Graduated compression stockings in the prevention of venous thromboembolism

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Background: Surveys still show a wide variation in routine use of deep vein thrombosis (DVT) prophylaxis despite its established place in current patient management. This article reviews the mechanism of action, efficacy and complications of stockings in preventing DVT.

Methods: Relevant publications indexed in Medline (1966–1998) and the Cochrane database were identified. Appropriate articles identified from the reference lists of the above searches were also selected and reviewed.

Results and conclusion: Graduated compression stockings reduce the overall cross-sectional area of the limb, increase the linear velocity of venous flow, reduce venous wall distension and improve valvular function. Fifteen randomized controlled trials of graduated compression stockings alone were reviewed. Stockings reduced the relative risk of DVT by 64 per cent in general surgical patients and 57 per cent following total hip replacement. The effect of stockings was enhanced by combination with pharmacological agents such as heparin; the combination is recommended in patients at moderate or high risk of DVT. Knee-length stockings are as effective and should replace above-knee stockings. Complications are rare and avoidable.

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Prevention of deep vein thrombosis (DVT) in hospitalized patients has received considerable attention because of the risk of potentially fatal pulmonary thromboembolism and the long-term morbidity associated with chronic venous valvular insufficiency. The result has been a continuing drop in the incidence and complications of DVT.

Without prophylaxis, the risk of DVT ranges from 25 to 30 per cent in general surgical patients to 70 per cent following some orthopaedic procedures. Prophylaxis, often consisting of a combination of pharmacological and mechanical agents, reduces the risk of DVT by 60–80 per cent in general surgical and 50–64 per cent in orthopaedic patients.

Despite the established place of prophylaxis in current patient management, more episodes of venous thromboembolism are reported in clinical practice than would be expected. Surveys show a wide variation in routine use of DVT prophylaxis. This variation may represent a lag between intended and actual implemented prophylaxis. There appears to be a shortfall in awareness of the mechanism of action and efficacy, especially of mechanical agents. Violation of established protocols, which may involve up to 30 per cent of patients, has also been reported.

Graduated compression stockings are the most widely used mechanical antithrombotic agents. They are of proven efficacy in general surgical patients. However, the case for stockings may not be as convincing in some other surgical specialties, especially orthopaedics, where patients are at much greater risk. The value of stockings for obstetric, long-stay general medical and geriatric patients is also unclear. Evidence supporting current stocking pressure profiles, which have been in use for over 25 years, needs reappraisal especially in patient groups in which stockings are not proving as effective. Evidence comparing the efficacy of thigh- versus knee-length stockings needs clarification. Although stockings are generally regarded as safe, complications occasionally occur.

This review considers the current evidence on the mechanism of action, design, efficacy and complications associated with graduated compression stockings in the prevention of venous thromboembolism.
Graduated compression stockings

![Diagram](image)

**Fig. 1** Possible mechanism of action of graduated compression stocking in preventing deep vein thrombosis

### Methods

Relevant publications indexed in Medline (1966–1998) were identified using the medical subject headings ‘stockings’, ‘clothing’, ‘bandages’, ‘thrombophlebitis’, ‘venous thrombosis’, ‘postoperative complications’ and ‘thrombosis/prevention’. The Cochrane database was also searched and relevant studies identified. Further articles identified from the reference lists of the above searches were also selected and reviewed. Odds ratios of studies reviewed were combined using the Mantel–Haenszel χ² procedure. Number needed to treat was calculated based on a 25 per cent risk of DVT in untreated general surgical patients and a 40 per cent risk following total hip replacement.

### Mechanism

The mechanism of action of compression stockings in preventing venous thrombosis remains unclear and is probably multifactorial (Fig. 1). Compression stockings achieve their effect by affecting the three classical aetiologetic factors described by Virchow (1856), namely stasis, endothelial damage and hypercoagulability. A decrease in the luminal diameter of the vein appears to play the key role.

