J Shoulder Elbow Surg (2020) 29, 2027–2035

ELSEVIER

Journal of Shoulder and Elbow Surgery

www.elsevier.com/locate/ymse

Improving the safety of shoulder arthroscopy in the beach chair position: a prospective randomized trial investigating the effect of compression stockings on cerebral desaturation events in obese patients

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Background: Devastating transient and permanent postoperative neurocognitive complications in previously healthy, low-risk patients have been observed after elective shoulder arthroscopy in the beach chair position (BCP). Continuous monitoring of cerebral oxygen saturation has been recommended to identify cerebral desaturation events (CDEs) and improve patient safety. However, the relatively high cost and limited availability of monitoring may not be cost-effective. More cost-effective and available measures, including the use of thigh-high compression stockings (CS), have been investigated. However, efficacy data of CS usage is limited, especially for obese patients, who have been shown to be at increased risk for CDEs. The purpose of this was study was to determine if the intraoperative addition of thigh-high compression stockings decreases the incidence, frequency, and magnitude of CDEs in obese patients undergoing shoulder arthroscopy in the BCP.

Methods: Thirty-three patients in the treatment group wore both thigh-high compression stockings (CS) and sequential compression devices (SCDs), and the remaining 33 patients in the control group wore SCDs alone. Cerebral oximetry was monitored during surgery using near-infrared spectroscopy.

Results: The incidence of CDEs was equal between groups, with 9 patients (27%) in each experiencing desaturation events. The median number of CDEs per patient was 3 for the control group and 1 for patients wearing CS ($P = .29$). There was no difference between groups in terms of median time from induction of anesthesia to onset of CDE ($P = .79$), median time from upright positioning to onset of CDE ($P = .60$), mean CDE duration per patient ($P = .22$), and median cumulative CDE duration ($P = .19$). The median maximal desaturation from baseline was also not different between groups: 27.6% in the control group and 24.3% in the treatment group ($P = .35$).

Conclusion: The combination of thigh-high CS and SCDs did not decrease the incidence, frequency, or magnitude of CDEs in patients undergoing shoulder arthroscopy in the BCP. Twenty-seven percent of patients undergoing shoulder arthroscopy in the BCP demonstrated CDEs with or without the use of CS. Therefore, further research is required to identify cost-effective, minimally invasive, and universally available methods of decreasing the incidence of CDEs during this common surgical procedure.

Level of Evidence: Level I; Randomized Controlled Trial; Treatment Study

Keywords: Cerebral desaturation events; beach chair position; compression stockings; shoulder arthroscopy; patient safety; cerebral perfusion

Approval for this trial was obtained from the Institutional Review Board at Loyola University Chicago, Health Sciences Division (no. 209868; ClinicalTrials.gov number NCT03996668).

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1058-2746/$ - see front matter
https://doi.org/10.1016/j.jse.2020.05.037

The beach chair position (BCP) is commonly used in both arthroscopic and open upper extremity surgery. Compared with the lateral decubitus position, the BCP provides an anatomic orientation of the shoulder, reduced risk of brachial plexus injury, reduced blood loss, ease of examination under anesthesia, simple conversion to an open approach if needed, and easier airway access for the anesthesiologist.[34,41] Despite these benefits, there are described disadvantages with beach chair positioning, including catastrophic neurologic and ophthalmologic complications. Case reports have described vision loss, brain death, stroke, and even death following shoulder arthroscopy in the BCP.[5,13,15,16,33,36,38]

These complications are rare and have only been reported in isolated case reports and small case series; however, the overall incidence is not known. Although the exact etiology is speculative, it is thought to be due at least in part to a hydrostatic gradient between the brain and heart created by beach chair positioning. This gradient can be increased by both unintentional and intentional hypotensive anesthesia, which has been used to diminish bleeding and thereby aid in intraoperative visibility.[33,41] The combination of BCP and hypotension can lead to cerebral hypoperfusion, and sustained hypoperfusion below a critical threshold may lead to ischemia and, rarely, devastating neurocognitive complications.[11,17,21,26,30,37,46]

