Venous thromboembolism: an insidious hazard Part III: role of graduated compression

MacLellan DG, BSc MD Grad.Dip.Bus.Admin FRACS

Abstract

Venous thromboembolism (VTE) continues to be a major cause of morbidity and mortality in hospitalised patients. Its long-term sequelae of post phlebitic syndrome and venous ulceration are significant burdens on the Australian health dollar. Prevention of VTE by appropriate prophylactic measures is unquestioningly the key to reducing acute and long-term consequences of deep venous thrombosis (DVT). Unfortunately, best practice guidelines for VTE prophylaxis are not optimally being followed in our hospitals.

In the first review article in this series [1], the incidence, prevalence and sequelae of VTE were discussed. The second article discussed the guidelines for prophylaxis and treatment of VTE [2]. However, considerable confusion exists about the role of graduated compression stockings in VTE prophylaxis and the relevance of difference compression levels. Many clinicians are also unfamiliar with intermittent pneumatic compression devices. This final article in the series seeks to clarify the role of compression therapy in VTE prophylaxis.

Primary Intention 2001; 9(4):169-174.

Background

The benefit of compression bandages for leg problems dates back to ancient Egyptian times. However, by the 18th century it was being popularised by prominent surgeons like Theden (1714-1779) who was the general surgeon to Frederick the Great. Theden promoted bandage use, stating:

"It seems almost too trivial to say much about: in point of fact, however, the discipline of bandages is extremely important as one can do more with them than anything else" [3].

Like many practitioners, he recognised the difficulty of preventing bandages from slipping. He solved that particular problem by sewing together the individual bandage windings!

Leggings and lace-up stockings were also recognised to be beneficial for circulatory disorders. Fabizio d'Aquapendente (1537-1619) is credited with the introduction of lace-up stockings for leg conditions; he manufactured them from dog leather. Later, prominent surgeons like Pierre Dionis, considered to be the founder of modern French surgical education, popularised the use of rigid lace-up stockings made from coarse linen or dog skin for the treatment of leg circulatory disorders. These stockings could be considered the precursors of the elastic and medical compression stockings used currently.

Donald G MacLellan

Canberra Clinical School, University of Sydney, Sydney NSW
The Canberra Hospital, Canberra ACT
Tel: (02) 6244 3037
Fax: (02) 6244 3042

Compression and leg circulation

Virchow postulated in 1856 that venous thromboembolism (VTE) was related to the presence of three factors (Virchow's triad):

- abnormalities in the vein wall e.g. trauma or inflammation;
- alterations in the blood constituents (hypercoagulability); and
- alteration in blood flow (stasis).

In more recent times, the effect of compression on improving lower limb circulation and preventing venous stasis has been the focus of considerable research. The effect of compression on venous blood flow rates was examined by Meyerowitz and Nelson [4] using a stocking delivering non-graduated pressure of 10mmHg. Eighty per cent of the 35 patients

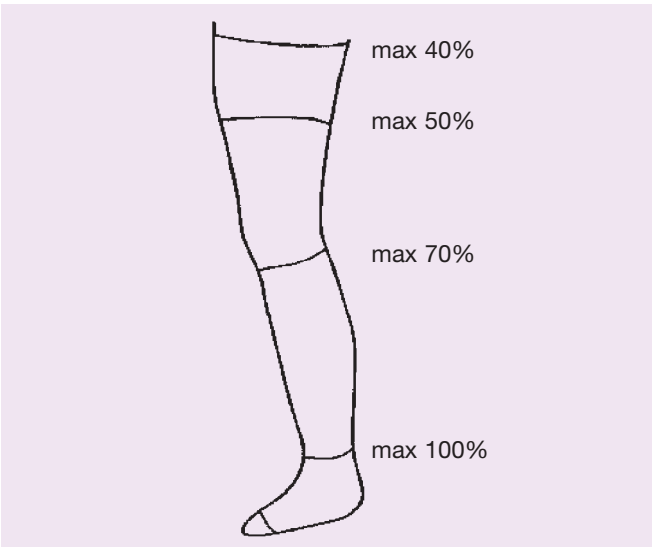
examined showed an increase in venous blood velocity with compression, but 20 per cent showed no change.