Effect of external compression on venous function

External compression reduces the overall cross-sectional area of the lower limb and increases the linear velocity of blood flow within the veins. An external pressure of 15 mmHg results in a 20 per cent reduction in the venous cross-sectional area and a significant increase in the velocity of flow in both superficial and deep venous systems. Increased velocity of flow reduces venous stasis and decreases the risk of thrombus formation by reducing venous wall distension, local contact time and the concentration of coagulation reactants. Compression stockings also improve evacuation of incompetent and incompletely emptied valvular cusps. Stasis within these cusps is associated with the initiation of venous thrombosis. Stockings have also been shown to enhance venous function by improving coaptation of valvular cusps, again reducing reflux-related stasis and the risk of thrombosis, especially in patients with valvular insufficiency.

Postoperative DVT is associated with intraoperative systemic venodilatation affecting both lower and upper limbs. Passive venodilatation stretches the endothelium beyond the support of the tunica media. The resulting intimal tears have been demonstrated on electron micro-
Discrediting uniform compression on the basis of trials of
DVT, evidence to support its superiority over uniform
graduated compression is of proven efficacy in preventing
large enough to affect the validity of their results. While
uniform compression in the supine position at 15° foot-down tilt. The hydrostatic
gradient introduced by this position (about 14 mmHg) is
scarcely representative of the patient lying in hospital and is
large enough to affect the validity of their results. While
graduated compression is of proven efficacy in preventing
DVT, evidence to support its superiority over uniform
compression appears inconclusive and needs revalidation.
Discrediting uniform compression on the basis of trials of
Tubigrip (Seton Health Group, Oldham, UK) is probably
inappropriate, as the latter is unlikely to deliver uniform
compression with increasing proximal lower limb circum-
ference. Instead, a reverse compression gradient or tourni-
quet effect is to be expected.

The design of the majority of stockings in current use is
based on a pressure profile of 18, 14, 8, 10, 8 mmHg from
ankle to thigh as recommended by Sigel et al. and
Lawrence and Kakkar, and confirmed by clinical trials in
comparison to untreated controls. Although 30 mmHg
at the ankle had a greater effect on velocity of flow than
18 mmHg, the latter was deemed safer, being less likely to
compromise subcutaneous oxygenation. Sparrow et al. showed that the efficiency of stockings correlated
closely with changes in calf compression if ankle compres-
sion was held constant; higher calf compression was more
effective. Varying ankle compression and ankle-calf gra-
dient were not as important. A profile of 16-8, 14-5 and
6-4 mmHg at the ankle, calf and thigh respectively proved
most effective. Although the 18 to 8 mmHg pressure profile
is effective, it may not necessarily represent the best profile
or be ideal in all clinical situations in which stockings are
needed for DVT prophylaxis. Further studies are needed to
determine the optimal profile in different clinical situations.
These studies would require a large number of subjects, a
wide variety of pressure profiles and postures, and should be
based on the effect of stockings on both venodilatation and
velocity of venous outflow.

Efficacy
Results of initial trials on the value of compression for
venous thromboprophylaxis were equivocal. Wilkins et al.
reported, in a post-mortem study, one non-fatal pulmonary
embolism (PE) in 100 deaths in 2346 patients with stockings
compared with six PEs (two fatal) in 89 deaths in 2395
untreated non-randomized controls. Makin reported a
reduced incidence of clinically diagnosed DVT with
Tubigrip. Rosengarten et al. and Browne et al. were
unable to demonstrate any difference between stockings
and control using the fibrinogen uptake test. These
discrepancies probably resulted from the use of Tubigrip
for compression, which exerts non-uniform and potentially
reverse gradient compression. In addition, the studies used
clinical diagnosis, which is undoubtedly unreliable in
predicting the incidence of DVT and PE. Subsequent
studies using better stocking design and more reliable
diagnostic tools provide a clearer picture.

General surgery
The majority of studies of stockings for the prevention of
venous thrombosis have been on general surgical patients.
Table 1 Results of randomized controlled trials of graduated compression stockings in preventing deep vein thrombosis