Although a direct relationship between decreased cerebral perfusion and postoperative neurocognitive deficits has not been definitively established,[32,41] continuous monitoring of cerebral oxygenation (rSO_2) has been recommended to help avoid potential neurologic complications and improve patient safety.[14,23] Methods for monitoring cerebral oxygenation include electroencephalography, invasive brain blood pressure monitoring, and cerebral oximetry using near-infrared spectroscopy (NIRS). NIRS is commonly used to measure cerebral oximetry because it is noninvasive and strongly correlates with middle cerebral artery flow velocity and cerebral hypoperfusion.[1] For these reasons, it has been used extensively in recent studies to define the incidence of cerebral desaturation events (CDEs) in patients undergoing arthroscopy in the BCP.[7,8,10,19,22,24,25,27,29,31,32,35,42,43,47,50-52]

However, the relatively high cost and limited availability of NIRS monitoring may not be cost-effective given the rare incidence of postoperative neurocognitive deficits. Therefore, it is important to consider more cost-effective measures that may limit the incidence of CDEs, thought to be a surrogate for cerebral hypoperfusion. Woo et al[52] investigated the incidence of hypotension and CDEs in a small patient population randomized to either compression stockings (CS) or no stockings and found a reduced incidence of hypotension but no change in the incidence of CDEs. However, more recent evidence suggests that obesity (body mass index [BMI] of 30 or greater) is an independent risk factor for CDEs during surgery in the BCP,[42,43,50] and Woo et al's study did not control for this variable. Tauchen et al[50] compared a prospective case series of obese patients wearing CS and sequential compression devices (SCDs) to a historical cohort of obese patients wearing only SCDs and found a decreased incidence of CDEs in the group with CS and SCDs. There is currently no randomized controlled trial investigating if thigh-high CS decrease the incidence, frequency, and magnitude of CDEs in obese patients (BMI $>$ 30) undergoing shoulder arthroscopy in the BCP. We hypothesized that the addition of CS would result in decreased incidence, frequency, and magnitude of CDEs.

Materials and methods

All patients undergoing shoulder arthroscopy in the BCP at our health system's ambulatory surgical center and 2 hospitals between August 2018 and February 2019 were considered for inclusion in the study. Patients were included if they were aged 18 years or older, had BMI of 30 or greater, and were able to receive a peripheral nerve block. Patients were excluded if they had documented carotid artery stenosis of 90% or greater, prior neck surgery, or were pregnant. Block randomization with a block size of 6 was performed for a total of 66 patients. Thirty-three patients in the treatment group wore CS (TED Anti-Embolism Stockings; Covidien, Mansfield, MA, USA) with SCDs (Vaso Press DVT system, Compression Therapy Concepts, Eatontown, NJ, USA) over them, and 33 patients in the control group wore SCDs alone. SCDs are the standard of care for mechanical deep venous thrombosis prophylaxis at our institution. Patient flow through the trial is displayed in the CONSORT diagram (Fig. 1). All procedures were performed by a board-certified orthopedic surgeon fellowship trained in either sports medicine or shoulder and elbow surgery. Demographic information was obtained from the patient on the day of surgery.

A standardized anesthesia protocol was used during the study. First, in the preoperative holding area, intravenous sedation consisting of 2-6 mg of midazolam was administered and an interscalene nerve block was placed under ultrasound guidance. Patients were then taken to the operating room, where patients were transferred to the operating table (Ultra Shoulder Positioner; Mizuho OSI, Union City, CA, USA) in the supine position. After cleansing with an alcohol swab, 2 NIRS sensors (INVOS 5100; Covidien) were placed on the forehead, and the baseline cerebral oxygen saturation (rSO_2) was obtained. This INVOS system is a US Food and Drug Administration–approved, commercially available cerebral oximeter that uses 2 wavelengths of near-infrared light to measure the ratio of oxyhemoglobin to total hemoglobin within cortical tissue to estimate tissue oxygenation.[45,50]