Sigel [5] was critical of non-graduated leg compression and examined the optimal compression to reduce venous stasis using a five chamber pneumatic sleeve extending from the ankle to mid thigh. Each chamber could be pressurised and monitored independently. The measurements were taken in the 15^0 foot down position. Sigel showed a pressure gradient of 18mmHg at the ankle to 8mmHg at the thigh produced an average increase in venous blood velocity of 38 per cent. Non-graduated compression of 11mmHg produced only a 10 per cent increase in venous blood velocity. Thus the 18-8 pressure profile for leg compression gained considerable prominence (Figure 1).

Lawrence and Kakkar [6] also used a five chamber pneumatic sleeve to examine leg compression profiles in the 15^0 foot down position. They confirmed the 18-8 profile produced a mean increase in deep venous blood flow velocity of approximately 75 per cent as well as an increase in muscle blood flow and subcutaneous tissue blood flow. They concluded that in the recumbent position, external graduated compression of approximately 20mmHg at the ankle, reducing to approximately 10mmHg in the upper thigh, produced substantial increases in deep venous blood flow velocity.

An important contribution to knowledge on the effect of graduated compression on blood volume was provided by Sparrow *et al* [7]. Using gamma scintigraphy and technetium-99m labelled erythrocytes, leg volume increases were examined on changing position from the supine to the upright. They used both 'antiembolic' stockings (20mmHg at the ankle) as well as other custom made stockings delivering varying pressures along the leg and studied the ability of these stockings to combat leg volume changes. All the results showed pooling in the upright position, despite the stockings. Thus they arrived at a most important conclusion. Antiembolic stockings (<20mmHg) are only valuable to patients in bed or in the supine position. Their use in ambulant patients has no proven prophylactic benefit.

Figure 1. Thigh length compression stocking pressure profile.



Compression and deep venous thrombosis (DVT) prophylaxis

One of the earliest trials on DVT prophylaxis [8] determined the benefit of elastic compression on 5426 medical and surgical patients randomly allocated to compression and non-compression groups. In 2346 patients wearing compression stockings, there were no deaths due to pulmonary embolism and only two non-fatal pulmonary embolisms were recorded. Of the 2395 patients in the control group, two died of pulmonary embolism confirmed at autopsy and there were 12 non-fatal episodes of pulmonary embolism. Unfortunately, these figures did not reach statistical significance.

Many studies followed that did reach statistical significance and showed that antiembolic stockings reduce the incidence of DVT. In a meta-analysis of seven studies, Colditz *et al.* [9] showed that in surgical patients with malignancy, stockings decreased the incidence of DVT from 27-11 per cent; when combined with heparin, the incidence fell further to 6 per cent.

A more recent and comprehensive review of graduated compression stockings using meta-analysis was undertaken by Wells *et al* [10]. They studied 35 randomised trials and found 12 met their tight inclusion criteria. Their findings were that graduated compression stockings were associated with a 68 per cent risk reduction for DVT.

Imperiale *et al.* [11] also conducted a meta-analysis examining the benefit of graduated compression stockings and other methods of prophylaxis in patients undergoing total hip replacement. They identified 56 trials satisfying their inclusion criteria. In comparison to control groups, all treatments except aspirin reduced the risk of DVT but only graduated compression stockings and low molecular weight heparin reduced the risk of pulmonary embolism and to equal effect.

Imperiale *et al.* [11] also provided information on the individual benefits of graduated compression stockings and low molecular weight heparin. The number needed to treat (NNT) is the number of patients who need to receive the

treatment to prevent one outcome event. For compression stockings, the NNT to prevent a DVT was 3.9, i.e. only 3.9 patients were required to wear compression stockings in order to prevent one episode of DVT. The equivalent NNT for low molecular weight heparin was 3.2. For compression stockings, the NNT to prevent pulmonary embolism was 51 and for low molecular weight heparin it was 49. These preventative measures are clearly very effective.

The majority of these studies were carried out using thigh length graduated compression stockings but Porteous *et al.* [12] compared thigh length to knee length stockings in 114 randomised patients. There was no difference shown between these two groups and they concluded that knee length stockings were equivalent in performance and were also more readily acceptable by patients than thigh length stockings.

It is clear from these studies that graduated compression stockings (Figure 2) are an effective form of prophylaxis, reducing the incidence of DVT and pulmonary embolism. However, they do not eliminate the risk and thus there are other forms of prophylaxis required to be considered in combination with graduated compression stockings to achieve further risk reduction.