<table>
<thead>
<tr>
<th>Reference</th>
<th>Year</th>
<th>Diagnostic test</th>
<th>Stockings</th>
<th>Control</th>
<th>Odds ratio</th>
<th>Risk reduction (%)</th>
<th>No. needed to treat†</th>
</tr>
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<tbody>
<tr>
<td>General/abdominal surgery</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Holtorf et al.14</td>
<td>1976</td>
<td>FUT</td>
<td>11 of 48</td>
<td>23 of 47</td>
<td>0.31 (0.12-0.82)</td>
<td>53</td>
<td>6</td>
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<tr>
<td>Scurr et al.52</td>
<td>1977</td>
<td>FU</td>
<td>8 of 70</td>
<td>26 of 70</td>
<td>0.22 (0.08-0.57)</td>
<td>69</td>
<td>5</td>
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<td>Torringen53</td>
<td>1980</td>
<td>FUT</td>
<td>4 of 50</td>
<td>12 of 50</td>
<td>0.31 (0.08-1.07)</td>
<td>67</td>
<td>6</td>
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<tr>
<td>Allan et al.54</td>
<td>1983</td>
<td>FUT/venography</td>
<td>15 of 97</td>
<td>37 of 123</td>
<td>0.33 (0.16-0.68)</td>
<td>67</td>
<td>7</td>
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<tr>
<td>Bergqvist and Lindblad55</td>
<td>1984</td>
<td>FUT</td>
<td>0 of 20</td>
<td>8 of 20</td>
<td>0.00 (0.00-0.55)</td>
<td>100</td>
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<tr>
<td>Wille-Jorgensen et al.56</td>
<td>1985</td>
<td>FUT/venography</td>
<td>2 of 10</td>
<td>11 of 10</td>
<td>0.17 (0.03-0.86)</td>
<td>81</td>
<td>5</td>
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<tr>
<td>Melbring and Palmer57</td>
<td>1986</td>
<td>FUT</td>
<td>1 of 54</td>
<td>2 of 54</td>
<td>0.49 (0.02-7.22)</td>
<td>52</td>
<td>9</td>
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<tr>
<td>Scurr et al.57</td>
<td>1987</td>
<td>FUT/venography</td>
<td>1 of 79</td>
<td>7 of 79</td>
<td>0.13 (0.01-0.11)</td>
<td>85</td>
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<tr>
<td>Wille-Jorgensen et al.58</td>
<td>1991</td>
<td>FUT/venography</td>
<td>2 of 93</td>
<td>12 of 83</td>
<td>0.14 (0.02-0.70)</td>
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<td>Total</td>
<td></td>
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<td>51 of 748</td>
<td>144 of 727</td>
<td>0.31 (0.22-0.44)</td>
<td>64</td>
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<td>Gynaecology</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turner et al.61</td>
<td>1984</td>
<td>FUT</td>
<td>0 of 104</td>
<td>4 of 92</td>
<td>0.00 (0.00-1.32)</td>
<td>100</td>
<td>7</td>
</tr>
<tr>
<td>Neurosurgery</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turpin et al.62</td>
<td>1989</td>
<td>FUT/venography</td>
<td>7 of 80</td>
<td>16 of 81</td>
<td>0.38 (0.14-1.09)</td>
<td>58</td>
<td>7</td>
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</tbody>
</table>

Values in parentheses are *percentages or 95 per cent confidence intervals. †Based on PEER (patient expected event rate) = 0.25. FUT, fibrinogen 125I uptake test; venography, contrast venography.

Table 1 shows the results of randomized controlled trials comparing the incidence of DVT in general surgical patients. The overall incidence of DVT was 51 (7 per cent) of 748 in the treatment group compared with 144 (19 per cent) of 757 in the control group. The summary odds ratio was 0.31, which translated to a relative risk reduction of 64 (95 per cent confidence interval 53–73) per cent in patients wearing stockings. Treating eight general surgical patients with graduated compression stockings prevented the occurrence of one DVT. Wells et al.61 reported a 68 per cent relative risk reduction of DVT in general surgical patients using stockings. In practice, stockings are often combined with pharmacological agents, especially low-dose heparin or LMWH. This combination leads to improved results (see later).