After baseline rSO_2 was obtained in the supine position, anesthesia was induced using propofol with or without succinylcholine. Either an endotracheal tube or laryngeal mask airway was placed; the type of airway used was at the discretion of the attending anesthesiologist. The anesthesiologists were not the same for all patients, as the study was carried out at different surgical centers. Anesthesia was maintained with sevoflurane with a fraction of inspired oxygen (FIO_2) of 50%. Appropriately sized thigh-high CS and SCDs or SCDs alone were placed, depending on study group. Patients were blinded to the intervention as they

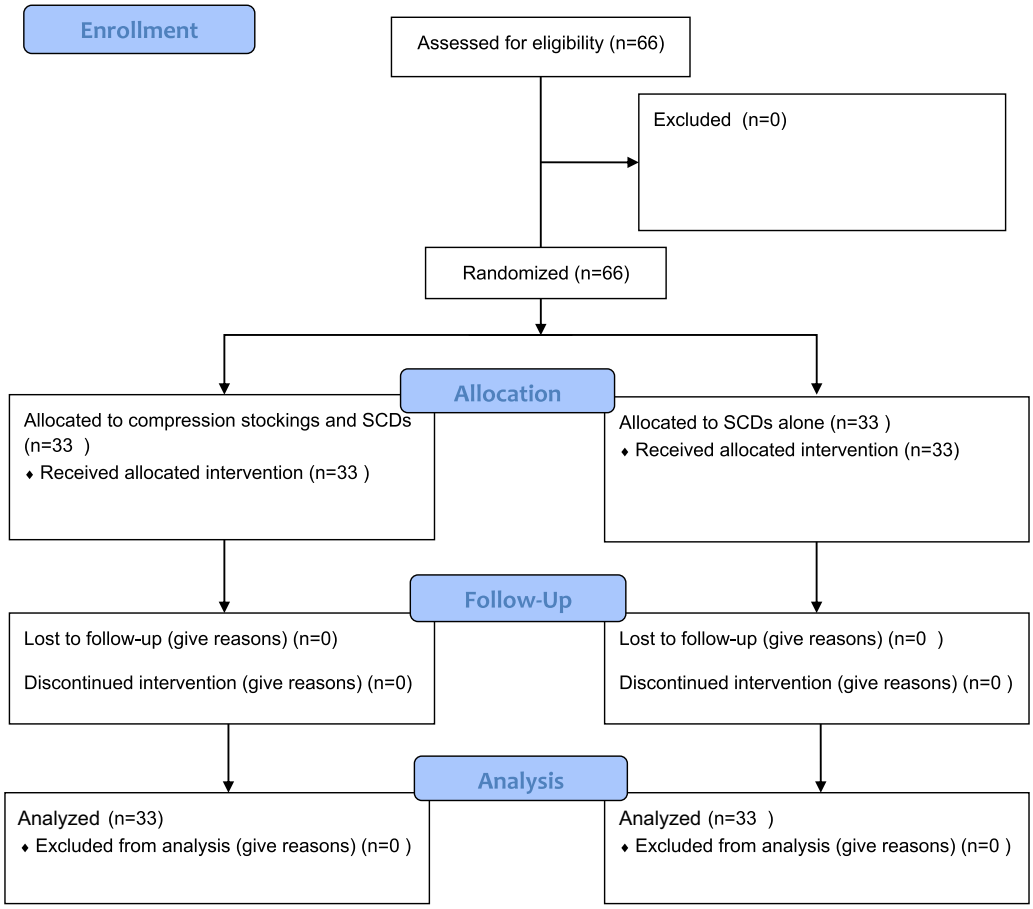

Figure 1 CONSORT Flow Diagram of patients through the trial. *SCDs*, sequential compression devices.

were induced under general anesthetic just prior to having compression devices placed on their lower extremities. A lower-body forced-air warming device (Bair Hugger; 3M Health Care, St. Paul, MN, USA) was placed over the patient's lower body prior to positioning. In all patients, the back portion of the table was angled 60° to 65°, depending on the attending surgeon's preference. A pillow was then placed under the knees to create about 20° of knee flexion. Standard intraoperative monitoring was performed, including noninvasive arterial blood pressure measurement obtained on the nonoperative brachial artery, electrocardiography, capnography, pulse oximetry, and axillary temperature measurement. End-tidal carbon dioxide was titrated to near 40 mm Hg and mean artery pressure kept between 75 and 80 mmHg. The cerebral oximeter automatically recorded rSO_2 data every 5 seconds.

