The Efficacy of Pneumatic Compression Stockings in the Prevention of Pulmonary Embolism After Cardiac Surgery*

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Introduction: Pneumatic compression stocking (PCS) devices have been introduced to decrease the incidence of postoperative deep venous thrombosis (DVT). However, their role in the prophylaxis against pulmonary embolism (PE) remains unclear. This study was undertaken to compare the prophylactic effectiveness of subcutaneous heparin (SCH) alone vs the combined use of PCS and SCH in the prevention of PE following cardiac surgery.

Methods: We studied 2,551 consecutive patients who underwent cardiac surgery over a 10-year period. They were randomly allocated to two groups. Group A included 1,196 patients who were treated with 5,000 U of SCH every 12 h and group B included 1,355 patients treated with a combined prophylactic regimen of PCS and SCH.

Results: The diagnosis of PE was established in 69 patients by either high-probability ventilation perfusion scan, pulmonary angiogram, or autopsy. The incidence of PE in group A patients was 4% (48/1,196) and in group B was 1.5% (21/1,355). The concomitant use of bilateral PCS and SCH reduced the frequency of postoperative PE in 62% in comparison to the prophylaxis with SCH alone (p<0.001).

Conclusions: These data suggest that the combined prophylactic method of bilateral PCS and SCH is superior to SCH alone in the prevention of PE after cardiac surgery.

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DVT=deep venous thrombosis; GCS=graduated compression stockings; PCS=pneumatic compression stockings; PE=pulmonary embolism; SCH=subcutaneous heparin; V/Q=ventilation perfusion

Key words: cardiac surgery; pneumatic stockings; pulmonary emboli; pulmonary emboli prophylaxis

Thromboembolism is a major cause of morbidity and mortality in patients undergoing major operations and approximately 10 to 20% of these events are potentially fatal.1,2 To our knowledge, studies regarding the specific use of these combined prophylactic methods in patients undergoing cardiac surgery were not previously reported.

This study was designed to determine if bilateral PCS used in addition to SCH would improve the prophylactic efficacy against PE in patients undergoing cardiac surgery.

Materials and Methods

From 1984 through 1994, a total of 2,786 patients underwent open heart surgery at our institution. Patients were randomly allocated to one of two treatment groups according to a table of random numbers. Those treated prophylactically with SCH comprised group A and those treated with combination of SCH and PCS comprised group B. Patients were excluded from either group for the following reasons: known DVT prior to surgery, bleeding complications, intraoperative death, intolerance to PCS, or withdrawal of prophylaxis before full ambulation. Scheme (Fig 1) shows the distribution of patients in each group and their outcome in regards to prophylaxis against PE.

In both groups, 5,000 U of SCH was given every 12 h. Group B patients were fitted with inflatable plastic leg sleeves that extended from the ankle to the proximal thigh. Each sleeve consisted of three chambers, two at the calf and one at the thigh. A compression wave was generated by the sequential compression device (SCD 5325; Kendall Company; Boston). The inflation cycle sequentially comp-

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pressed the lower calf, upper calf, and thigh to a peak pressure of 35 to 40 mm Hg for 11 s every 60 min. The stockings were removed for short periods when patients were ambulating.

Both prophylactic methods were started immediately after surgery and continued for 4 to 5 days or until patients were fully ambulatory.

PE following cardiac surgery was considered in all patients with unexplained dyspnea or significant hypoxia in relation to baseline levels and no interval change in their chest radiographs. All such patients underwent ventilation perfusion (V/Q) scans and/or pulmonary angiography. Those patients in whom the V/Q scan was reported as intermediate or low probability were evaluated subsequently by pulmonary angiography.

Patients in both groups were compared for all investigated parameters by means of the \( \chi^2 \) test and Mann-Whitney U test. Two-tailed \( p \) value less than 0.05 was considered statistically significant; a 95% confidence interval was also used to compare treatment methods.

**Results**

The clinical and surgical profile of groups A and B are shown in Table 1. The diagnosis of postoperative PE was confirmed in 69 patients, 25 of them were diagnosed by high-probability V/Q scan, 42 by pulmonary angiogram, and 2 by autopsy.

The incidence of postoperative PE in patients who received SCH alone (group A) was 4%, while among patients who were treated with SCH and bilateral PCS (group B), the incidence was 1.5%. The combined prophylactic method added a reduction of 62% (95% confidence interval, 47.2 to 71.3%) in the risk of developing PE, in comparison to the prophylaxis by SCH alone (\( p < 0.001 \)) (Fig 1).

**Discussion**

The purpose of this study was to evaluate the role of bilateral PCS in the prevention of PE following open heart surgery. It has been suggested that venous stasis induced by surgery can result in marked changes in vein diameters and the concomitant surgical mechanical stress can induce microtears in the endothelial layer. Patients undergoing cardiac surgery usually have significant vascular endothelial damage due to the harvesting of the saphenous veins from the lower extremities. All these factors and prolonged immobilization increase the risk of developing DVT in such patients.

Several investigators have reported the use of mechanical compression devices as prophylactic means against postoperative DVT. Their effects on the venous circulation include a reduction of venous stasis, by increasing the linear blood flow velocity and decreasing venous blood flow clearance time.