Direct evidence of the value of graduated compression stockings in preventing fatal PE is inconclusive. Numbers limit most trials, as a large sample size would be required to show a significant reduction because of the low incidence of PE, particularly as the widespread use of heparin has increased risk of fatal PE in the latter group65. The incidence of DVT exceeds 50 per cent in untreated controls (Table 2); however, thromboprophylaxis appears to be less effective in orthopaedic than in other forms of surgery10,70–73. Although the majority of orthopaedic surgeons use pharmacological prophylaxis, the risk of bleeding leading to wound haematoma, infection and implant failure is perceived as unacceptable by a minority74. Physical agents are safer and more acceptable in this regard75,76. Examining the results of the randomized trials shows a 57 per cent overall relative risk reduction in incidence of DVT following total hip replacement in patients who used patients following symptomatic proximal vein thrombosis reported mild to moderate post-thrombotic syndrome in 19 patients (20 per cent) wearing stockings compared with 46 controls (47 per cent) (P<0.001). In addition, only 11 patients (11 per cent) wearing stockings developed a severe post-thrombotic syndrome compared with 23 control patients (23 per cent) (P<0.001)64.
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Table 2 Randomized controlled trials of graduated compression stockings for deep vein thrombosis prophylaxis following total hip replacement

<table>
<thead>
<tr>
<th>Reference</th>
<th>Year</th>
<th>Diagnostic test</th>
<th>Stockings</th>
<th>Control</th>
<th>Odds ratio†</th>
<th>Risk reduction (%)</th>
<th>No. needed to treat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ishak and Morley⁸⁶</td>
<td>1981</td>
<td>Venography</td>
<td>7 of 35 (20)</td>
<td>22 of 41 (54)</td>
<td>0.22 (0.07-0.67)</td>
<td>63</td>
<td>4</td>
</tr>
<tr>
<td>Fredin et al.⁷⁷</td>
<td>1989</td>
<td>Venography</td>
<td>13 of 44 (30)</td>
<td>21 of 46 (46)</td>
<td>0.50 (0.19-1.30)</td>
<td>35</td>
<td>7</td>
</tr>
<tr>
<td>Kalodiki et al.⁸⁶</td>
<td>1996</td>
<td>Venography</td>
<td>12 of 38 (32)</td>
<td>13 of 14 (93)</td>
<td>0.04 (0.00-0.32)</td>
<td>66</td>
<td>3</td>
</tr>
<tr>
<td>Barnes et al.⁹⁹</td>
<td>1978</td>
<td>Doppler</td>
<td>0 of 8 (0)</td>
<td>5 of 10 (50)</td>
<td>0.00 (0.00-1.08)</td>
<td>100</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>32 of 125 (26)</td>
<td>61 of 111 (55)</td>
<td>0.23 (0.12-0.42)</td>
<td>57</td>
<td>4</td>
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</table>

Values in parentheses are †percentages or †95 per cent confidence intervals. †Based on PEER (patient expected event rate) = 0.4. Venography, contrast venography; Doppler, Doppler ultrasonography.

stockings compared with controls (Table 2). Treating only four patients with stockings prevented the occurrence of one DVT following total hip replacement. A recent meta-analysis of methods of prophylaxis following total hip replacement suggested that, while all recommended methods except aspirin decreased the risk, LMWH and stockings had the greatest relative value in preventing venous thromboembolism⁷⁷. Although LMWH proved more effective, it was associated with a risk of bleeding and heparin-induced thrombocytopenia⁴¹,⁷⁸-⁸⁰. Reporting a placebo-controlled, randomized clinical trial on 78 patients undergoing total hip replacement, Kalodiki et al.⁵⁸ demonstrated that the combination of LMWH (enoxaparin 40 mg daily) and stockings was more effective in preventing DVT than LMWH alone, and that stockings alone were better than nothing (13, 28 and 57 per cent incidence of proximal DVT in LMWH and stocking group, LMWH alone and untreated control groups respectively). The combination of LMWH and stockings is recommended in patients undergoing hip replacement.

Venous thromboembolism following total knee replacement is especially resistant to prophylaxis⁷⁹,⁸¹,⁸². This may be due to intraoperative positioning for optimal access, direct vascular injury from intraoperative limb manipulation and the thigh tourniquet which is inflated to 450-500 mmHg to achieve a bloodless field⁸³,⁸⁴. Use of a thigh tourniquet impairs venous drainage, damages the endothelium, confines coagulation reactants from surgical trauma below the tourniquet and may increase the risk of venous thrombosis and large emboli⁸⁵-⁸⁸. Hui et al.¹⁹ reported a significant reduction in proximal and calf venous thrombosis after total knee replacement when patients wore below-knee stockings compared with that in controls (32 versus 66 per cent). Above-knee stockings were less effective.