In accordance with the standard practice at our institution and the protocol of multiple previous studies,[32,42,43] a CDE was defined as a decrease in the rSO_2 of 20% or greater from the preoperative baseline. This threshold is also the level at which conscious patients experience clinical manifestations of cerebral hypoperfusion, including syncope.[43,44] Although no direct link between decreased cerebral perfusion and postoperative neurocognitive deficits has been established,[41,46] a set definition of CDE is useful for standardization and serving as a surrogate for potentially devastating neurologic events and interventions aimed at reversal. The cerebral oximeter was continuously monitored by the orthopedic surgery resident (A.G.) or medical student (W.D.) throughout every procedure. If a CDE did occur, the anesthesiologist was instructed to treat each CDE with a predetermined protocol of either phenylephrine in 80-μg increments, 5 mg of ephedrine, or a fluid bolus. Which of these interventions to use was at the discretion of the treating anesthesiologist. For each CDE that occurred, its time of initiation and duration were recorded. In addition, details of each operation were recorded, including the operative procedure performed, length of surgery, type of airway used, anesthetic agents used, and nerve block used.

Statistical analysis

An a priori power analysis was performed using data from a similar study by Tauchen et al.[50] Assuming a 25% difference in the proportion of patients who experienced a CDE, power set at 80%, and a 2-sided test with the significance level set at .05, it was determined that 66 patients were required to detect a significant difference in incidence of CDE between groups. Differences in continuous demographics between those in the treatment group and control group were assessed using Student *t* tests. Differences in categorical demographics were assessed using chi-square tests, with the exception of coronary artery disease and chronic obstructive pulmonary disease, which were assessed using Fisher exact tests. Differences in continuous measured outcomes

Table I Demographic characteristics as a function of stocking use

	Overall, n (%) (N = 66)	No compression stockings, n (%) (n = 33)	Compression stockings, n (%) (n = 33)	*P* value
Incidence of CDE	18 (27)	9 (27)	9 (27)	>.99
Male	28 (42)	9 (27)	19 (58)	.013
Age, yr, mean (SD)	53.3 (11.6)	56.8 (9.4)	49.7 (12.6)	.012
BMI, mean (SD)	35.4 (4.6)	35.7 (4.2)	35 (5)	.53
LOS, min, mean (SD)	118.8 (38.9)	120.3 (41)	117.4 (37.2)	.76
DM	18 (27)	10 (30)	8 (24)	.58
PVD	0 (0)	0 (0)	0 (0)	
HTN	34 (52)	20 (61)	14 (42)	.14
OSA	13 (20)	3 (9)	10 (30)	.030
CAD	4 (6)	2 (6)	2 (6)	>.99
COPD	1 (2)	0 (0)	1 (3)	>.99
Smoker	10 (15)	4 (12)	6 (18)	.49
LMA used for airway	16 (24)	6 (18)	10 (30)	.25
Bed inclination of 60	36 (55)	20 (61)	16 (48)	.32
Surgery location: ASC	55 (83)	29 (88)	26 (79)	.32

CDE, cerebral desaturation event; *SD*, standard deviation; *BMI*, body mass index; *LOS*, length of surgery; *DM*, diabetes mellitus; *PVD*, peripheral vascular disease; *HTN*, hypertension; *OSA*, obstructive sleep apnea; *CAD*, coronary artery disease; *COPD*, chronic obstructive pulmonary disease; *LMA*, laryngeal mask airway; *ASC*, ambulatory surgery center.

between groups were assessed using nonparametric Wilcoxon tests, whereas categorical outcomes were assessed using Fisher exact tests. Because of the nonparametric nature of age, BMI, and length of surgery, medians and interquartile ranges were used to summarize these variables. All statistical analyses were performed using SAS, version 9.4 (Cary, NC, USA). All *P* values are 2-sided and statistical significance was based on alpha <0.05.