The ultimate goal of DVT prophylaxis is reduction of the incidence of PE. Although several multicenter trials have demonstrated a reduction in the incidence of PE in patients receiving SCH, the conclusions of the study have not been universally accepted. However, the use of DVT prophylaxis continues to be based on the premise that a lower incidence of DVT will lead to a lower incidence of PE.

Most venous thrombi originate in the soleal plexus of the calf. Approximately 20% of such untreated thrombi will propagate proximally and eventually cause PE. However, some patients who develop PE will not have evidence of DVT of the lower extremities, which

**Table 1—Clinical and Surgical Profile**

<table>
<thead>
<tr>
<th>Variables*</th>
<th>Group A</th>
<th>Group B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. (%)</td>
<td>No. (%)</td>
</tr>
<tr>
<td>Clinical Characteristics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Obesity</td>
<td>291 (24)</td>
<td>338 (25)</td>
</tr>
<tr>
<td>COPD</td>
<td>165 (15)</td>
<td>225 (17)</td>
</tr>
<tr>
<td>CHF</td>
<td>49 (4)</td>
<td>71 (5)</td>
</tr>
<tr>
<td>Varicose veins</td>
<td>92 (8)</td>
<td>123 (9)</td>
</tr>
<tr>
<td>Prior right heart catheterization</td>
<td>186 (16)</td>
<td>183 (14)</td>
</tr>
<tr>
<td>Prior MI</td>
<td>385 (32)</td>
<td>413 (30)</td>
</tr>
<tr>
<td>Prior CABG</td>
<td>66 (6)</td>
<td>70 (5)</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men</td>
<td>814 (68)</td>
<td>968 (71)</td>
</tr>
<tr>
<td>Woman</td>
<td>382 (32)</td>
<td>387 (29)</td>
</tr>
<tr>
<td>Mean age, yr</td>
<td>65±11</td>
<td>63±13</td>
</tr>
<tr>
<td>Type of cardiac surgery</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CABG</td>
<td>1,006 (84)</td>
<td>1,181 (87)</td>
</tr>
<tr>
<td>CABG+valve replacement</td>
<td>82 (7)</td>
<td>90 (7)</td>
</tr>
<tr>
<td>CABG+LVA</td>
<td>14 (1)</td>
<td>17 (1)</td>
</tr>
<tr>
<td>CABG+AICD</td>
<td>3 (2)</td>
<td>4 (2)</td>
</tr>
<tr>
<td>Valve replacement</td>
<td>57 (5)</td>
<td>66 (5)</td>
</tr>
<tr>
<td>Shunt repair</td>
<td>11 (1)</td>
<td>13 (1)</td>
</tr>
<tr>
<td>Atrial myxoma resection</td>
<td>2 (2)</td>
<td>3 (2)</td>
</tr>
</tbody>
</table>

*Statistical difference not significant; CABG=coronary artery bypass graft; CHF=congestive heart failure; MI=myocardial infarction; Cath=catheterization; AICD=automatic implantable cardiac defibrillator; LVA=left ventricle aneurysmectomy.
probably is related to emboli arising from the pelvic venous system; thus, it is not surprising that mechanical compression devices fail to prevent this complication in such patients.

PCS compress the veins, but for a relatively short period, with a concomitant increase in flow velocity. However, graduated compression stockings (GCS) produce a continuous compression that may be detrimental for wound healing. The use of GCS produce an average increase of 20 to 33% in blood flow over baseline, while PCS produce an increase of 240% in blood flow velocity.33,34 A comparison of these measurements by earlier investigators has clearly demonstrated that PCS increase linear velocity far in excess of that produced by GCS.36 Other studies have also demonstrated a relative activation of the fibrinolytic system during the use of PCS, although a similar effect has not been demonstrated with GCS.37,38 Despite these findings, the prophylactic use of PCS has not been clearly shown to be superior to other mechanical means in preventing thrombosis; however, its use is more suited for cardiac surgery patients, especially for those who had harvestation of saphenous veins.

The failure of a single method of prophylaxis to abolish DVT has encouraged the development of additional methods besides antithrombotic agents. The following were among the combinations used in those trials: heparin and dextran; GCS and dextran; GCS and PCS; and GCS and heparin.36,39-44 Most of these studies applied compression stockings only on one leg and the other was used as control. Furthermore, these combined methods were found to have variable effects in reducing the incidence of postoperative DVT, which was used as an indirect prophylactic measure against PE.

This study was designed to determine if the combined treatment of heparin and PCS was more effective than the conventional use of heparin alone as a postoperative prophylaxis against PE. We did not consider PCS alone as a third limb because of our reluctance to abandon the traditional recommendation of heparin prophylaxis postoperatively. Thus, our intent was not to compare PCS alone vs heparin alone.

Clinical Implications

Data obtained from this study indicate that the combined use of bilateral PCS and SCH added a reduction of 62% in the risk of developing PE after cardiac surgery in comparison to the use of SCH alone. These results and those reported by others44,45 suggest that the combined use of mechanical compression devices and heparin might further decrease the incidence of this complication in patients undergoing major surgical procedures.

References


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