The risk of late-onset venous thrombosis persists for at least 5 weeks after joint replacement⁸⁹,⁹⁰. Patients may therefore benefit from continued use of stockings after discharge from hospital. The value of graduated compression stockings in patients with a fractured hip is still under evaluation.

Gynaecology, obstetrics and urology

The overall risk of DVT ranges between 4 and 45 per cent in gynaecological and 8-80 per cent in urological patients⁹¹, the highest risk being after operations for malignancy⁹². The risk in pregnancy is five times higher than that in non-pregnant age-matched patients. A randomized controlled trial of the value of stockings in 196 patients undergoing major gynaecological surgery showed a significant reduction in venous thrombosis (zero in treated versus 4 per cent in controls; P<0.05)⁵⁹. In addition, by preventing venous pooling, stockings may also reduce catecholamine release with beneficial effects for the circulation in pregnancy⁹³,⁹⁴. Clinical data on the effect of stockings in preventing DVT in pregnancy are, however, insufficient.

There are no prospective randomized controlled studies of the effect of stockings in urological patients. Hansberry et al.⁹⁵ compared use of compression stockings with pneumatic compression alone or heparin-dihydroergotamine alone in 74 patients undergoing neoplastic urological procedures using indium-labelled platelet scans. There was no significant difference in the incidence of DVT in the three groups.

Neurology and neurosurgery

Thromboembolism is a major concern in neurological and neurosurgical patients, especially those with spinal cord injury, brain tumour, head injury, stroke and patients undergoing surgery. The risk of DVT in general neurosurgical patients ranges between 19 and 50 per cent⁹⁶. The main advantage of mechanical methods of thromboprophylaxis in these patients is the avoidance of the small but catastrophic risk of intracranial or spinal bleeding complications associated with pharmacological agents⁹⁷. External
Pneumatic compression is effective in these patients\textsuperscript{60,98,99}, although its use may be limited by patient compliance. The ease of application and management of stockings may be an advantage. In a recent randomized controlled trial comparing stockings alone versus stockings combined with intermittent pneumatic compression, the DVT rate was 9 per cent for stockings only and 9 per cent for stockings and pneumatic compression, compared with 20 per cent in untreated controls\textsuperscript{90}. Stockings alone appeared sufficient. Another multicentre trial showed that LMWH reduced the rate of DVT from 21 per cent with stockings alone, to 14 per cent with stockings and nadroparin (relative risk reduction 34 per cent; \( P = 0.018 \))\textsuperscript{100}.

Stockings may suffice as the sole agent, especially where pharmacological agents are contraindicated. Graduated compression stockings combined with LMWH or low-dose heparin should provide adequate DVT prophylaxis in neurological and neurosurgical patients.

**Medical**

In a study of autopsy-proven PE in 2388 hospital deaths, Sandler and Martin\textsuperscript{101} showed that only 24 per cent of the 239 patients who died from PE had undergone recent surgery. Although the emphasis in the literature is on surgical patients, DVT is also important in medical patients\textsuperscript{102-104}. The efficacy of pharmacological agents, especially heparin, in preventing DVT in patients with heart failure, myocardial infarction and chest infections has been demonstrated by clinical trials\textsuperscript{105,106}. In contrast, clinical evidence of the value of mechanical prophylaxis in medical patients is limited. A recent prospective randomized trial of graduated compression stockings in 80 patients aged 70 years and above with acute myocardial infarction, using the fibrinogen uptake test, showed DVT in eight control legs compared with none in legs with stockings\textsuperscript{107}. With the exception of this trial and data on stroke patients, no other studies on the efficacy of graduated compression stockings in general medical patients were found. The available data suggest that there is a place for stockings in DVT prophylaxis in medical patients. This is particularly important when hospitalization is prolonged, in patients aged over 40 years and in the presence of medical conditions known to predispose to DVT.

**Recurrent deep vein thrombosis**

Previous DVT is a major predisposing factor to DVT recurrence\textsuperscript{108}. Belcaro et al.\textsuperscript{63} studied the efficacy of graduated compression stockings in preventing recurrent DVT in 224 patients following an episode of DVT. Three years later the recurrence rate was 46 per cent in untreated controls compared with 9, 5 and 2 per cent in patients using stockings, ibuprofen or stockings and ibuprofen respectively.