Results

All 66 consecutive patients from the study period were included; none met exclusion criteria. The control group was composed of 33 patients with a mean age of 56.8 years (standard deviation [SD] 9.4), and the treatment group was also composed of 33 patients who were on average younger, with a mean age of 49.7 years (SD 12.6, $P = .012$) (Table I). The control group consisted of 9 males and 24 females, and the treatment group consisted of 19 men and 14 women ($P = .013$). The mean BMI for the control group was 35.7, compared to 35.0 for the treatment group ($P = .53$). The only statistical difference between the 2 groups in terms of medical comorbidities was the incidence of obstructive sleep apnea, with 3 patients in the control group and 10 in the treatment group ($P = .030$). Otherwise, the presence of diabetes mellitus, peripheral vascular disease, hypertension, coronary artery disease, chronic obstructive pulmonary disease, and smoking were similar between groups. The mean length of surgery, 120.3 minutes (SD 41) in the control group and 117.4 minutes (SD 37.2) in the treatment group, was similar ($P = .76$). There was also no difference between groups with the use of laryngeal mask airway instead of endotracheal tube ($P = .25$). Two of the 3 attending surgeons involved in the study elevate the head of the operating room table 65° from the horizontal, whereas the third elevates 60°. There were no differences between groups in terms of head of bed elevation angle ($P = .32$). In addition, the proportion of surgeries taking place at the ambulatory surgery center, as opposed to our 2 hospital-based surgical centers, was not different between groups ($P = .32$). Of note, all patients, regardless of surgery location, underwent outpatient procedures and were discharged home on the day of surgery.

The incidence of CDEs was equal between groups, with 9 patients (27%) in each experiencing desaturation events. For the control group, the median number of CDEs was 3, and the median for the treatment group was 1 ($P = .29$) (Table II). The median time from induction of anesthesia to onset of CDE was 31.5 minutes in the control group and 26.3 minutes in the treatment group ($P = .79$). Similarly, the time from upright positioning to onset of CDE was similar between groups: 26.7 minutes in the control group and 20.2 minutes in the treatment group ($P = .60$). The mean CDE duration was 4.4 minutes for the control group and 2.6 minutes for the treatment group ($P = .22$). Although there was a trend toward higher median cumulative CDE duration for patients in the control group, 16.8 minutes vs. 2.6 minutes, the difference did not meet statistical significance ($P = .19$). The median maximal desaturation from baseline was also similar between groups: 27.6 minutes in the control group vs. 24.3 minutes in the treatment group ($P = .35$). For patients who experienced CDEs, the only difference between groups was age (65 years in the control group vs. 50 years in the treatment

Table II Comparison of CDEs as a Function of stocking use

	Overall, median (IQR) (n = 18)	No compression stockings, median (IQR) (n = 9)	Compression stockings, median (IQR) (n = 9)	*P* value
Age, yr	57.5 (50, 65)	65 (59, 66)	50 (46, 55)	.019
BMI	34.8 (33.1, 37.1)	35.4 (33.7, 37.1)	33.4 (32.8, 39.5)	.72
Number of CDEs per patient	2 (1, 4)	3 (2, 4)	1 (1, 3)	.29
Time from induction to onset of CDE, min	28.2 (13.6, 39.5)	31.5 (24.8, 39.5)	26.3 (13.6, 32.9)	.79
Time from upright positioning to onset of CDE	20.6 (8.1, 32.2)	26.7 (16, 32.2)	20.2 (8.1, 25.4)	.60
Mean CDE duration per patient	3.5 (0.9, 8.9)	4.4 (3.4, 8.9)	2.6 (0.5, 4)	.22
Cumulative CDE duration, min	9.3 (1.5, 23.8)	16.8 (3.6, 29.5)	2.6 (0.5, 14.1)	.19
Maximum desaturation from baseline	25 (23.3, 37.7)	27.6 (23.8, 43.2)	24.3 (22.7, 33.3)	.35

