Compression Stockings and Venous Function

Paul J. Zajkowski, BS, CCRP; Mary C. Proctor, MS; Thomas W. Wakefield, MD; Jess Bloom, RVT; Beverlee Blessing; Lazar J. Greenfield, MD

Hypothesis: Surgical compression stockings measurably improve venous physiologic mechanisms, and stocking brands do not differ from one another.

Methods: Eleven patients, (8 men and 3 women [mean age, 53 years]), were included. Six patients had primary venous insufficiency and 5 patients had secondary venous insufficiency; 5 patients were in CEAP class 4 and 6 were in CEAP class 5. Patients were randomly assigned to a sequence of 4 brands of knee-high, open-toe, 30– to 40-mm Hg stockings. Each patient wore a stocking for a 1-month equilibration period, then a different stocking monthly for 4 months in a row. Air plethysmography examinations were performed with and without stockings before and after each month of wear. Patients filled out a daily stocking record log and a monthly satisfaction survey. Stockings underwent compression testing after use.

Results: Stockings controlled reflux better than they improved calf muscle pump function. With stockings on, patients in CEAP 4 benefited more than those in CEAP 5 in decreasing reflux, while patients in CEAP 5 benefitted more than those in CEAP 4 in improving calf muscle pump function. Changes in residual volume fraction were improved in patients in CEAP 5 wearing stockings but not in patients in CEAP 4. Patients with primary disease had greater volumes of reflux and calf ejection than with secondary disease. There were no hemodynamic differences between stocking brands but there were differences in patient compliance and acceptance.

Conclusions: Surgical support stockings seem to be more effective in controlling reflux than in improving calf muscle pump function. All stocking brands function equally as measured by air plethysmography.

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in either a program of walking or bicycling. Then, monthly for the next 4 months, patients wore a different stocking brand (the first month’s stocking was the same brand as that used in the equilibration period). At the end of each month, patients underwent repeated APG with and without their stockings. Patients were asked to wear their stockings in pairs, even if they had only one leg affected with CVI. Air plethysmography values were collected in patients with and without stockings and then compared with patient characteristics concerning primary vs secondary disease and CEAP class 4 vs 5. For all of the analyses, the study time points were combined together.

Air plethysmography, introduced in 1987, uses a calibrated air cuff to encircle the leg and determine changes in volume. These changes in volume are used to determine various aspects of the calf muscle pump, residual venous obstruction, and CVI. The amount of blood in the leg is called the venous volume (VV); the rate of filling of the leg during standing is determined by the venous filling time until 90% VV is reached (VFT90) and the venous filling index (VFI); the amount of blood ejected from the leg with calf muscle function (a single rise to the tip-toe position) is called the ejection volume (EV) and ejection fraction (EF = EV/VV × 100%); the amount of blood remaining after 10 tip-toe movements is called the residual volume (RV) and the residual fraction (RVF = RV/VV × 100%); the emptiness of blood from the leg at the level of the iliofemoral segment is called the outflow fraction (OF). Indices of reflux include VV, VFI, VF1 with superficial occlusion (VFI-S), and VFT90, while indices of calf muscle pump function include EV, EF, and RV. Outflow fraction reflects outflow obstruction, while VF1 is a measure of the physiology of the leg as an entire entity. The most reproducible and accurate parameter of the test is the VFI15 for correlation to chronic venous disease, reflux, and even the response to venous surgery (although initially the RVF was felt to provide a linear correlation between ambulatory venous pressure measured invasively and measured non-invasively by APG). A

The patients were asked to fill out and turn in a daily log of their stocking use, exercise, and leg elevation, as well as a satisfaction survey concerning each brand of stocking used. Questions addressed stocking comfort, ease of application and removal, cleaning, stockinette, pressure, and overall rating. After stocking use, the stockings were sent for compression pressure testing at the ankle and calf (Hatra Hose Pressure Tester; Hatra, Nottingham, England) and then the stockings were returned to the patients to keep. Data were tabulated and then several parameters were analyzed, including the overall effect of compression stockings on venous hemodynamics, comparison of stockings between brands, and tabulations of log and survey data. The study was approved by the University of Michigan (Ann Arbor) institutional review board for human subject research.