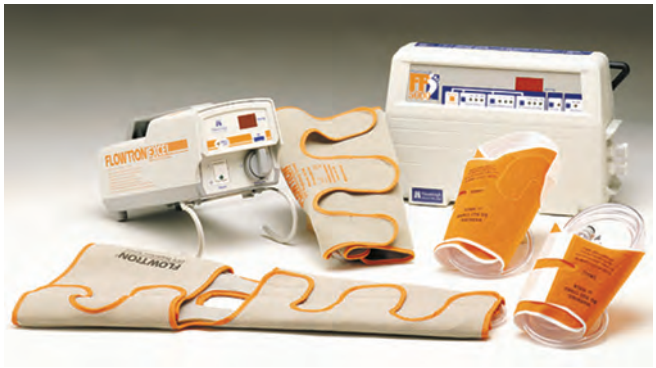
Intermittent pneumatic compression

These devices deliver intermittent compression sequentially to the lower limbs (Figure 3). They provide prophylactic protection by increasing the blood flow in the deep veins [13] and increasing fibrinolytic activity.

Antiembolic stockings and intermittent graduated external pneumatic compression were compared in a trial of 70

Figure 2. Thigh length graduated compression stocking.

Figure 3. Pneumatic sequential compression devices: leg garment and pump on the left and the foot pump system on the right.



patients undergoing craniotomy by Bucci *et al* [14]. Prophylaxis commenced pre-operatively and ended when the patients were fully ambulant. One patient in either group had non-fatal thromboembolic complications post-operatively. The authors concluded that either method of mechanical prophylaxis was effective in this high risk group of patients.

Scurr *et al.* [15] compared the effect of intermittent sequential pneumatic compression used alone or in combination with graduated compression stockings in DVT prophylaxis. They found that simultaneous use of intermittent pneumatic compression and graduated compression stockings was more effective than intermittent pneumatic compression alone.

There are a number of similar studies identifying the benefit of intermittent pneumatic compression in DVT prophylaxis. Intermittent pneumatic compression is particularly effective in combination with heparin therapy in high risk groups or when heparin therapy is contraindicated.

Foot impulse technology (Figure 3) has been shown, in combination with graduated compression stockings, to reduce the incidence of proximal vein thrombosis following hip and knee surgery. This technology also allows mechanical compression in circumstances where the lower limbs are otherwise inaccessible to graduated compression stockings and other forms of intermittent pneumatic compression, for instance due to the presence of external fixateurs on the lower limbs.

Proper use of graduated compression stockings

There are some hazards associated with the use of graduated compression stockings. Their use in patients with critical

ischaemia of the lower limbs is contraindicated [16]. Compliance with appropriate fitting and wearing of graduated compression stockings is a major challenge. No benefit ensues if, for instance, the stockings role down the limb; then they can act as a tourniquet and cause ulceration [17].

There is a considerable variability in the performance of various stockings. When Thomas *et al.* [18] examined the compression profiles of different brands of stockings in their laboratory, significant differences were found between levels of compression and the graduated pressure profiles produced by the various branded stockings. This occurred to the extent that even a reversed pressure gradient from the ankle to calf was noted to be produced by some of the stockings; this has been reported by others [7, 12].

Many stockings therefore do not produce a profile resembling that proposed by Sigel [5] and indeed may not act as a prophylactic agent when fitted to the individual patient. Details of the performance of individual graduated compression stockings have been published [19]. The National Working Party for the Prevention of VTE have also recommended that purchasers of graduated compression stockings take heed of the ideal characteristics in the selection of graduated compression stockings for DVT prophylaxis (Table 1) [19]. The National Working Party also recommend that hospitals and clinicians adopt systems and policies to ensure compliance with best practice in DVT prophylaxis (Table 2).

The optimum duration of DVT prophylaxis and treatment is unknown and thus decisions regarding time of commencement and completion of prophylaxis should be made for each patient individually. In most of the studies referenced in this article, prophylaxis was used for at least 7-10 days. However, early discharge patients may spend a considerable amount of time resting at home. They may not be truly ambulant at home and thus they may be at increased risk of DVT.

There is no conclusive evidence to form recommendations for ambulatory patients. Nevertheless, it is important to be cautious with early discharge patients as they may still be at risk and may need continued prophylaxis during their convalescence at home. As these patients become more ambulant at home, they may require to wear graduated compression stockings with a higher pressure profile.

