Geriatric Nursing 40 (2019) 558–564

Contents lists available at ScienceDirect

Geriatric Nursing

journal homepage: www.gnjournal.com

Feature Article

High compression leg bandaging prevents seated postural hypotension among elderly hospitalized patients

Benny Papismadov, RN[a,b], Irma Tzur, MD[a,c], Shimon Izhakian, PhD, MD[a,c], Dana Barchel, MD[a,c], Muhareb Swarka, MD[a,c], Hanni Phatel, RN[a,c], Ilana Livshiz-Riven, PhD, RN[b], Oleg Gorelik, MD[a,c,*]

[a] Department of Internal Medicine "F", Assaf Harofeh Medical Center, Zerifin 70300, Israel
[b] Department of Nursing, The Leon and Mathilde Recanati School for Community Health Professions, Faculty of Health Sciences, Ben-Gurion University of the Negev, Beer-Sheba, Israel
[c] Sackler Faculty of Medicine, Tel Aviv University, Ramat Aviv, Israel

ARTICLE INFO

Article history:
Received 15 March 2019
Received in revised form 19 April 2019
Accepted 25 April 2019
Available online 9 May 2019

Keywords:
Postural hypotension
Seating
Compression bandages
Hospitalization
Elderly

ABSTRACT

Postural hypotension (PH) is a very common and often symptomatic disorder among elderly hospitalized patients. Little is known about measures for preventing previously unknown PH in this population. We evaluated the effectiveness of high compression leg bandaging in preventing seated PH during the initial phase of ambulation, among elderly inpatients without a history of PH. We compared the occurrence of seated PH between patients who were bandaged ($n = 100$) and unbandaged ($n = 100$). The rate of seated PH was significantly lower in the bandaged than the unbandaged group (27% vs. 51%, $p < 0.001$, relative risk reduction 47%, and the number of patients needed to treat 4.2). On multivariate analysis, not wearing leg bandaging was one of the variables most significantly associated with eventual occurrence of PH ($p = 0.002$, odds ratio 2.65, and 95% confidence interval 1.42–4.97). We conclude that during ambulation of elderly inpatients, high compression leg bandaging is beneficial to prevent seated PH.

Introduction

Postural hypotension (PH) is a clinically important disorder that predicts increased morbidity and mortality.[1–6] PH can be classified into two pathophysiological forms: neurogenic (structural) and non-neurogenic (functional).[3,5,6] Neurogenic PH is chronic and results from autonomic failure due to multiple system atrophy, Parkinson's disease, pure autonomic failure, and neuropathies.[3,5,6] Non-neurogenic PH is often acute and may be caused by volume depletion, venous pooling, medications, hypertension, heart failure, and other disorders.[3,5,6]

PH is a very common and often symptomatic disorder in elderly hospitalized patients.[7–10] In this population, the prevalence of PH can be as high as 65–75%.[7–10] Among acutely ill elderly inpatients, the prevalence of PH is particularly high due to an additive effect of multiple predisposing factors for non-neurogenic PH.[8–11] Such patients are often weak, connected to medical devices, and at a high risk for symptomatic standing PH during their ambulation following bed rest.[9,10,12] Therefore, evaluating standing PH in hospitalized older patients may be difficult and potentially dangerous, and sitting before standing is recommended.[9,10,12] In this patient population, rates of seated PH (16–56%) are generally lower than those of standing PH (22–75%).[10,12] However, among older patients in internal medicine wards, PH (rates are 49–56%) and related symptoms (rates are 25–81%) are common on sitting at the initial phase of ambulation.[12–15] Thus, measures for preventing seated PH should be undertaken.[10,12]

The application of various lower body compression devices is recommended for managing chronic PH.[3,5,6] However, the evidence supporting this recommendation is limited, because the benefit of compression therapy was evaluated in short-term studies with small sample sizes.[6,16–19] Moreover, little is known about the preventive effect of compressive garments on previously unknown PH. In a single available investigation, 61 acutely ill inpatients, older than 65 years, who had been bedridden for at least 36 h, were evaluated for seated PH in a bandaged and unbandaged state within two consecutive days.[14] In the evaluations performed with lower limb compression bandaging, PH did not appear less often, although seating-induced dizziness, palpitations, and heart rate acceleration were largely prevented.[14] The results of that study may have been affected by its crossover design, the relatively small sample size, and the use of a bandage that achieved only moderate compression. Thus, the benefit of leg compression bandaging on the prevention of PH at an initial PHase of ambulation of hospitalized patients warrants further investigation.

* Corresponding author at: Department of Internal Medicine "F", Assaf Harofeh Medical Center, Zerifin 70300, Israel.
E-mail address: internal6@asaf.health.gov.il (O. Gorelik).

https://doi.org/10.1016/j.gerinurse.2019.04.004
0197-4572/$ – see front matter © 2019 Elsevier Inc. All rights reserved.

The aim of the present study was to examine the hypothesis that elderly inpatients without history of PH, who were exposed to wearing leg compression bandages on first sitting mobilization, would be less likely to develop PH than matched patients who did not wear the bandaging.