RESULTS

After giving written consent, 13 subjects entered and 11 completed the study. Two subjects dropped out due to compliance issues. Demographic information and subject characteristics are presented in Table 1. The 3 women and 8 men had a mean age of 53 years. Six had primary CVI and 7 demonstrated both deep and superficial venous disease. Six of the subjects were classified as CEAP 5 and 5 were classified as CEAP 4. Ten of the subjects had at least 1 prior surgical procedure for venous disease. Each subject had APG examinations performed 6 times during the study; all but the first were performed with and without stockings. The subjects completed a 1-month equilibration period to control for prior differences in stocking use.

HEMODYNAMIC EFFECTS OF SURGICAL SUPPORT STOCKINGS

We initially compared APG parameters with and without stockings, taking all time points together. Stockings controlled reflux better than they improved calf muscle pump function, with decreases in VV, VFI, and VF1, and an increase in VFT90 (all statistically nonsignificant but still demonstrating a positive effect of stockings, Figure 1). We then stratified patients into cause (primary vs secondary) and CEAP class (4 vs 5). There were no differences between patients with primary and secondary CVI and changes in APG variables with and without stockings (Figure 2). However, there were differences depending on CEAP class. In patients classified as CEAP 4, VFT90 was lengthened with vs without stockings, while in patients in CEAP 5, VFT90 was shortened slightly with vs without stockings. Ejection volume was decreased in patients in CEAP 4 with vs without stockings, while it remained essentially unchanged in patients in CEAP 5 with vs without stockings. Ejection fraction was decreased in patients in CEAP 4 with vs without

Table 1. Patient Characteristics*

<table>
<thead>
<tr>
<th>Patient No./Age, y/Sex</th>
<th>Ethnicity</th>
<th>Cause</th>
<th>CEAP Class</th>
<th>Venous Disease</th>
<th>Prior Venous Surgery</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/47/M</td>
<td>White</td>
<td>Secondary</td>
<td>5</td>
<td>Deep</td>
<td>SEPS, open perforator ligation</td>
</tr>
<tr>
<td>2/51/M</td>
<td>White</td>
<td>Primary</td>
<td>4</td>
<td>Deep, superficial</td>
<td>Varicose vein removal × 2</td>
</tr>
<tr>
<td>3/74/M</td>
<td>White</td>
<td>Primary</td>
<td>4</td>
<td>Deep, superficial</td>
<td>None</td>
</tr>
<tr>
<td>4/47/M</td>
<td>White</td>
<td>Secondary</td>
<td>5</td>
<td>Deep, superficial</td>
<td>Varicose vein removal, SEPS, skin graft</td>
</tr>
<tr>
<td>5/46/M</td>
<td>White</td>
<td>Primary</td>
<td>4</td>
<td>Deep, superficial</td>
<td>Varicose vein removal</td>
</tr>
<tr>
<td>6/58/F</td>
<td>White</td>
<td>Primary</td>
<td>5</td>
<td>Deep, superficial</td>
<td>SEPS</td>
</tr>
<tr>
<td>7/58/F</td>
<td>White</td>
<td>Secondary</td>
<td>5</td>
<td>Deep, superficial</td>
<td>Open linton, valve transplantation</td>
</tr>
<tr>
<td>8/44/F</td>
<td>White</td>
<td>Primary</td>
<td>4</td>
<td>Deep</td>
<td>SPFF venous bypass, AV fistula</td>
</tr>
<tr>
<td>9/48/M</td>
<td>Black</td>
<td>Secondary</td>
<td>5</td>
<td>Deep</td>
<td>Vein valve transplant</td>
</tr>
<tr>
<td>10/63/M</td>
<td>White</td>
<td>Primary</td>
<td>5</td>
<td>Deep</td>
<td>Varicose vein removal</td>
</tr>
<tr>
<td>11/45/M</td>
<td>White</td>
<td>Secondary</td>
<td>4</td>
<td>Deep</td>
<td>Varicose vein removal</td>
</tr>
</tbody>
</table>

*CEAP indicates clinical manifestations, etiologic factors, anatomic involvement, and pathophysiologic features; SEPS, subfascial endoscopic perforator surgery; SPFF, saphenopopliteal, femorofemoral; and AV, arteriovenous.
stockings, while it remained essentially unchanged in patients in CEAP 5. Residual volume fraction increased slightly in patients in CEAP 4 with vs without stockings, while it decreased in patients in CEAP 5 with vs without stockings (Figure 3, arrows). Finally, VFI and VFIS were decreased slightly in patients in CEAP 4 with vs without stockings, while they were essentially unchanged in patients in CEAP 5 with vs without stockings (Figure 3).

