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□ Clinical Research Article □

The effect of sequential compression device on hypotension in the sitting position during shoulder arthroscopy; a comparison with elastic stocking

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Background: The sitting position under general anesthesia is associated with hemodynamic instability. The purpose of this study was to compare the efficacy of a sequential compression device (SCD) with that of elastic stockings (ES) in reducing the incidence of hypotension and other hemodynamic instability in the sitting position during shoulder arthroscopy.

Methods: Fifty-one patients undergoing shoulder arthroscopy were randomly assigned into one of three groups to receive no treatment (control group, n = 17), SCD (SCD group, n = 17) or ES (ES group, n = 17). Hemodynamic variables were measured 5 min after induction of anesthesia (baseline values), and every 1 min from 1 to 5 min after raising the patient to a 70^o sitting position (T1-5) with the beach-chair.

Results: The incidences of hypotension (proportion, 95% CI) were 12/17 (0.71, 0.47－0.87), 5/16 (0.31, 0.14－0.56) and 7/15 (0.47, 0.25－0.70) in the control, SCD and ES group, respectively. The incidence was significantly lower in the SCD group than that in the control group (P = 0.038). At 1 min after sitting position, mean arterial pressure in the control group was significantly lower than that in the SCD group and it was significantly decreased from the baseline value.

Conclusions: SCD could significantly reduce the incidence of hypotension with less hemodynamic instability in the sitting position during shoulder arthroscopy. Although the incidence of hypotension was decreased with the elastic stocking, there was no statistical significance. **(Korean J Anesthesiol 2009; 57: 417～21)**

Key Words: Arthroscopy, Hemodynamics, Shoulder.

INTRODUCTION

As a result of advanced surgical techniques, shoulder arthroscopy is becoming more common and the sitting position gained wide acceptance among orthopedic surgeons because lateral decubitus position was associated with injuries to the brachial plexus and forearm nerves [1]. Although the sitting position provides anatomic advantage, easier airway access and less bleeding, the sitting position is associated with significant hemodynamic derangement that may compromise the cerebral circulation. Pohl and Cullen [2] have reported four cases of ischemic brain and spinal cord injury during shoulder arthroscopy in the sitting position. Avoidance of these catastrophic complications may be achieved by aggressively treating hypotension, which is defined as blood pressure lower than 80% of baseline, to enhance the margin of safety [3].

The strategies of recruiting the blood from the lower extremities by wrapping the leg and by using a sequential compression device (SCD) have proven effective in reducing the incidence of hypotension associated with spinal anesthesia during ceasarean section [4,5]. Since sitting position during general anesthesia also aggravates venous pooling, authors hypothesized that both recruiting strategies would be effective in decreasing

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hypotension. The purpose of this study was to compare the efficacy of a sequential compression device (SCD) with that of elastic stockings (ES) in reducing the incidence of hypotension and other hemodynamic instability in the sitting position during shoulder arthroscopy.

MATERIALS AND METHODS

This is a prospective, double blinded and randomized study. Following approval by the local ethical committee and informed consent, 51 American society of anesthesiologist (ASA) physical status class I patients undergoing shoulder arthroscopy in the sitting position were randomly divided into three groups (n = 17 in each) using sealed envelop system. Patients with obesity (body mass index > 28 kg/m^2), hypertension or diabetes mellitus were excluded from this study. Patients in SCD group were treated with SCD Response Compression System (Kendall Healthcare Products Co., USA), patients in ES group were treated with the ES, and patients in the control group were not mechanically treated during the study period of anesthesia induction.

Patients were premedicated with intramuscular midazolam 2－3 mg and glycopyrrolate 0.2 mg 1 hr before operation. Prehydration with 7 ml/kg colloid solution of 6% HES 130/0.4 (Voluven, Fresenius Kabi, Germany) was administered over a period of 20－40 min and a radial artery catheter was inserted under local anesthesia in pre-anesthetic room. On arrival in the operating room, all patients had appropriate size sleeves of the SCD were applied to the lower limbs and patients in the ES group wore ES beneath SCD sleeves. The SCD Response Compression System was initiated before the induction of anesthesia in the SCD group and after the study period (5 min after the sitting position) in the ES and control group. An independent researcher blinded to the group recorded the data.

The standardized general anesthetics were used for the induction of anesthesia with propofol 2 mg/kg, remifentanil 1 μg/kg and rocuronium 0.6 mg/kg, and maintained with remifentanil 0.1 μg/kg/min and end- tidal sevoflurane 1 vol%. Ventilation was controlled to maintain normocapnia (expiratory PCO_2 32－38 mmHg) using a constant fresh gas flow of 3 L/min (60% air in oxygen) in a semi-closed circle system. No further ventilatory adjustments were made during the study.