Methods

Study population and design

Fig. 1 presents the study population and design. This single-center comparative study was conducted in the Department of Internal Medicine "F". This is one of six Departments of Internal Medicine in Assaf Harofeh Medical Center, a tertiary care university hospital located at Zerifin, Israel. The study population comprised elderly patients admitted for a variety of acute medical disorders who were either bandaged (intervention group) or unbandaged (comparison group).

The intervention group ($n = 100$) was evaluated during hospitalization in the period April–November 2018 for the occurrence of seated PH and associated manifestations, using a standardized protocol. Eligibility criteria were age ≥70 years, bed rest lasting at least 12 h, cooperation, and willingness to provide informed consent. Exclusion criteria were impaired consciousness, hemodynamic or respiratory instability, other medical conditions with contraindication for ambulation, previously known PH, and a contraindication for application of compression bandage such as: ankle circumference of less than 18 cm or arterial insufficiency of the legs (see Fig. 1). Patients were treated and confined to bed irrespective of the study protocol (according to their clinical condition and the nature of their acute illness), until ambulation was indicated by the decision of an attending physician or nurse.

The intervention was performed once, on transition from a lying to sitting position, in the morning while fasting, and prior to oral drug administration. Blood pressure (BP) and heart rate measurements were recorded in the supine position by SureSigns VS2+TM vital signs monitor (Philips Medical Systems, The Netherlands). The device was regularly calibrated by qualified electronics personnel according to the manufacturer's instructions. An upper arm cuff with appropriate size was placed at the heart level. To avoid the effect of first BP measurement stress, BP was assessed three times at 3-minute intervals. If differences in systolic and diastolic BP values did not exceed 8 and 3 mmHg, respectively, the measurements were considered acceptable and the third value was taken as the supine baseline. In cases of higher variability, BP determinations were repeated until three sequential estimations satisfied the above-mentioned criteria. Thereafter, high compression bandages (SurePress™, ConvaTec Ltd, United Kingdom)[20,21] were applied by the research nurses (B.P. and H.P), with the assistance of two personnel members, along both legs (see Table 1).

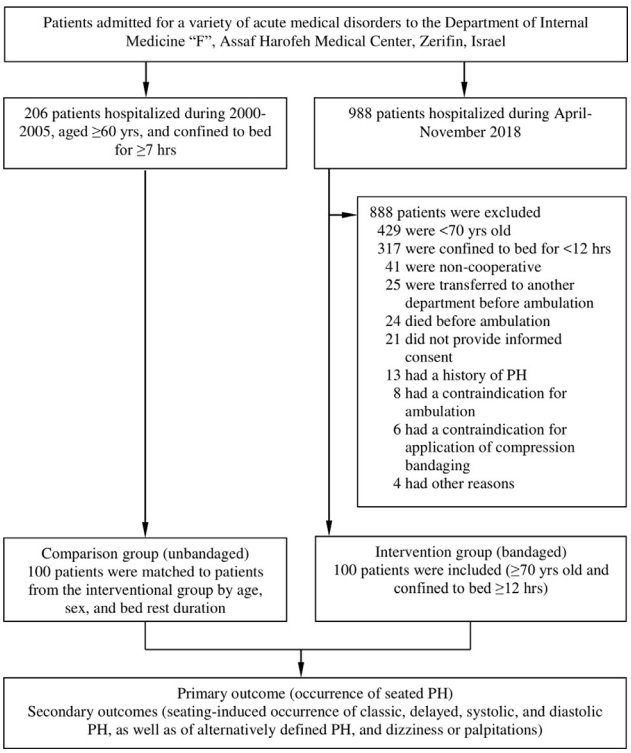

Fig. 1. Flowchart presenting the study design. Abbreviation: PH, postural hypotension.

Table 1
Protocol of the leg wrappings.

Elastic wrap bandages were applied from the ankle to the groin. The bandages have a yellow center line and two rectangular extension indicators for easier application and for appropriate level of compression. They are available in two leg sizes: ankle circumference 18–28 cm (small rectangles) and more than 28 cm (large rectangles). According to the instructions of the bandage manufacturer, the bandage was stretched so that the designed rectangles were transformed into squares, to obtain a level of compression 40 ± 10% mmHg at the ankle.

Immediately after wearing the bandage, each patient was passively transited in bed from supine to sitting position, with legs bent at the knees and hanging over the side of the bed. BP, heart rate, and the appearance of associated symptoms were registered at 1, 3, and 5 min following the seating. For safety reasons, measures to prevent falling were undertaken. In patients with severe symptoms or low BP, the orthostatic test was aborted, with immediate return to the lying position. After completion of the study protocol, only patients demonstrating PH on the last determination were returned to the supine position.

We established the comparison group by selecting 100 patients from 206 participants in two previous studies in our department.[13,15] In those studies, the patient population and the standardized protocols for PH evaluation were similar to those of the intervention group of the current study, except for the use of compression bandage. The relevant cumulative data were: mean age 75.9 ± 9 years, 62% females, mean duration of bed rest 56.3 ± 63 h, and rate of seated PH (classic or delayed) 45.2%, according to the current criteria for the PH definition, as delineated below. Patients from those studies were matched one-to-one to patients in the intervention group of the current study by age (±2 years), sex, and duration of bed rest (±4 h).