**APG RESULTS WITH STOCKINGS COMPARED WITH PATIENT CHARACTERISTICS**

We found that cause of disease predicted more APG parameters than CEAP class when reviewing APG studies with stockings. In patients with primary disease, VV, VFI, VFIS, EV, RV, RVF, and OF were statistically significantly higher than in patients with secondary disease (Figure 2, asterisks), while EF was lower. In patients in CEAP 4, VV, VF90, and EV were statistically significantly higher than in patients in CEAP 5 (Figure 3, asterisks). Older patients were found to have statistically greater VV, VFI, VFIS, EV, RV, RVF, and OF. Additionally, the timing of the study influenced RV, with a clear increase in RV noted during the course of the study.

**STOCKING COMPARISON**

We compared each brand of surgical support stockings with several parameters, including the maintenance of the manufacturer’s stated pressure at the ankle and calf after use; patient convenience measures as reflected in the patient survey (comfort, ease of placement and removal, ease of upkeep, and feeling of pressure by the stocking); and patient compliance (time worn and use of adjunctive exercise and elevation). There was no association between APG changes and compliance. The stocking that held its pressure the best at the ankle was Jobst, but no stocking was superior in the calf. Placing these data into a matrix, the brand with the best result was Juzo, followed by Jobst and Sigvaris, and then MediStrumpf (Table 2). There were no statistical differences between any APG parameter and the brand of stockings.

**COMMENT**

We used a noninvasive test (APG) to determine the physiologic changes resulting from each patient’s program for CVI management, and data were obtained with and without stockings for each patient. Limitations to the APG include the overlap between patients with varicose veins and those with CVI, variations in repeated measures, and variations in the time of day studied. To control these variables, all patients were in CEAP clinical class 4 or 5, and APG studies were performed by the same experienced technician in a vascular laboratory approved by the Intersocietal Commission for the Accreditation of Vascular Laboratories (Columbia, Md), and all studies were performed in the morning.

Others have addressed the issue of surgical support stockings, exercise, and the changes on APG testing. In 22 patients with superficial venous insufficiency and 9 patients with deep venous insufficiency, the elastic support
of thigh-high stockings with the ankle compression targeted at 18 to 27 mm Hg was evaluated. This support resulted in a significant VV reduction in patients with superficial venous insufficiency but not in those with deep venous insufficiency; a significant increase in VFT90 and decrease in VFI in both groups; EV did not change in the group with superficial venous insufficiency but it did change in the group with deep venous insufficiency; and the EF improved in both groups. The RV was decreased by the application of the stockings for superficial venous insufficiency only, while the RVF was reduced in both groups. In another study, lightweight surgical compression (7-14 mm Hg) decreased reflux and increased EF in women with moderate varicose veins, while in 2 other studies, stockings were felt to primarily affect the superficial venous system and not the deep venous system.

Even the lymphatic and fibrinolytic systems have been implicated as affected favorably by stockings. A structured exercise program works by improving calf muscle pump function, as measured by an increase in EF and a decrease in RVF, without a change in VFI or VV.

We found that stockings appeared to control reflux better than they improved calf muscle pump function. These results improved in patients wearing the stockings compared with those not wearing the stockings (as has been seen in another study). Patients in CEAP 4 benefited more than those in CEAP 5 in decreasing indices of reflux with vs without stockings, while patients in CEAP 5 benefited more than those in CEAP 4 in terms of indices of calf muscle pump function with vs without stockings. The absolute values of the changes were small, however, and differences, while clinically important, were not statistically different. Overall changes in RVF were improved in patients in CEAP 5 wearing stockings but not in patients in CEAP 4.

Cause of disease seemed to predict changes in APG parameters more than CEAP class with the use of surgical stockings when comparing APG results with patient characteristics. Patients with primary disease had greater volumes of reflux and calf muscle ejection than those with secondary disease. This is likely due to open venous conduits in patients with primary disease and partially obstructed venous channels in patients with secondary disease from nonresolved chronic venous thrombosis. Patients aged revealed a similar interesting effect. Patients in CEAP 4 wearing stockings also had greater VV, VFT90, and EV than those in CEAP 5 wearing stockings. Finally, there seemed to be little hemodynamic reason to choose one stocking over another; other factors, such as patient acceptance and compliance, were important in choosing one brand of stocking over another.