**Comparison with other prophylactic agents**

Graduated compression stockings reduce the risk of DVT by 64 per cent in general surgical patients. Tables 3 and 4 show the results of trials that compare the effect of stockings alone or combined with other prophylactic modalities. Graduated compression stockings combined with low-dose heparin performed better than stockings or heparin alone (Table 3). LMWH combined with stockings was better than stockings alone (Table 4). Compression stockings and pneumatic compression were equally effective (Table 5). Stockings are, however, easier to manage. Either stockings or pneumatic compression may be used during operation and postoperative mechanical prophylaxis can be continued with stockings alone. In hip replacement, a meta-analysis

### Table 3 Venous thromboprophylaxis using graduated compression stockings with and without low-dose heparin

<table>
<thead>
<tr>
<th>Reference</th>
<th>Year</th>
<th>Type of surgery</th>
<th>Diagnostic test</th>
<th>LDH</th>
<th>Stockings and LDH</th>
<th>Stockings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Torngren\textsuperscript{63}</td>
<td>1980</td>
<td>Abdomen</td>
<td>FUT</td>
<td>12</td>
<td>4 of 98 (12)</td>
<td>2 of 63</td>
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<tr>
<td>Bow and Goldson\textsuperscript{100}</td>
<td>1983</td>
<td>Abdomen</td>
<td>FUT</td>
<td>15</td>
<td>2 of 63 (3)</td>
<td></td>
</tr>
<tr>
<td>Wille-Jorgensen et al.\textsuperscript{56}</td>
<td>1985</td>
<td>Abdomen</td>
<td>FUT</td>
<td>11</td>
<td>2 of 86 (2)</td>
<td>4 of 52</td>
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<tr>
<td>Wille-Jorgensen et al.\textsuperscript{56}</td>
<td>1985</td>
<td>Abdomen</td>
<td>FUT</td>
<td>12</td>
<td>2 of 79 (3)</td>
<td></td>
</tr>
<tr>
<td>Fasting et al.\textsuperscript{110}</td>
<td>1985</td>
<td>Abdomen</td>
<td>FUT</td>
<td>4</td>
<td>3 of 52 (6)</td>
<td>2 of 20</td>
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<tr>
<td>Moser et al.\textsuperscript{111}</td>
<td>1976</td>
<td>General</td>
<td>FUT</td>
<td></td>
<td>2 of 20 (10)</td>
<td>5 of 20</td>
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<tr>
<td>Nicolaides et al.\textsuperscript{112}</td>
<td>1972</td>
<td>General</td>
<td>FUT</td>
<td>1</td>
<td>29 of 122 (24)</td>
<td></td>
</tr>
<tr>
<td>Borow and Goldson\textsuperscript{109}</td>
<td>1985</td>
<td>General</td>
<td>FUT</td>
<td>2</td>
<td>15 of 108 (14)</td>
<td></td>
</tr>
</tbody>
</table>

Values in parentheses are percentages. LDH, low-dose heparin; FUT, fibrinogen \textsuperscript{125}I uptake test; Tc-pl, Technetium\textsuperscript{99m}-Tc-plasmin scan for deep vein thrombosis
Table 4 Venous thromboprophylaxis using graduated compression stockings with and without low molecular weight heparin

<table>
<thead>
<tr>
<th>Reference</th>
<th>Year</th>
<th>Type of surgery</th>
<th>Diagnostic test</th>
<th>Stockings</th>
<th>Stockings and LMWH</th>
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<tbody>
<tr>
<td>Lassen et al. [113]</td>
<td>1991</td>
<td>Hip arthroplasty</td>
<td>Venography</td>
<td>45 of 97 (46)</td>
<td>30 of 97 (31)</td>
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<td>Kalodiki et al. [108]</td>
<td>1996</td>
<td>Hip arthroplasty</td>
<td>Venography</td>
<td>12 of 32 (38)</td>
<td>8 of 32 (25)</td>
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<td>Nurmohamed et al. [100]</td>
<td>1996</td>
<td>Neurosurgery</td>
<td>Venography</td>
<td>51 of 24 (21)</td>
<td>33 of 241 (14)</td>
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<tr>
<td>Levine et al. [114]</td>
<td>1996</td>
<td>Knee surgery</td>
<td>Venography</td>
<td>60 of 124 (48)</td>
<td>29 of 66 (30)</td>
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</tbody>
</table>

Values in parentheses are percentages. LMWH, low molecular weight heparin.