Travel related VTE

Considerable media attention has been focussed recently on the so-called 'economy class syndrome'. The level of concern generated by highlighting the condition has resulted in a Federal Government inquiry and a major collaborative study by the World Health Organization, airlines and researchers into air travel related VTE. Unfortunately, it is evident that there is a serious deficiency in accurate information about the condition [20].

While definitive advice on prevention of travel related VTE is not available, there are some general, common sense recommendations worthy of being adopted [19, 20]. Travellers should have a generous fluid intake, avoid combining sedatives and excess alcohol, wear non-restrictive clothing and regularly mobilise their ankles and calves by foot exercises. While walking around the aircraft may be hazardous during flight due to unanticipated clear air turbulence, exercise before and after travel and during stop-overs is recommended.

Table 1. Ideal characteristics for the selection of graduated compression stockings for DVT prophylaxis.

- Evidence of clinical efficacy.
- Pressure of 16mm Hg to 20mm Hg at the ankle with graduated compression to the knee or above.
- Appropriate and individual sizing for each patient.
- Sizing range should be suitable for a large percentage of the population and the window of coverage should be clearly defined.
- Washing and reuse guidelines should be provided.
- Appropriate manufacturing standards are necessary to ensure quality control.
- Independent testing and compression profile of each stocking brand using internationally accepted methods.

Table 2. Recommendations for implementation of best practice VTE prophylaxis guidelines.

- Hospital policies include VTE best practice prophylaxis guidelines.
- VTE prophylaxis guidelines should be included in clinical pathways, ward and specialist unit guidelines and intern manuals.
- Hospitals undertake regular audit of extent and quality of the VTE prophylaxis.
- Clinicians ensure that individual patient VTE risk assessment and recommended prophylaxis is documented in the case notes.
- Include familiarisation of VTE prophylaxis guidelines in intern and registrar orientation, hospital grand rounds and hospital newsletters.

It is increasingly the considered view that there is a role for the use of graduated compression stockings during flight for travellers who have no contraindications e.g. advanced peripheral vascular disease. Scurr *et al.*[21] recently completed a randomised trial of volunteers over the age of 50 years undertaking long haul flights out of London and returning within 6 weeks. The volunteers were examined by venous duplex scans and d-dimers within 48 hours of their return. Half the volunteers wore below knee graduated compression stockings (20-30mmHg) during the flights and the other half of the volunteers received no specific prophylaxis. This study found that none of the volunteers wearing the stocking developed a DVT compared with 12 out of 116 (10 per cent) volunteers not wearing the stockings.

It is crucial that the compression stockings are accurately measured and fitted for the individual traveller. As the legs will be in a dependent position during travel, a compression level >20mmHg is required. Travellers at high risk of VTE should also seek specific medical advice before travelling as some will require consideration of low molecular weight heparin prophylaxis.

Classification of graduated compression stockings

The classification of graduated compression stockings can be confusing. There are a number of recognised classification systems (Table 3) but unfortunately each of these systems classifies stockings according to different levels of compression.

Some of these systems are used in labelling stockings available in Australia. Therefore, incorrect prescribing may occur if the stockings are simply described as Class I-IV without defining which of the systems is being adopted. A more reliable description of compression stockings is to use their pressure profile in mmHg. As stated previously, stockings used for VTE prophylaxis in recumbent patients generally have an external compression level of up to 20mmHg at the ankle and approximately 20-30mmHg for the at risk travelling public. The higher levels of compression are also used to manage lower limb oedema, prevent venous ulceration and its recurrence and in the management of lymphoedema.

Conclusion

Graduated compression stockings are valuable in the prophylaxis of DVT for low and medium risk patients. In combination with other mechanical and pharmacological prophylactic methods, graduated compression stockings are also valuable in high risk patients. Care should be exercised in the measurement and fitting of the graduated compression stockings for the individual patient and compliance is essential for prophylactic benefits. With many brands available for purchase, the selection of the particular brand of graduated compression stocking should be dependent on the performance of that brand in comparison with the ideal characteristics of graduated compression stockings.

Graduated compression stocking prophylaxis in hospital remains sub-optimal and requires all clinicians to ensure appropriate policies and guidelines are in place in their hospital and in their own specialist unit. Constant vigilance of prophylactic practice will be the surest way our patients may avoid the insidious hazards of VTE.

