation to remove. Alternatively, the isotope technique reflects flow in the main axial veins of the limb, whereas the retained contrast may lie principally in the gastrocnemius and soleal veins.

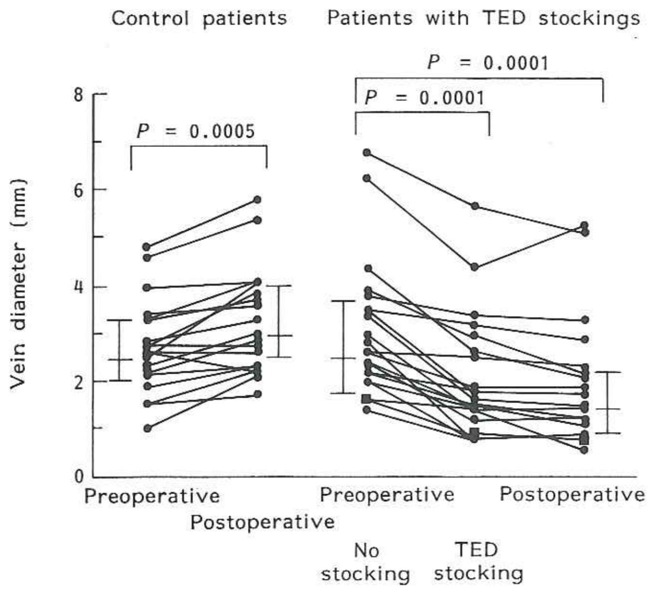

Figure 1 *Vein diameters at the start and end of surgical procedures in the control and TED stocking groups. There is distension in the control group, but a marked decrease in diameter in the stocking group*

The efficacy of ultrasound imaging in studying the lower limbs has been the subject of extensive study in our department. We have been able to show previously that venous distension occurred during operations, but we experienced some difficulty in ensuring that precisely the same segment of vein was studied on each occasion. This was overcome in the present study by investigating only one vein at a time without removing the transducer between observations. This limits the movement between transducer and patient to a small amount, essential when studying veins in the range 2–5 mm in diameter. The wavelength of ultrasound at 7 MHz in human tissues (about 0·25 mm) permits an accurate estimate of the vein diameter to be made. The ultrasound machine employed in this study indicates dimensions to a resolution of 0·1 mm, therefore small changes in vein diameter could easily be detected. It was disappointing that flow velocities could not be measured reliably in the gastrocnemius veins, but we felt justified in studying these vessels since this is the location where DVTs are thought to originate and our previous investigations showed that these were the most likely to distend. It seems probable that the slow clearance of radiographic contrast material from this region observed by previous authors is due to the low flow velocities in these vessels. So far other groups of veins have not been investigated by continuous imaging. Although it is desirable to understand the effects of anti-embolism stocking on the axial veins, we were restricted in this study to examining one vein per patient which has limited the total number of anatomical sites investigated.

The recent demonstration of the association of postoperative deep vein thrombosis and venous distension in the upper limb suggested a possible mechanism for producing endothelial damage which might precipitate deep vein thrombosis[12], assuming that such processes also affected the veins of the lower limb. We were previously able to confirm that lower limb vein distension did occur during surgical procedures. The gastrocnemius veins seemed to be most greatly affected by this phenomenon and the degree of distension was increased by the administration of intravenous saline, a factor which has previously been associated with a predisposition to deep vein thrombosis[17].

Virchow[18] originally associated deep vein thrombosis with venous stasis, changes in the blood and damage to the vein wall. The haematological abnormalities leading to post-operative deep vein thrombosis include decreased levels of the coagulation inhibitors protein C, protein S and antithrombin III[9]. Stasis is most prominent in the valve sinuses[16] and thrombosis frequently occurs first in the soleal and gastrocnemius veins where flow is probably only rapid under conditions of exercise. Certainly in this study the flow velocity in all patients was not greater than 5 mm/s, corresponding with the minimum velocity which our machine could register. It seems likely that this might render these vessels particularl sensitive to deep vein thrombosis.

There can be no doubt that TED stockings resulted in an impressive reduction in diameter of the gastrocnemius veins in the patients studied, amounting in total to a median of 48 per cent (IQR, 26–53 per cent) of the original size. This clearly will have a substantial effect on the emptying and flow in these vessels. In addition, no venous distension occurred during the operation in the stocking group; in fact the gastrocnemius veins showed a small decrease in diameter. The stockings would provide protection from the effects of venodilation seen in the control group, and suggested by Comerota *et al.*[12] as a cause of endothelial injury and hence deep vein thrombosis.

Acknowledgements

This study was supported in part by Kendall Healthcare Products Company, Mansfield, Massachussetts and the Special Trustees of The Middlesex Hospital.

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Paper accepted 16 January 1991

H-3795

H-3795