The present study was carried out in accordance with the Declaration of Helsinki and was approved by the institutional Ethics Committee (approval number 0007-18-ASF). Informed consent was obtained from each patient.

Data collection

Demographic and clinical data were obtained from patients' charts, hospital records, and standardized reports of PH evaluations. The data included the following variables: age, sex, duration of bed rest, the main reason for admission, comorbidities (hypertension, coronary artery disease, heart failure, anemia, renal failure, cerebrovascular disease, diabetes mellitus, and neurodegenerative disorder/polyneuropathy), the use of relevant medications (diuretics, beta-receptor blockers, renin-angiotensin system antagonists, calcium antagonists, psychotropic agents, nitrates, and alpha-receptor blockers), and the seating-induced appearance of dizziness or palpitations. Heart rate,

Table 2
Definitions used in the study.

Disorder	Definition criteria
Hypertension	Patient's history, data from previous and current hospitalizations, or the use of anti-hypertensive medications.
Coronary artery disease	Typical findings on a coronary angiography, stress tests, or a hospitalization with acute coronary syndrome.
Diabetes mellitus	Persistent fasting hyperglycemia (≥126 mg/dl) or a history of chronic anti-hyperglycemic treatment.
Anemia	The World Health Organization criteria: a hemoglobin concentration of <12 g/dl in women and <13 g/dl in men.
Renal failure	Any value of estimated glomerular filtration rate <60 ml/min/1.73m^2 during the current hospitalization.
Heart failure, cerebrovascular disease, and neurodegenerative disorder/ polyneuropathy	According to data from the present hospitalization or previous medical records.
Arterial insufficiency of the legs	The presence of ischemic skin ulcers in the lower extremities, chronic intermittent leg claudication, or a history of peripheral arterial disease (ankle-brachial index ≤0.9).
Seated PH	A composite of classic and delayed PH, according to the current guidelines:[22,23] systolic BP under 90 mmHg, a drop of ≥20 mmHg in systolic BP, or a drop of ≥10 mmHg in diastolic BP, in any of the measurements in the sitting position. In hypertensive patients, a fall of ≥30 mmHg in systolic BP was required.[22,23]
Classic PH	PH determined within 3 min of sitting.
Delayed PH	PH determined only at 5 min of sitting.
Systolic PH	A postural drop in systolic BP under 90 mmHg and of ≥20 mmHg in normotensive patients, or of ≥30 mmHg in hypertensive patients.
Diastolic PH	A postural drop of ≥10 mmHg in diastolic BP.
Alternative diagnosing of PH	The occurrence of seated PH or a symptomatic postural BP fall with less magnitude than is required for diagnosis of seated PH.[24,25]
Dizziness	Impaired consciousness, fainting, lightheadedness, and temporary visual disturbances.

Abbreviations: PH, postural hypotension; BP, blood pressure.

systolic BP, and diastolic BP in the supine position and at 1, 3, and 5 min following sitting were recorded.

Table 2 presents the definitions used in the study.

Study outcomes

The primary outcome of the study was the eventual development of seated PH. Secondary outcomes included the seating-induced occurrences of classic, delayed, systolic, diastolic and alternatively defined PH, and of dizziness or palpitations. We evaluated the possible preventive effect of leg compression bandaging on the outcomes.

Sample size calculation

Based on findings of previous studies on similar patient populations,[13–15] we expected a rate of seated PH of 52% among patients not wearing compression bandaging. We determined that a sample size of 100 for each group would provide power of 82.5% to yield a statistically significant result. This computation assumes that the difference in rates of PH between the unbandaged and bandaged groups is 20% (specifically, 52% vs. 32%).

Statistical analysis

The statistical analysis was performed using the Biomedical Package software.[26] For quantitative data, the results were expressed as means and standard deviations for data with normal distributions, and as median (range) for data without normal distributions. For qualitative data, the results were expressed as the percentages of presented cases. Statistical comparisons were performed between the data obtained for the unbandaged vs. the bandaged group, and for groups of patients with vs. without PH. Pearson's chi-square and Fisher's exact tests were used as appropriate for comparisons of categorical variables. Continuous variables were compared with the use of the Student's *t*-test. Analysis of variance (ANOVA) with repeated measurements was used to determine changes over time of continuous variables. Two-sided p values < 0.05 were considered to indicate statistical significance. To examine the independent preventive effect of compression bandaging on PH, all variables that were suspected as potential confounders of this association in the univariate analysis ($p \leq 0.1$) were re-evaluated by the stepwise logistic regression model, and the areas under the curves (AUCs) of the receiver operating characteristic plots were determined.

Results

Baseline characteristics (Table 3)

In the entire cohort, the mean age was 81.7 ± 7 years (range 70–98 years), 63% were women, and the mean bed rest duration was 79.9 ± 73 h (median value 62 h and range 12–450 h). The most common reasons for admission were infection, decompensated heart failure, and acute coronary syndrome.