References

1. MacLellan DG. Venous thromboembolism: an insidious hazard. Part 1: incidence, prevalence and sequelae. Primary Intention 2000; **8**:57-61.
2. Chalasani V & MacLellan DG. Venous thromboembolism: an insidious hazard. Part II: prophylaxis and treatment. Primary Intention 2000; **8**:98-103.
3. Hohlbaum GG. The History of Medical Compression Hosiery. In: Hohlbaum CG (ed). The Medical Compression Stocking. Stuttgart: Schattauer, 1989 p106-113.
4. Meyerowitz BR & Nelson R. Measurement of the velocity of blood in the lower limb veins with and without compression. Surgery 1964; **56**:481-486.
5. Sigel B, Edelstein AL, Savitch L, Savitch L, Hasty JH & Felix WR: Type of compression for reducing venous stasis. Arch. Surgery 1975; **110**:171-175.

Table 3. Classification system for graduated compression stockings.

Country	Class I (mm Hg)	Class II (mm Hg)	Class III (mm Hg)	Class IV (mm Hg)
USA	18-30	30-40	40-50	
Germany	18.05-21.05	23.31-32.33	33.83-45.86	>49
France	I0-15	15-20	20-36	>36
Switzerland/Italy	18-21	26.25-33.75	36.75-48.75	>54
United Kingdom	14-17	18-24	25-35	>35
International system	20-30	30-40	40-50	>50

6. Lawrence D & Kakkar V. Graduated, static, external compression of the lower limb, a physiological assessment. British Journal of Surgery 1980; **67**:119-121.
7. Sparrow RA, Hardy JG & Fentem PH. Effect of 'antiembolism' compression hosiery on leg blood volume. British J of Surgery 1995; **82**: 53-59.
8. Wilkins RW, Mixter G, Stanton JR & Litter J. Elastic stockings in the prevention of pulmonary embolism, a preliminary report. NEJM 1952; **246**:360-364.
9. Colditz GA, Tuden RL & Oster G. Rates of venous thrombosis after general surgery, combined results of randomised clinical trials. Lancet 1986; **2**:143-146.
10. Wells PS, Lensing AWA & Hirsh J. Graduated compression stockings in the prevention of post operative venous thromboembolism. Arch. Int. Med 1994; **154**:67-72.
11. Imperiale TF & Speroff T. A meta-analysis of methods to prevent venous thromboembolism following total hip replacement. J. Amer Med. Association 1994; **271**:1780-1785.
12. Porteous MJC, Nicholson, EA, Morris LT, James R & Negus D. Thigh length versus knee length stockings in the prevention of deep venous thrombosis. British J of Surgery 1989; **76**:296-297.
13. Schwenk W, Bohm B, Fugener A & Muller JT. Intermittent pneumatic sequential compression (ISC) of the lower extremities prevents venous stasis during laparoscopic cholecystectomy. A prospective randomised study. Surg. Endoscopy 1998; **12**:7-11.
14. Bucci MN, Papadopoulos SM, Chan JC, Campbell JA & Hoff JT. Mechanical prophylaxis of venous thrombosis in patients undergoing craniotomy: a randomised trial. Surg. Neurology 1989; **32**:285-88.
15. Scurr JH, Coleridge-Smith PD & Hasty JH. Regimen for improved effectiveness of intermittent pneumatic compression in deep venous thrombosis prophylaxis. Surgery 1987; **102**:815-819.
16. Merret ND & Hanel KC. Ischaemic complications of graduated compression stockings in the treatment of deep venous thrombosis. Post. Grad. Med. Journal 1993; **809**:232-234.
17. Tillman RM, Marsh DR & Leyland H. Untitled short report. BMJ 1991; **303**:1560.
18. Thomas S, Toyick N & Fisher B. Graduated External Compression and the Prevention of Deep Vein Thrombosis (2nd ed). Bridgend: SMLT, 2000.
19. Fletcher J, MacLellan DG, Fisher C, Gibbs H, Matthews G, Stacey MC & Van Rij A. Prevention of Venous Thromboembolism. Best Practice Guidelines for Australia & New Zealand (2nd ed). Canberra: HEMI, 2001.
20. Gallus AS & Baker RI. Economy class syndrome. Med J Aust 2001; **174**:264-5.
21. Scurr JH, Machin SJ, Bailey-Smith S, Mackie IJ, McDonald S & Coleridge Smith PD. Frequency and prevention of symptomless deep-vein thrombosis in long-haul flights: a randomised trial. Lancet 2001; **357**:1485-9.