Hemodynamic variables, including heart rate (HR) and mean arterial pressure (MAP), were measured before (pre-induction values) and 5 min after induction of anesthesia (Tsupine, baseline values), and every 1 min from 1 to 5 min after raising the patient to a 70^o sitting position (T1-5) with beach-chair (AMSCO®, 3085-SP™, STERIS®, USA). Pressure transducer was positioned at the midaxillary level when patients were supine and at the level of the 5th intercostal space anteriorly when they were sitting. Hypotension was defined as a MAP below 60 mm Hg or 80% of baseline values and treated with ephedrine i.v. (if HR < 80 beats/min) in 5 mg increments every minute until corrected. If HR was higher than 80 beats/min, phenylephrine i.v. was given in 0.05 mg increments every minute and total dose of ephedrine and phenylephrine was recorded.

Based on our preliminary study with similar anesthetic technique, we expected the incidence of hypotension associated with beach-chair position in the control group to be 70% and a reduction in the incidence of 30% with an effective treatment. This study was powered to detect such a reduction with type I error of 0.05 (two-tailed) and desired power of 0.8. Based on these assumptions, 15 patients per group were required. We assumed a dropout rate of 10% and increased the sample size to 17 patients per group.

Values were expressed as mean ± SD, or a number of patients (%). Statistical analyses were performed using SAS 9.1 for windows (SAS Institute Inc., Cary, NC, USA). Differences in the incidence of hypotension and the use of vasopressor among the groups were analyzed using the chi-square test. Differences in hemodynamic variables among the groups were analyzed with one-way ANOVA with the Bonferroni correction. A P value < 0.05 was considered significant.

RESULTS

Among 17 patients recruited for each group, one in SCD group and two in ES group were excluded from analysis due to the failure of arterial cannulation in the pre-anesthetic room, acute preoperative hypertension without medical history of chronic hypertension and the change of operative procedure, respectively. There were no differences in patient characteristics among 3 groups (Table 1).

The preoperative hemodynamic variables and the use of vasopressor during induction are listed in Table 2. There were no differences in preoperative hemodynamic variables among the groups. The incidences of hypotension (proportion, 95% confidence interval) were 12/17 (0.71, 0.47－0.87), 5/16 (0.31, 0.14－0.56), and 7/15 (0.47, 0.25－0.70) in control, SCD and ES group, respectively. The incidence was significantly lower

Table 1. Demographic Data

	Control (n = 17)	SCD (n = 16)	ES (n = 15)
Age (yr)	43.7 ± 11.2	37.5 ± 12.4	41.2 ± 12.8
Sex (M/F)	11/6	14/2	12/3
Weight (kg)	63.9 ± 10.5	72.7 ± 11.1	68.2 ± 13.0
Height (cm)	164 ± 7	169 ± 7	168 ± 6

Values are mean ± SD or number of patients. Control: patients without sequential compression device or elastic stocking, SCD: patients with sequential compression device, ES: patients with elastic stocking.

Table 2. Preoperative Hemodynamics and the Incidence of Hypotension after the Sitting Position

	Control (n = 17)	SCD (n = 16)	ES (n = 15)
Preoperative hemodynamics			
SBP (mmHg)	133 ± 15	37 ± 10	141 ± 10
MBP (mmHg)	96 ± 10	98 ± 9	98 ± 11
DBP (mmHg)	75 ± 10	76 ± 7	79 ± 10
HR (beats/min)	72 ± 11	73 ± 12	76 ± 17
Incidence of hypotension (n)	12	5*	7
Dose of ephedrine (mg)	0 (0−5)	0 (0−0)	0 (0−5)
Dose of phenylephrine (μg)	50 (0−100)	0 (0−75)	0 (0−50)

Values are mean ± SD, range (IQR) or number of patients. SBP: systolic blood pressure, MBP: mean blood pressure, DBP: diastolic blood pressure, HR: heart rate, Control: patients without sequential compression device or elastic stocking, SCD: patients with sequential compression device, ES: patients with elastic stocking. *$P < 0.05$, compared with control group.

in the SCD group than that in the control group (P = 0.038).

At T1, MAP in the control group was significantly lower than that in the SCD group (P = 0.036) and significantly decreased from the baseline values (Tsupine) (P = 0.03) (Fig. 1).

DISCUSSION

In this study, hypotension was frequently observed within 5 min after the sitting position and the incidence of hypotension in the control group was 71%, which was significantly decreased to 31% with the use of SCD. Although elastic stocking did reduce the incidence of hypotension to 47%, it was not statistically significant.

The consequence of arterial hypotension associated with the sitting position may be aggravated by the depressant effects of intravenous induction and volatile agents on myocardial contractility during general anesthesia and the changes in venous return following intermittent positive pressure ventilation [6]. As much as 1,500 ml was reported to be sequestered in the venous system of the lower limbs due to the effect of gravity, increased diffusion through the capillary walls and venous dilatation associated with volatile anesthetic agents [7,8]. A previous study using indicator dilution technique have confirmed that 14% of blood volume was redistributed from the intra- to the extrathoracic compartment in anesthetized patients after a change from the supine to the sitting position [9]. A number of techniques have been advocated to attenuate the hemodynamic effects of patient placement in the sitting position.