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Corresponding author and reprints: Thomas W. Wakefield, MD, 2210 THCC, University of Michigan Medical Center, 1500 E Medical Center Dr, Ann Arbor, MI 48109-0329 (e-mail: thomasww@umich.edu).

REFERENCES

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Table 2. Matrix Ranking of Stocking Performance

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Ankle Pressure</th>
<th>Calf Pressure</th>
<th>Comfort</th>
<th>Ease in Putting On</th>
<th>Ease in Removing</th>
<th>Ease in Cleaning</th>
<th>Compliance of Wearing Time</th>
<th>Compliance of Exercise</th>
<th>Compliance of Elevation</th>
<th>Overall Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>BSN-Jobst Inc, Charlotte, NC</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Juzo Inc, Cuyahoga Falls, Ohio</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Medi USA, Whitsett, NC</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Sigvaris Inc, Peachtree City, Ga</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

These data support the importance of a treatment plan for CVI that includes compression stockings, exercise, and leg elevation. As the study evaluated all time points together, it is not a true longitudinal study comparing pretreatment with posttreatment APG values. Thus, it is difficult to make firm recommendations about treatment based on the current data. However, we did find benefits of stockings, suggesting their importance in the management of CVI. All brands of surgical support stockings that were tested seemed to function equally in hemodynamic evaluation as measured by APG values, suggesting that the choice of stocking depends more on other factors, such as compliance, acceptance, durability, and possibly cost (although this factor was not specifically addressed in this study). Surgical support stockings along with intermittent leg elevation and an exercise program together seem to decrease venous reflux rather than to improve calf muscle pump function, especially in those with less severe CVI (CEAP 4). However, the more severe the CVI, the more effective stockings seem to be in improving calf muscle pump function. Owing to the limited number of subjects in our investigation, a larger prospective study to address these issues in more detail seems warranted. Additionally, issues such as the effect of a venous management program over time and the addition of a supervised, standardized exercise program are raised by this study and need to be addressed further.


ARCHIVES OF INTERNAL MEDICINE

Supplemental Oxygen Use in Ischemic Stroke Patients: Does Utilization Correspond to Need for Oxygen Therapy?

Arthur M. Pancioli, MD; Mark J. Ballard, MD; Mary E. Grulee, MD; Edward C. Jauch, MD, MS; David F. Perkis, MA

Background: In 1994, the American Heart Association Stroke Council concluded that there were no data to support the routine use of supplemental oxygen in patients who had a stroke. More recently, supplemental oxygen has been suggested to be potentially detrimental. The purpose of this study was to determine the extent of oxygen use in ischemic stroke patients and whether patients receiving oxygen had indications for its use.

Methods: A literature search was performed to generate a comprehensive list of explicit criteria for supplemental oxygen use. When the literature disagreed, the criteria were included in the list to overestimate rather than underestimate the justification for oxygen use. A retrospective chart review of consecutive, nonintubated, ischemic stroke patients admitted to a university hospital was performed. Statistical tests and logistic regression models were constructed to identify the presence of unjustified oxygen use within the sample. Hospital charges were used to quantify opportunities for resource conservation.

Results: A total of 167 patient charts were reviewed yielding a total of 600 inpatient days abstracted. One hundred two patients (61.1%) received oxygen during some portion of their hospitalization. Of the 322 days that patients received oxygen, 147 (45.6%) met at least 1 criterion for oxygen use. Of the 278 days that patients did not receive oxygen, 69 (24.8%) met at least 1 of the criteria for oxygen use. There were 384 days for which no criteria were met. Of these, a patient still received oxygen 45.6% of the time (175 days). Factors associated with oxygen use included the presence of at least 1 justifying criteria as well as increasing age and male sex. Withholding oxygen from those not medically justified by the criteria could produce resource savings of roughly 45%.

Conclusions: Using a literature-based list of criteria for supplemental oxygen use, only 45.6% of days of oxygen use were justified in our ischemic stroke population. This study demonstrates that oxygen therapy is commonly given to ischemic stroke patients without clear indication, and opportunities exist for substantial resource conservation. (2002;162:49-52)

Corresponding author and reprints: Arthur M. Pancioli, MD, Department of Emergency Medicine, University of Cincinnati College of Medicine, 231 Albert Sabin Way, Cincinnati, OH 45267-0769 (e-mail: Arthur.Pancioli@uc.edu).