Demographic characteristics, duration of bed rest, and the main reasons for admission were comparable between the intervention and comparison groups. Coronary artery disease and heart failure were more frequently observed in the unbandaged group, while cerebrovascular disease was more common in the bandaged group. Patients in the unbandaged group were more often treated with diuretics and less likely received psychotropic agents than the bandaged patients.

Comparison of clinical and hemodynamic data between the bandaged and unbandaged groups (Table 4)

The rate of seated PH (primary outcome) was significantly lower in the intervention than the comparison group (27% vs. 51%, $p < 0.001$). The wearing of leg bandaging was associated with absolute and relative risk reductions in PH of 24% and 47%, respectively (the number of patients needed to treat was 4.2). Moreover, classic, systolic, diastolic, and alternatively defined PH less frequently occurred in the bandaged than the unbandaged group ($p = 0.006$, $p = 0.021$, $p < 0.001$, and $p = 0.005$, respectively). Statistically significant differences were not observed between the groups in the occurrence of PH symptoms and in the mean values of heart rate. A seating-induced fall in BP appeared to be largely prevented by compression bandaging. Thus, among the bandaged patients, BP levels remained practically stable in the sitting position. This contrast with the progressive declines in the mean values of systolic (Fig. 2A, $p = 0.047$) and diastolic (Fig. 2B, $p = 0.002$) BP in the unbandaged patients.

The study protocol was completed for all patients in the intervention group. No serious adverse events (syncope, fall, or life-

Table 3
Baseline characteristics of the patients included in the study.

Variable	Entire group ($n = 200$)	Comparison (unbandaged) group ($n = 100$)	Intervention (bandaged) group ($n = 100$)	p value[a]
Age, y	81.7 ± 7	81.8 ± 7	81.7 ± 8	0.9
Female sex	63.0%	63.0%	63.0%	1.0
Bed rest duration (hours)	79.9 ± 73	79.3 ± 65	80.5 ± 81	0.9
Main reasons for admission				
Infection	29.0%	30.0%	28.0%	0.8
Exacerbation of heart failure	24.5%	29.0%	20.0%	0.2
Acute coronary syndrome	19.5%	20.0%	19.0%	0.9
Stroke	15.5%	11.0%	20.0%	0.1
Other	11.5%	10.0%	13.0%	0.6
Comorbid diseases				
Hypertension	88.0%	91.0%	85.0%	0.3
Coronary artery disease	55.5%	65.0%	46.0%	**0.011**
Anemia	53.0%	53.0%	53.0%	1.0
Chronic heart failure	52.0%	63.0%	41.0%	**0.002**
Cerebrovascular disease	44.5%	33.0%	56.0%	**0.002**
Renal failure	44.0%	48.0%	40.0%	0.3
Diabetes mellitus	41.0%	46.0%	36.0%	0.1
Neurodegenerativedisorder/polyneuropathy	12.5%	9.0%	16.0%	0.2
Medications used				
Diuretics	57.0%	73.0%	41.0%	<**0.001**
Beta-receptor blockers	51.0%	53.0%	49.0%	0.7
Renin-angiotensin system antagonists	45.0%	45.0%	45.0%	1.0
Psychotropic agents	37.0%	28.0%	46.0%	**0.013**
Calcium antagonists	34.0%	38.0%	30.0%	0.3
Nitrates	23.5%	29.0%	18.0%	0.1
Alpha-receptor blockers	19.5%	20.0%	19.0%	0.9

Data are exspressed as means ± SD or percentages of presented cases.
[a] Statistical comparison between unbandaged and bandaged groups. Bold entries in the table indicate a p value of < 0.05.

threatening arrhythmia) were observed. No local leg complications occurred following application of the compression bandage, and significant discomfort related to wearing the bandaging was not reported by the patients. Moreover, the nursing staff relayed positive feedback regarding the ease of using the bandages.

Comparison of characteristics of patients with and without PH (Tables 5 and 6)

Demographic characteristics and prevalence of relevant comorbidities were comparable between patients with ($n = 78$) and without

Table 4
Clinical variables of the intervention and comparison groups.

Variable	Comparison (unbandaged) group ($n = 100$)	Intervention (bandaged) group ($n = 100$)	p value
Occurrence of PH			
PH (classic or delayed)	51.0%	27.0%	<**0.001**
Classic PH	40.0%	22.0%	**0.006**
Delayed PH	11.0%	5.0%	0.2
Systolic PH	32.0%	17.0%	**0.021**
Distolic PH	45.0%	21.0%	<**0.001**
Alternatively defined PH	74.0%	54.0%	**0.005**
Occurrence of PH symptoms			
Dizziness	46.0%	37.0%	0.2
Palpitations	28.0%	23.0%	0.5
Dizziness or palpitations	51.0%	44.0%	0.3
Heart rate (beats/min)			
Supine	77.9 ± 18	73.9 ± 14	0.07
Following 1 min sitting	82.0 ± 19	80.8 ± 15	0.6
Following 3 min sitting	81.5 ± 18	78.8 ± 14	0.3
Following 5 min sitting	81.5 ± 19	77.7 ± 14	0.1
Systolic BP (mmHg)			
Supine	146.0 ± 24	144.7 ± 24	0.7
Following 1 min sitting	144.0 ± 28	143.8 ± 25	0.9
Following 3 min sitting	143.0 ± 26	145.2 ± 23	0.5
Following 5 min sitting	138.6 ± 26	142.6 ± 24	0.3
Diastolic BP (mmHg)			
Supine	72.9 ± 15	68.7 ± 14	**0.043**
Following 1 min sitting	72.8 ± 18	72.4 ± 13	0.8
Following 3 min sitting	72.2 ± 15	73.8 ± 13	0.4
Following 5 min sitting	70.2 ± 15	70.6 ± 13	0.8