Table 5 Venous thromboprophylaxis using graduated compression stockings and pneumatic compression

<table>
<thead>
<tr>
<th>Reference</th>
<th>Year</th>
<th>Type of surgery</th>
<th>Diagnostic test</th>
<th>Stockings</th>
<th>Pneumatic compression</th>
<th>Stockings and pneumatic compression</th>
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<td>Bucci et al. [115]</td>
<td>1989</td>
<td>Neurosurgery</td>
<td>IPG</td>
<td>1 of 38 (3)</td>
<td>1 of 32 (3)</td>
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<td>Hansberry et al. [95]</td>
<td>1991</td>
<td>Urological</td>
<td>Platelet scan*</td>
<td>5 of 25 (20)</td>
<td>3 of 24 (13)</td>
<td>—</td>
</tr>
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<td>Turpe et al. [90]</td>
<td>1989</td>
<td>Neurosurgery</td>
<td>FUT</td>
<td>7 of 80 (9)</td>
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<td>Goldhaber et al. [116]</td>
<td>1995</td>
<td>Cardiac</td>
<td>Ultrasonography</td>
<td>38 of 172 (22)</td>
<td>33 of 172 (19)</td>
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Values in parentheses are percentages. \(^{111}\)In-labelled platelet scan. IPG, impedance plethysmography; FUT, fibrinogen \(^{125}\)I uptake test.

Based on 56 trials showed an unadjusted pooled risk of 21 per cent for use of stockings compared with 16 per cent for LMWH and 24 per cent for low-dose heparin \[77\]. Only LMWH and stockings were shown to reduce the risk of PE in the analysis. Although this agrees with the report by Wilkins et al. on the value of stockings in preventing PE, the few trials evaluating this suggestion are limited by small numbers.

Graduated compression stockings alone are effective for the prevention of DVT. Their effect is, however, enhanced by pharmacological agents such as low-dose heparin and LMWH. Stockings alone could provide adequate prophylaxis for patients at low risk of DVT. Patients at moderate or high risk should be managed with stockings combined with LMWH or low-dose heparin \[117,118\].

**Thigh-length versus knee-length stockings**

The majority of studies on prevention of venous thrombosis have been on thigh- or full-length stockings. Thigh- or full-length stockings are more expensive, more difficult to put on and less tolerated than knee-length stockings \[119,121\]. Lawrence and Kakkar \[43\] found no increase in deep venous flow velocity when whole limb compression (18–8 mmHg) was applied compared with below-knee compression (18–14 mmHg). Porteous et al. \[122\] compared thigh- and knee-length stockings in a randomized trial using the fibrinogen uptake test and found no significant difference in their ability to prevent DVT. Sparrow et al. \[47\] observed that the portion of the stocking above the tibial plateau was relatively ineffective in decreasing venous pooling, but appeared to compromise the value of the stocking at lower levels. This prompted concern that the thigh- or full-length stockings may actually be inferior to knee-length stockings. The above-knee segment of a thigh stocking often rolls down, either hanging loosely around the knee or exerting a garter-like tourniquet effect \[121,122\], thus compromising the effect of the stocking and potentially increasing the risk of thrombosis. A recent survey of patient compliance showed a significantly higher number of improperly applied thigh-length than knee-length stockings \[119\]. Knee-length stockings should replace thigh-length stockings, being equally effective, cheaper, more likely to fit correctly and better tolerated by patients.

**Customized stockings**

Customized stockings, tailored to the patient’s leg dimensions, are usually made from high-modulus yarn with substantial variations in the pressure profile with changing limb circumference. Johnson et al. \[124\] compared these with commercially available non-custom low-modulus circular...
knit stockings, but found no advantage. Non-customized stockings actually appeared superior in that their low modulus allowed for flexibility in the calf diameter within the target pressure profile. While commercial non-customized stockings may be preferable to tailored stockings, studies suggest that they do not always conform to the pressures specified by their manufacturers. There may be a case for customized stockings in patients with pronounced calf–ankle disproportion, as in severe lipodermatosclerosis.