BMI, body mass index; *CDE*, cerebral desaturation event; *IQR*, interquartile range (quartile 1, quartile 3).

group, $P = .019$) (Table III). The incidence of CDE did not vary by surgeon ($P = .28$). No patients in either group underwent cognitive testing or were evaluated specifically for neurologic sequelae after the procedure. There were no apparent complications noted after surgery for any of the patients. One patient in the control group who had a CDE was treated with a fluid bolus. All other patients in both groups received ephedrine, phenylephrine, a fluid bolus, or a combination thereof for treatment of CDEs.

Discussion

In this prospective investigation, 66 obese patients were randomized to wearing either thigh-high CS and SCDs or SCDs alone. The hypothesis was not supported; there were no differences between groups in the incidence, frequency, and magnitude of CDEs. Similarly, there was no difference between groups in terms of time from induction to onset of CDE, time from upright positioning to onset of CDE, and median cumulative CDE duration.

Although some advocate for universal, continuous rSO_2 tracking to avoid potential neurologic complications and improve patient safety,[32,37] NIRS monitoring may not be cost-effective given the rare incidence of postoperative neurocognitive deficits. Neurocognitive changes in the setting of NIRS-documented CDEs have been described. Murphy et al[31] reported on a patient who had postoperative transient delirium following arthroscopic shoulder surgery with a 34-minute intraoperative CDE. Kocaoglu et al[24] described a patient who underwent arthroscopic rotator cuff repair and subsequently developed visual symptoms lasting 48 hours. Nonetheless, permanent neurocognitive deficits are rare following arthroscopy in the BCP, and have not been described in the setting of CDE identified by NIRS.

Therefore, it is important to assess more cost-effective measures that may limit the incidence of CDEs, and thus potentially improve the safety profile of the surgery. A recent Cochrane review demonstrated that airline passengers wearing compressions stockings can expect a reduction in symptomless DVT and leg edema.[9] Another Cochrane review concluded that CS are efficacious in diminishing the risk of DVT, proximal DVT, and pulmonary embolism in hospitalized patients across multiple surgical specialties.[39] CS are theorized to displace superficial venous blood into the deep system, thereby increasing the deep system's flow velocity and volume and prevent thrombosis.[4]

The hemodynamic implications of these findings have recently led to investigations on the effects of thigh-high CS on CDEs. To our knowledge, only 2 previous studies have investigated the efficacy of CS in reducing desaturation events. Tauchen et al[50] compared a prospective case series of patients wearing CS and SCDs to a historical cohort of patients wearing only SCDs. They found a decreased incidence of CDEs in the group with CS. The only prospective, randomized study on the subject was performed by Woo et al,[52] who investigated the incidence of hypotension and CDEs in a small patient population randomized to either CS or no stockings and found a reduced incidence of hypotension but no change in the incidence of CDEs.

However, there are a few limitations to Woo et al's[52] study: a small study population of 38 patients; included patients underwent a variety of procedures, including shoulder arthroscopy, arthroplasty, and open reduction internal fixation for fractures about the shoulder girdle; and they did not control for BMI. More recent evidence suggests that the incidence of CDEs is higher in patients with increased BMI.[40,43,50] Further, obese patients are prone to impaired cerebral perfusion[12] and endothelial dysfunction,[2] which may impair autoregulation and, in effect, cerebral blood flow. Lastly, Woo et al's patients were randomized to wearing thigh-high CS or no mechanical prophylaxis on their lower extremities. We felt it was appropriate that our control group wear SCDs as they are the standard of care for mechanical deep venous thrombosis prophylaxis at our institution and are commonly used during surgical procedures in the United States.

Table III Demographic characteristics as a function of stocking use among individuals who experienced CDEs.