Data are expressed as means ± SD or percentages of presented cases. Abbreviations: PH, postural hypotension; BP, blood pressure. Bold entries in the table indicate a p value of < 0.05.

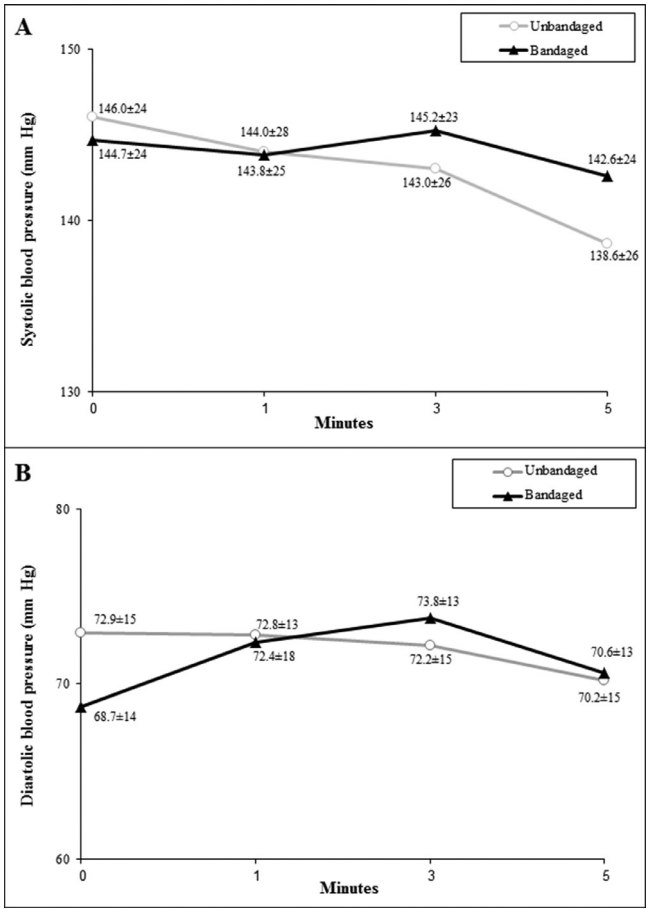

Fig. 2. Trajectories of mean ± SD values of systolic (A) and diastolic (B) BP prior to and 1, 3, and 5 min following sitting in the unbandaged vs. bandaged states. The respective p values for comparison of changes in systolic and diastolic BP over time (by ANOVA with repeated measurements) are 0.047 and 0.002. Abbreviations: BP, blood pressure; ANOVA, analysis of variance.

($n = 122$) PH (Table 5). Longer bed rest tended to be associated with PH. Patients with PH were more likely admitted for stroke than patients without PH. Treatments with offending medications were similar in patients with and without PH, except for less frequent administration of psychotropic agents in the PH group.

Table 6 compares clinical data between patients with and without PH. Overall, typical PH symptoms occurred more frequently than the diagnosis of PH (47.5% and 39.0%, respectively). The occurrence of PH symptoms was significantly associated with the development of PH. Moreover, the mean supine and sitting values of heart rate were significantly higher in patients with than without PH. Among patients with PH, the mean levels of systolic and diastolic BP were higher in the lying position, and lower following sitting, compared to the patients who did not demonstrate PH.

Multivariate analysis

Age, sex, the unbandaged state, and potential confounders for the association of compression bandaging with the occurrence of PH were re-evaluated by a stepwise logistic regression analysis. Not wearing leg bandaging remained one of the variables most significantly associated with the eventual development of PH (Table 7): odds ratio 2.65, 95% confidence interval 1.42–4.97.

Table 5
Comparison of baseline characteristics between patients with and without pH.

Variable	Patients without pH ($n = 122$)	Patients with pH ($n = 78$)	p value
Age, y	82.1 ± 8	81.1 ± 7	0.4
Female sex	60.7%	66.7%	0.4
Bed rest duration (hours)	72.8 ± 76	91.1 ± 69	0.08
Main reasons for admission			
Infection	30.3%	26.9%	0.6
Exacerbation of heart failure	23.8%	25.6%	0.8
Acute coronary syndrome	23.0%	14.1%	0.1
Stroke	10.7%	23.1%	**0.027**
Other	12.3%	10.3%	0.8
Comorbid diseases			
Hypertension	87.7%	88.5%	0.9
Coronary artery disease	57.4%	52.6%	0.5
Heart failure	53.3%	50%	0.6
Anemia	54.1%	51.3%	0.7
Cerebrovascular disease	44.3%	44.9%	0.9
Renal failure	39.3%	51.3%	0.06
Diabetes mellitus	46.7%	32.1%	0.1
Neurodegenerative disorder/polyneuropathy	12.3%	12.8%	0.9
Medications used			
Diuretics	59%	53.8%	0.5
Beta-receptor blockers	54.1%	46.2%	0.3
Renin-angiotensin system antagonists	44.3%	46.2%	0.8
Psychotropic agents	43.4%	26.9%	**0.024**
Calcium antagonists	34.4%	33.3%	0.9
Nitrates	26.2%	19.2%	0.3
Alpha-receptor blockers	19.7%	19.2%	0.9