Indications

Patients at risk of DVT may be classified into low-, moderate- and high-risk groups based on the aggregate of predisposing factors. Graduated compression stockings may be used as sole prophylactic agent in patients at low risk of DVT. Stockings may also be used alone in situations where pharmacological prophylaxis is contraindicated and for long-term prevention of recurrence following 3–6 months of anticoagulation for a single episode of DVT. Patients at moderate or high risk should be managed with stockings in combination with LMWH or low-dose heparin. Stockings should be applied at least 2 h before operation, and continued during and after surgery until the patient is fully mobile. Stockings are particularly beneficial in the bedridden. The practice of sitting patients out of bed early after operation can be hazardous. Sitting with the knees flexed to 90° or more for a patient with thigh-length stockings causes a marked increase in popliteal–stocking interface pressure. This compromises the effect of the stockings and may jeopardize thrombo prophylaxis. The risk of venous thromboembolism subsists after discharge from hospital. Stockings may potentially be valuable in reducing this risk. With the increasing trend towards early discharge from hospital, a properly conducted randomized controlled trial of the value of graduated compression stockings following discharge is necessary.

Complications

Although graduated compression stockings are relatively safe, they are not without risk. The main concern is impairment of subcutaneous tissue oxygenation, especially in patients with existing peripheral vascular compromise. A stocking pressure of 10 mmHg produces a 10 per cent reduction in cutaneous blood flow, 10 mmHg a 25 per cent drop and 60 mmHg an 84 per cent drop. An estimate of the hazards of compression treatment of the leg by 154 Scottish surgeons showed that at some stage up to one-third had recognized a patient with damage to the leg as a result of compression therapy. Compression stockings for DVT prophylaxis were associated with 38 of the 147 cases reported. Patients with peripheral arterial disease and diabetics with neuropathy are particularly at risk, and cases resulting in necrosis and amputation have been reported. Arterial occlusion, thrombosis and gangrene over the anterior aspect of the ankle secondary to the tourniquet effect of multiple layers of rolled down stocking have also been reported. It is therefore essential that significant arterial compromise and peripheral neuropathy are excluded before applying stockings. Manufacturers advise against the use of stockings in patients with an ankle:brachial pressure index less than 0.7. Stockings should also be sized and fitted correctly. Leg measurements should be reviewed regularly especially in swollen or swelling legs, as changes in leg girth significantly change the amount of pressure exerted rendering the stocking ineffective or threatening tissue oxygenation. An increase in leg circumference of 5 cm can double the amount of pressure being applied by a stocking.

Conclusions

Graduated compression stockings provide an effective, safe, cheap and convenient means of preventing DVT. Stockings increase the linear velocity of venous outflow, prevent stasis and venous distension, and enhance emptying of valvar cusps. Properly used, stockings can reduce the risk of DVT in hospitalized patients by 55–70 per cent. Evidence on the value of graduated compression stockings in preventing fatal PE is limited and inconclusive. In combination with LMWH or low-dose heparin, stockings provide adequate prophylaxis for the majority of patients at risk. Knee-length stockings are preferable, being effective and potentially superior to thigh- or full-length stockings. Knee-length stockings are cheaper and better tolerated, and should replace thigh- and full-length stockings for DVT prophylaxis. Continued use of stockings to prevent late venous thrombosis following discharge from hospital may be beneficial in patients with poor mobility. The role of stockings in preventing DVT recurrence is noteworthy. Attention to the vascular and neurological status of the leg, proper sizing and regular review of the legs should limit the rare occurrence of ischaemic complications with stockings.

Acknowledgements

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34 Stewart GJ, Schaub RG, Niewiarowski S. Products of tissue injury. Their induction of venous endothelial damage and...


64 Brandjes DPM, Buller HR, Heijboer H, Huisman MV, de Rijk M, Jagt H et al. Randomised trial of effect of compression


93 Hobel CJ, Castro L, Rosen D, Greenspoon JS, Nessim S. The effect of thigh-length support stockings on the hemodynamic


123 Heath DJ, Kent SJS, Johns DL, Young TW. Arterial