	Overall (n = 18)	No compression stockings (n = 9)	Compression stockings (n = 9)	*P* value
Male	8 (44)	2 (22)	6 (67)	.15
Age, yr, median (IQR)	57.5 (50, 65)	65 (59, 66)	50 (46, 55)	.019
BMI, median (IQR)	34.8 (33.1, 37.1)	35.4 (33.7, 37.1)	33.4 (32.8, 39.5)	.72
LOS, min, median (IQR)	107.5 (75, 131)	98 (75, 125)	117 (79, 135)	.43
DM	5 (28)	2 (22)	3 (33)	>.99
PVD	0 (0)	0 (0)	0 (0)	
HTN	15 (83)	8 (89)	7 (78)	>.99
OSA	4 (22)	1 (11)	3 (33)	.58
CAD	1 (6)	1 (11)	0 (0)	>.99
COPD	0 (0)	0 (0)	0 (0)	
Smoker	2 (11)	0 (0)	2 (22)	.47
LMA used for airway	2 (11)	1 (11)	1 (11)	>.99
Bed inclination of 60°	12 (67)	5 (56)	7 (78)	.62
Surgery location: ASC	13 (72)	8 (89)	5 (56)	.29

CDEs, cerebral desaturation events; *IQR*, interquartile range (quartile 1, quartile 3); *BMI*, body mass index; *LOS*, length of surgery; *DM*, diabetes mellitus; *PVD*, peripheral vascular disease; *HTN*, hypertension; *OSA*, obstructive sleep apnea; *CAD*, coronary artery disease; *COPD*, chronic obstructive pulmonary disease; *LMA*, laryngeal mask airway; *ASC*, ambulatory surgery center.
Unless otherwise noted, values are n (%).

The findings shown in this study corroborate Woo et al's[52] of no difference in CDE incidence. Also, in agreement with our study's findings, Tauchen et al[50] did not find any differences in number of CDEs per patient, time from induction or upright positioning to onset of CDE, CDE duration, or maximum desaturation from baseline when comparing their control and treatment groups. However, Tauchen et al's study did demonstrate a lower incidence of CDEs for patients wearing CS (1 of 23 patients, 4%) compared with those not wearing CS (7 of 24 patients, 29%; $P = .048$). One reason that may account for this discrepancy is their study did not control for bed inclination angle and its potential effect on CDE incidence. Songy et al[47] demonstrated a linear decline in rSO_2 for an increasing BCP angle. In this study, the bed inclination angle was either 60° or 65° depending on attending surgeon preference, and the proportion of patients undergoing surgery at a beach chair angle of 60° was equal between groups ($P = .32$). Second, their study compared a prospective group to a historical control, which may have unintentionally introduced variables that changed over time and affected outcomes. There is a wide range of CDE incidence reported in the literature for patients receiving general anesthesia in the BCP: Songy et al[47] found a 0% incidence in a cohort of 50 patients, and Murphy et al[32] reported an 80% incidence. The incidence of CDE in this study of 27% for both the treatment and control groups falls within this range.

There are several possible explanations for why CS were unable to prevent CDEs. First, the theoretical mechanism of action of CS has not been supported by the literature. CS are designed to increase the velocity of venous blood flow and thereby decrease venous stasis and the propensity to develop thrombosis. However, studies have shown there is little to no increase in popliteal and femoral venous blood flow velocity when CS are worn.[48,49] Second, although reviews report the efficacy of CS reducing the incidence of DVT and PE,[9,39] this topic remains controversial, especially in the orthopedic literature, wherein multiple trials deem them ineffectual.[3,6,20] Thus, if the effectiveness of CS in altering local hemodynamics in the lower extremities remains a controversial topic, it is unlikely they exert a clinically significant effect on distant, cerebral perfusion.