Data are exspressed as means ± SD or percentages of presented cases. Abbreviation: PH, postural hypotension. Bold entries in the table indicate a p value of < 0.05.

Discussion

This interventional pragmatic clinical study confirmed our hypothesis. We demonstrated the benefit of high compression leg bandaging in the prevention of seated PH during an initial phase of ambulation, among elderly internal medicine inpatients at high risk

Table 6
Comparison of clinical variables between patients with and without PH.

Variable	Patients without PH ($n = 122$)	Patients with PH ($n = 78$)	p value
Bandaged state	59.8%	34.6%	<**0.001**
Appearance of PH symptoms			
Dizziness	32.8%	55.1%	**0.002**
Palpitations	20.5%	33.3%	**0.047**
Dizziness or palpitations	41.0%	57.7%	**0.029**
Heart rate (beats/min)			
Supine	73.7 ± 14	79.4 ± 18	**0.019**
Following 1 min sitting	79.2 ± 15	84.8 ± 19	**0.029**
Following 3 min sitting	77.4 ± 14	84.3 ± 18	**0.005**
Following 5 min sitting	76.1 ± 14	85.0 ± 19	<**0.001**
Systolic BP (mmHg)			
Supine	142.8 ± 21	149.3 ± 28	0.07
Following 1 min sitting	147.6 ± 23	138.1 ± 31	**0.019**
Following 3 min sitting	147.8 ± 22	138.3 ± 27	**0.009**
Following 5 min sitting	146.4 ± 22	131.5 ± 27	<**0.001**
Diastolic BP (mmHg)			
Supine	67.2 ± 11	76.3 ± 17	<**0.001**
Following 1 min sitting	73.9 ± 13	70.6 ± 19	0.2
Following 3 min sitting	74.6 ± 13	70.5 ± 15	**0.046**
Following 5 min sitting	72.1 ± 12	67.7 ± 16	**0.039**

Data are expressed as means ± SD or percentages of presented cases. Abbreviations: PH, postural hypotension; BP, blood pressure. Bold entries in the table indicate a p value of < 0.05.

Table 7
Variables that were most significantly associated with the occurrence of PH in the entire study group (stepwise logistic regression analysis, AUC = 0.729).

Variable	*p* value	Odds ratio	95% confidence interval
Diastolic BP[a]	<0.001	1.25	1.11–1.40
Unbandaged state	0.002	2.65	1.42–4.97
Bed rest duration[b]	0.060	1.11	1.00–1.22

Abbreviations: PH, postural hypotension; AUC, the area under the curve of the receiver operating characteristic plots; BP, blood pressure.
[a] For each 5 mmHg increment.
[b] For each 24 h increment.

for developing PH. The use of lower limb compression bandages reduced the risk of PH occurrence by 47%. The number of patients needed to be bandaged to prevent one case of PH is calculated as 4.2. To the best of our knowledge, this study of 200 patients is the largest investigation to evaluate the effect of a compression device on PH. Previous studies included relatively small sample sizes, in the range of 10–73, and focused on patients with established PH.[16–19] Notably, the patients included in the current study were at high risk for symptomatic standing PH during their ambulation following bed rest. Thus, for safety reasons and according to recommendations in the medical literature, we evaluated PH following the transition from supine to sitting, instead of in the standing position.[9,10,12]

The main novelty of the present study is the investigation of the preventive role of compression bandaging in patients with previously unknown PH. The only trial that has been reported on a similar population was conducted in our department.[14] There, following bed rest lasting at least 36 h, 61 acutely ill inpatients older than 65 years were evaluated for seated PH in a crossover design. Each patient was studied in unbandaged and lower limb moderate compression bandaging states, within two consecutive days. The occurrence of PH was the same, 55.7%, in the bandaged and unbandaged states, although seating-induced dizziness, palpitations, and heart rate acceleration were largely reduced in the bandaged state.[14] In contrast to that investigation, the current study clearly demonstrated the benefit of leg compression bandaging on the primary study outcome (occurrence of seated PH) and the secondary outcomes (development of classic, systolic, diastolic, and alternatively defined PH).