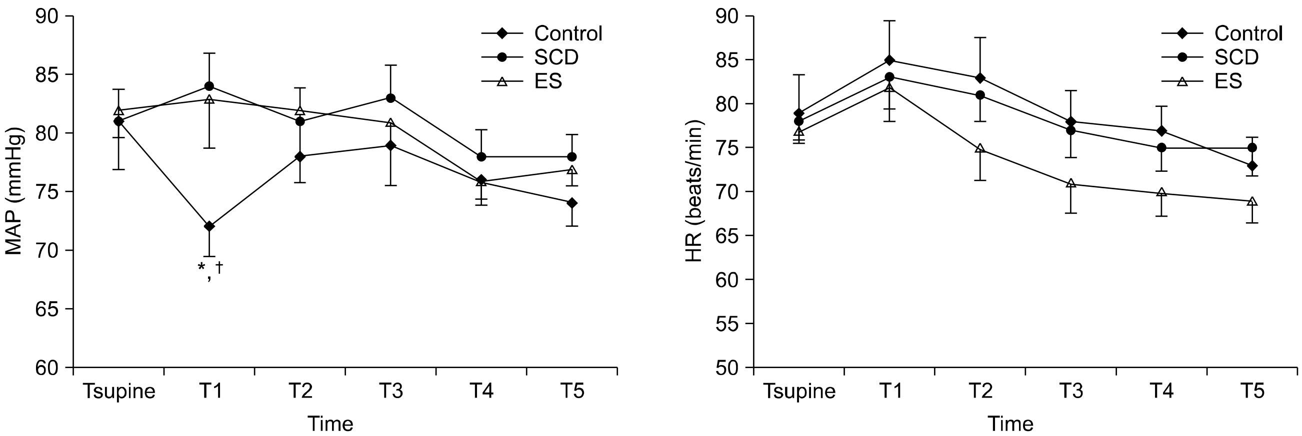

Fig. 1. The changes of mean arterial pressure (MAP) and heart rate (HR) after the sitting position. At T1, MAP in control group was significantly lower than that in SCD groupand significantly decreased compared with the baseline values (Tsupine) within the group. *$P < 0.05$, vs. control group, †$P < 0.05$, vs. baseline values within the group.

Colloid preloading (10 ml/kg) 30 min before starting general anesthesia could prevent the decrease of the systolic and central venous pressures after sitting position without adverse effects [10]. In this study, pre-hydration with 7 ml/kg colloid solution was administered 20−40 min before anesthesia induction but the incidence of hypotension was high in the control group. Cunningham and Hourihan [11] have suggested that wrapping of the legs, application of anti-gravity suits and positioning of the knees at right heart level may all have potential hemodynamic benefits in the sitting position.

It is probable that the efficacy of any compression device in reducing hypotension is a direct result of the reduction in lower limb blood volume. The ES was able to prevent venous stasis and also increase femoral venous flow velocity [12]. A properly applied ES provides 18 mmHg pressure in the ankle, 14 mmHg in the calf and 8 mmHg in the thigh. Hobel et al. [13] reported that ES were associated with favorable cardiovascular changes and increased MAP in the pregnant subjects, who had significant hemodynamic changes when they change from the sitting position to the lateral recumbent position and then change to standing with ambulation. They concluded that ES significantly increase the afterload by mechanically preventing pooling of blood in the lower extremities. Authors hypothesized that the elastic compression of the lower extremities would be effective on hypotension associated with the sitting position. However, although the incidence of hypotension in the ES group was lower compared to that in the control group, there was no statistically significance.

The thigh-high intermittent SCD prevents pooling of the blood in the lower limbs by producing a 12-s period of compression at a preset pressure followed by a 60-s period of decompression. The SCD pressure is sequentially applied from the ankle to the thigh to produce a milking action. The SCD has been shown to be superior to single chamber compression by producing a high average and peak velocity of flow in the femoral veins, moving a greater volume of blood [14,15]. Studies in normal volunteers have shown that SCD can move approximately 125 ml of blood during the compression phase [14]. Although no studies have compared SCD blood volume recruitment in supine vs. sitting position, it is well known that patients in sitting position have more venous blood trapped in the lower extremities and volatile anesthetic induced vasodilation will increase the pooling even further. Thus, theoretically, the SCD would move an even greater blood volume centrally in this patient population, which is likely the cause of maintenance of relatively stable MAP during sitting position in this study. The result of this study was consistent with previous studies on the effect of SCD on spinal anesthesia associated with hypotension in parturients [5,16]. Horiuchi et al. [17] suspected increased venous return with intermittent lower extremity pneumatic compression by observing short, marked decreases in pulmonary artery blood temperature at times corresponding to the inflation of the compression device.

In conclusion, although the incidence of hypotension was decreased with the use of both SCD and elastic stocking, significant reduction was achieved only with SCD in the sitting position during shoulder arthroscopy.

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