There are many anesthesia factors that can impact cerebral oximetry, so an attempt was made to standardize the perioperative protocol. Because of individual patient differences and judgments made by anesthesia providers, there were times when slight deviations in the protocol were necessary. Two patients in the treatment group and 1 patient in the control group had desflurane for their inhalational anesthetic instead of sevoflurane. One patient had her sevoflurane mixed with nitrous oxide. It is unclear if these pharmacologic differences affect cerebral oximetry. There were 2 deviations in maintenance anesthetic in each group, and none of these patients experienced CDEs.

There were 9 patients in both groups who had regional blocks with a mixture of 1.3% liposomal bupivacaine and 0.5% bupivacaine instead of 0.5% bupivacaine alone. Among the liposomal bupivacaine blocks in the control group, 1 was infraclavicular, and 1 was supraclavicular. In the treatment group, 1 of the liposomal bupivacaine blocks was supraclavicular. Liposomal bupivacaine consists of bupivacaine hydrochloride, which is encapsulated in lipid bilayers and designed to provide a prolonged, sustained release for longer postoperative pain control.[28] A recent Cochrane review of 7 trials investigating liposomal

bupivacaine reported no adverse events within 30 days of surgery,[18] and there is no evidence to suggest patients are more or less likely to have CDEs when administered this formulation compared to 0.5% bupivacaine alone. Similarly, site of injection—interscalene vs. supraclavicular vs. infraclavicular—is unlikely to affect cerebral perfusion. In sum, these small deviations in the anesthesia protocol were unlikely to result in relevant changes in cerebral oximetry. Further, the length of surgery, and as a result, the time of patients' exposure to anesthetic, was equal between groups ($P = .76$). The proportion that received general anesthetic with an laryngeal mask airway, as opposed to endotracheal tube, was also equal ($P = .25$).

There are some limitations to this study. First, the sample size is relatively small. Performing an accurate power analysis was somewhat difficult given the wide variability of CDE incidence rates in the literature. The power analysis was based on Tauchen et al's[50] study, which is methodologically most closely related to this study. Second, patients randomized to wearing CS were younger, consisted of more men, and had a higher incidence of obstructive sleep apnea. Nonetheless, this does not necessarily indicate improper randomization. Further, there are currently no data to suggest these differences have any effect on the occurrence of CDEs. A previous study investigated independent risk factors for CDE and did not demonstrate any differences between patients who experienced CDEs and those who did not in terms of gender ($P = .47$), presence of obstructive sleep apnea ($P = .14$), or age ($P = .24$).[40] This study also established that patients with a BMI greater than 34 were determined to have a 12.4 times greater chance of having intraoperative desaturation events. In this study, the mean BMI of both groups exceeded 34 (35.7 for the control group and 35.0 for the treatment group, $P = .53$).

Third, there were small deviations in the anesthesia protocol. However, there is no evidence these small changes in the standardized protocol put subjects at greater risk of CDE. Invasive blood pressure monitoring data were not collected for this study, as placing arterial lines for these minimally invasive, outpatient procedures was deemed excessive. Continuous cerebral perfusion data were also not compared between groups. Although there may be some value in comparing continuous cerebral oximetry values, 20% below baseline has been accepted in the literature as the level below which neurologic manifestations of desaturation become apparent. For this reason, and the ability to compare these data to previous studies', only data below the predetermined threshold were analyzed. Arterial duplex testing was also not performed for this study because it was not logistically and economically feasible. Patients with documented carotid artery stenosis greater than 90% were excluded, but it is possible some participants exceeded this threshold without being identified. Lastly, these results may not be generalizable to nonobese patients.

Conclusion

The purpose of this was study was to determine if the intraoperative addition of thigh-high CS decreases the incidence, frequency, and magnitude of CDEs in obese patients undergoing shoulder arthroscopy in the BCP. In this series, the use of thigh-high CS did not affect these outcomes. Twenty-seven percent of patients undergoing shoulder arthroscopy in the BCP demonstrated CDEs regardless of thigh-high compression stocking use. Therefore, further research is required to identify cost-effective, minimally invasive, and universally available methods of decreasing the incidence of CDEs during this common surgical procedure.

Disclaimer

Source of Funding: Walgreen's Foundation.

The authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

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