The discrepancies between the current study and our previous one may have several explanations. First, the results of the former study may have been affected by its crossover design. Specifically, the effect of prolonged bed rest on PH may have differed between the first and second study days due to initial mobilization. In addition, the high day-to-day variability of PH that is known to exist in hospitalized patients[9,10,25] may have been responsible for the appearance or disappearance of PH in any given patient. By contrast, in the present study, the bandaged and unbandaged patients were matched for duration of bed rest and evaluated once only. Second, the present investigation comprised a larger sample size, which was determined prior to study initiation, in order to provide statistical power for the primary outcome. Third, a bandage obtaining high compression was used in the current study, while moderate compression bandages were applied in the former trial. It is conceivable that bandaging with higher compression more effectively reduces blood pooling in the lower limb capacitance vessels. This may result in attenuation of the postural decline in the venous return to the heart and avoidance of PH.[16–19] Finally, the traditional PH definition was used in the former study,[22] while in the present investigation PH was defined according to the current guidelines.[22,23] These guidelines require more strict criteria to diagnose PH in hypertensive patients.

Management of PH in hospitalized patients is based mainly on non-pharmacologic interventions.[9,10] These include various lower body compression garments, such as stockings, bandages, and suits, which achieve knee-length (calves), thigh-length, or abdominal compression.[16–19] Wearing thigh-length compression bandaging is a simple, inexpensive, and safe technique that has demonstrated effectiveness as a treatment of PH.[17–19] We firstly demonstrated the benefit of such on the primary prevention of PH. Moreover, we confirmed that lower limb compression bandages are comfortable, harmless, and easily applied. The safety of the bandaging worn in the study may be explained by its short-term use, extensibility, and achievement of appropriate compression.

To the best of our knowledge, no documented studies have compared the effectiveness and safety between various compression garments. For independent patients with chronic PH, using custom-fitted elastic garments seems easier and less time-consuming than applying compression bandages. However, elastic stockings/hosiery have no advantage for elderly acutely ill inpatients who have difficulty putting them on, and thus require help of health care providers. Moreover, custom-fitted compression garments are more expensive than bandages.[19] The cost depends on the size, the level of compression, and the quality of the material. For thigh-length compression hosiery, the cost ranges from $50 to $200, compared to $25–40 for the bandages used in the current study. In addition, complaints of discomfort, soreness, and itching in the legs have been reported by some patients while using elastic stockings.[5,19] Taking the data together, we suggest that extensible bandaging has advantages over other compression garments in our patient population.

In older inpatients, PH is generally non-neurogenic and involves risk factors that are potentially reversible. These include the use of certain medications, venous pooling, volume depletion, and comorbidities.[9,10] In the present study, higher supine levels of diastolic BP, not wearing compression bandages, and longer bed rest were the most significant predictors of PH.

Supine hypertension and prolonged recumbency have been established as important predisposing factors for PH in hospitalized patients.[7–10,15] Higher supine values of BP per se have been found to increase risk for the development of PH.[10,27] In addition, antihypertensive medications and comorbidities that are associated with hypertension (diabetes mellitus, heart failure, and renal insufficiency) may cause or aggravate PH.[10,27] The main pathophysiologic mechanism for the development of PH after immobility is increased blood pooling in low body capacitance vessels, which results in worsening of the postural fall in the venous return to the heart.[9–11] Moreover, during prolonged bed rest, an impaired vasoconstrictor compensatory response due to decreased baroreceptor function, and hypovolemia caused by increased diuresis via diminished secretion of antidiuretic hormone, may contribute to orthostatic intolerance.[9–11] In addition, in some patients, volume depletion due to insufficient fluid intake, treatment with diuretics, and loss of fluids via the gastrointestinal tract may increase the risk of PH. Notably, PH related to immobility and dehydration is a transient state that usually resolves following mobilization and correction of hypovolemia. In this clinical situation, the temporary use of compression bandaging during the initial phase of ambulation, as in the current study, decreases venous pooling by applying external counter-pressure on the lower limbs. This approach seems rational and effective in facilitating early ambulation, ameliorating deconditioning, and restoring a normal hemodynamic response to orthostatic stress.

The present study has several limitations. The most important limitation is the establishment of a comparison group based on a historical cohort of patients. Ideally, for research purposes, patients should have been randomly assigned to not wearing a bandage or to wearing a sham bandage. However, the patients who were enrolled in the intervention group were at a high risk for symptomatic PH, estimated at 52%. Hence, we decided not to enroll a prospective control group of patients, without offering them compression bandaging due to research purposes. Such a study design would be harmful, unethical, and contradictory to the principles of Good Clinical Practice. We believe that the matching by age, sex, and duration of bed rest, of patients in the same clinical setting, mitigates the possible

selection bias. An additional limitation of the present study is that only leg bandages were worn. Extension of bandaging to the abdomen has been reported to increase the positive effect in patients with PH.[17,19] Nevertheless, we demonstrated a clear benefit of lower limb compression bandaging on PH prevention.

Conclusions

This is the first report in the literature that demonstrated that the application of high compression leg bandaging reduces the risk of occurrence of seated PH in elderly inpatients, during the initial phase of their ambulation. Compression leg bandaging is inexpensive and safe, and may be easily applied by health care providers to hospitalized patients. Among inpatients at a high risk for development of PH, the use of this technique is recommended as a non-pharmacologic intervention.

Funding

Compression bandages SurePress™ were provided free of charge for use in the study by ConvaTec Ltd, United Kingdom. This manufacturer had no role in the study design, the collection, analysis, and interpretation of data, the writing of the manuscript, or the decision to submit the manuscript for publication.

Conflicts of interest

None.

References

1. Rose KM, Eigenbrodt ML, Biga RL, et al. Orthostatic hypotension predicts mortality in middle-aged adults: the Atherosclerosis Risk In Communities (ARIC) study. *Circulation*. 2006;114:630–636.
2. Fedorowski A, Stavenow L, Hedblad B, et al. Orthostatic hypotension predicts all-cause mortality and coronary events in middle-aged individuals (The Malmö Preventive Project). *Eur Heart J*. 2010;31:85–91.
3. Fedorowski A, Melander O. Syndromes of orthostatic intolerance: a hidden danger. *J Intern Med*. 2013;273:322–335.
4. Ricci F, Fedorowski A, Radico F, et al. Cardiovascular morbidity and mortality related to orthostatic hypotension: a meta-analysis of prospective observational studies. *Eur Heart J*. 2015;36:1609–1617.
5. Ricci F, De Caterina R, Fedorowski A. Orthostatic hypotension: epidemiology, prognosis, and treatment. *J Am Coll Cardiol*. 2015;66:848–860.
6. Freeman R, Abuzinadah AR, Gibbons C, et al. Orthostatic hypotension: JACC state-of-the-art review. *J Am Coll Cardiol*. 2018;72:1294–1309.
7. Weiss A, Grossman E, Beloosesky Y, et al. Orthostatic hypotension in acute geriatric ward: is it a consistent finding? *Arch Intern Med*. 2002;162:2369–2374.
8. Gorelik O, Fishlev G, Litvinov V, et al. First morning standing up may be risky in acutely ill older inpatients. *Blood Press*. 2005;14:139–143.
9. Feldstein C, Weder AB. Orthostatic hypotension: a common, serious and underrecognized problem in hospitalized patients. *J Am Soc Hypertens*. 2012;6:27–39.
10. Tzur I, Izhakian S, Gorelik O. Orthostatic hypotension in internal medicine wards. *Curr Med Res Opin*. 2019;35:947–955.
11. Gorelik O, Feldman L, Cohen N. Heart failure and orthostatic hypotension. *Heart Fail Rev*. 2016;21:529–538.
12. Gorelik O, Cohen N. Seated postural hypotension. *J Am Soc Hypertens*. 2015;9:985–992.
13. Cohen N, Gorelik O, Fishlev G, et al. Seated postural hypotension is common among older inpatients. *Clin Auton Res*. 2003;13:447–449.
14. Gorelik O, Fishlev G, Almoznino-Sarafian D, et al. Lower limb compression bandaging is effective in preventing signs and symptoms of seating-induced postural hypotension. *Cardiology*. 2004;102:177–183.
15. Gorelik O, Almoznino-Sarafian D, Litvinov V, et al. Seating-induced postural hypotension is common in older patients with decompensated heart failure and may be prevented by lower limb compression bandaging. *Gerontology*. 2009;55:138–144.
16. Smit AA, Wieling W, Fujimura J, et al. Use of lower abdominal compression to combat orthostatic hypotension in patients with autonomic dysfunction. *Clin Auton Res*. 2004;14:167–175.
17. Podoleanu C, Maggi R, Brignole M, et al. Lower limb and abdominal compression bandages prevent progressive orthostatic hypotension in elderly persons. *J Am Coll Cardiol*. 2006;48:1425–1432.
18. Gorelik O, Shteinshnaider M, Tzur I, et al. Factors associated with prevention of postural hypotension by leg compression bandaging. *Blood Press*. 2014;23:248–254.
19. Smeenk HE, Koster MJ, Faaij RA, et al. Compression therapy in patients with orthostatic hypotension: a systematic review. *Neth J Med*. 2014;72:80–85.
20. Moody M. Comparison of Rosidal K and SurePress in the treatment of venous leg ulcers. *Br J Nurs*. 1999;8:345–355.
21. Alavi A, Sibbald RG, Phillips TJ, et al. What's new: management of venous leg ulcers. *J Am Acad Dermatol*. 2016;74:643–664.
22. Freeman R, Wieling W, Axelrod FB, et al. Consensus statement on the definition of orthostatic hypotension, neurally mediated syncope and the postural tachycardia syndrome. *Clin Auton Res*. 2011;21:69–72.
23. Brignole M, Moya A, de Lange FJ, et al. ESC Scientific Document Group: 2018 ESC Guidelines for the diagnosis and management of syncope. *Eur Heart J*. 2018;39:1883–1948.
24. Hollister AS. Orthostatic hypotension: causes, evaluation, and management. *West J Med*. 1992;157:652–657.
25. Naschitz JE, Rosner I. Orthostatic hypotension: framework of the syndrome. *Postgrad Med J*. 2007;83:568–574.
26. Dixon (Chief editor) WJ. *BMDP Statistical Software*. Los-Angeles: University of California Press; 1993.
27. Biaggioni I. Orthostatic hypotension in the hypertensive patient. *Am J Hypertens*. 2018;31:1255–1259.