Can subclavian/infraclavicular axillary vein collapsibility index predict spinal anesthesia-induced hypotension in cesarean-section operations?

E. ASLANLAR[1], M. SARGIN[1], D.A. ASLANLAR[2], Ö. ÖNAL[1]

[1]Department of Anesthesiology, Medicine Faculty, Selcuk University, Konya, Turkey
[2]Meram State Hospital, Konya, Turkey

Abstract. – OBJECTIVE: Spinal anesthesia-induced hypotension (SAIH) is relatively common in pregnant women and has serious maternal and fetal side effects. In patients who are hypovolemic during spinal anesthesia, there may be a significant decrease in blood pressure caused by the decrease in preload. Subclavian vein sonography is a useful method for evaluating preoperative intravascular volume status.

This study aimed to evaluate the efficacy of the pre-operative subclavian vein or infraclavicular axillary vein (SCV-AV) collapsibility index for predicting SAIH in cesarean-section (C-section).

PATIENTS AND METHODS: In this prospective observational study, 82 women undergoing elective C-sections were recruited. Sonographic evaluation of SCV-AV was assessed before spinal anesthesia. After spinal anesthesia, changes in blood pressure were noted. The main outcome was the association between the SCV-AV measurements (diameter and collapsibility index) and SAIH.

RESULTS: Hypotension developed in 53 (64%) patients after spinal anesthesia. The collapsibility index of the SCV-AV during spontaneous breathing and deep inspirium was not a significant predictor of a decrease in mean blood pressure (MBP) after spinal anesthesia (*p*<0.979, *p*<0.380).

CONCLUSIONS: It was found that the SCV-AV collapsibility index is not a predictor of SAIH in pregnant women undergoing elective C-sections.

Key Words:
Subclavian vein, Collapsibility index, Hypotension, Spinal anesthesia, Cesarean-section.

Introduction

In C-section operations, neuraxial anesthesia is recommended instead of general anesthesia to prevent fetal exposure to anesthetic drugs and to avoid maternal airway complications. Spinal anesthesia is one of the neuraxial anesthesia methods, which is preferred over epidural anesthesia because it is an easier and faster method[1]. One of the most important complications of spinal anesthesia is hypotension, and its incidence is 15.3-33% in the normal population, while it can reach 70% in pregnant women[2]. Despite sufficient fluid load, venous pooling in the lower extremities due to aortocaval compression of the pregnant uterus and low systemic vascular resistance in pregnant women cause obstetric patients to be more susceptible to SAIH[3]. SAIH causes nausea, vomiting, and dyspnea in the mother, low Apgar scores, and umbilical acidosis in the fetus. These adverse effects have been associated with the severity and duration of hypotension[4].

The best method of preventing SAIH, which has serious maternal and fetal side effects, is controversial[3,4]. Many methods, such as left lateral tilt, leg elevation, intravenous crystalloid/colloid loading, or prophylactic vasopressors, have been attempted to prevent SAIH[5]. However, there is growing evidence that non-selective liquid preloading or co-loading is not effective in preventing hypotension; moreover, excessive fluid intake can cause maternal complications[6]. Furthermore, empiric fluid loading has the potential to cause volume loading, especially in patients with cardiac disease[7]. As a result, investigating the parameters that predict SAIH becomes mandatory to avoid empiric fluid loading and to apply this method only in patients who are anticipated to develop SAIH[3].

Although extensive research[8-10] has been conducted in recent years to estimate preoperative intravascular volume status, this remains a chal-

Corresponding Author: E. Aslanlar, MD; e-mail: emine.aslanlar@selcuk.edu.tr

lenging issue. Inferior vena cava (IVC) sonography has been reported in many studies[8-10] as a noninvasive, reliable, and useful technique for assessing intravascular volume status. In a previous study[9], it was stated that the incidence of SAIH decreased after fluid administration under the guidance of IVC ultrasonography before spinal anesthesia, but the IVC collapsibility index was not useful for predicting SAIH. The intravascular volume status can be evaluated with subclavian vein (SCV) because IVC evaluation may be limited owing to the large uterus in pregnant women. In fact, a correlation has been reported between the SCV collapsibility index and the IVC collapsibility index[11]. Although there are studies[12] in the literature that have reported the use of IVC to predict SAIH in pregnant women, no studies have reported the use of SCV.

The aim of this study was to measure the preoperative diameter and collapsibility index of SCV-AV during spontaneous and deep inspirium and examine whether these parameters could predict SAIH in patients undergoing C-sections.

Patients and Methods

Study Design

Ethical approval for this prospective, observational study (Ethical Committee No. 2020/426) was provided by Selçuk University Local Ethics Committee on 30.09.2020. The trial was registered in ClinicalTrials.gov (registration number, NCT05120258). The study was conducted during the period from November 2021 to March 2022 after obtaining written informed consent from all included patients.

Patients aged 18-40 years, with American Society of Anesthesiologists (ASA) physical status 2, and scheduled for cesarean-section under spinal anesthesia were included in this study. Patients with ASA physical status 3 or 4, emergency cases, contraindications for spinal anesthesia, and planned general anesthesia were excluded from the study.

Measurements

Ultrasonographic measurements were performed before spinal anesthesia was administered. All patients were lying at the supine position with a left lateral tilt of 15° and breathing spontaneously for at least 5 min before assessment. Right SCV diameters were performed in the supine position with a left lateral tilt of 15° using ultrasonography (USG) device (Mindray Bio-medical Electronics Co., Shenzhen, China) and a high-frequency linear probe (6-14MHz). The short axis image of the SCV was obtained by placing the probe just below the clavicle and scanning it from the midline laterally. Since the SCV continues as the infraclavicular axillary vein after the 1st rib, the visualized vein may correspond to the SCV/AV due to subtle differences in probe position. The patient in the supine position was asked to do a normal inspiration and then a deep inspiration (as deeply as possible and exhale naturally), and the minimum diameter (dSCV-AVmin) and maximum diameter (dSCV-AVmax) of the SCV/AV were measured in the M-mode of ultrasound at a medium sweep speed during both normal (Figure 1) and deep inspiration (Figure 2). The collapsibility index was calculated according to the equation: collapsibility index = (dSCV-AVmax −dSCV-AVmin) / dSCV-AVmax * 100[8]. Ultrasonographic measurements were performed by the same anesthesiologist with 5 years of experience in sonography.

Anesthesia Management

All patients were fasted for 8 hours before surgery. Standard monitoring (Electrocardiography, noninvasive blood pressure (NIBP), and peripheral oxygen saturation measurements) was applied. Heart rate (HR), systolic blood pressure (SBP), and mean blood pressure (MBP) were recorded immediately before spinal anesthesia and defined as baseline values. Two 20-gauge intravenous cannulas were inserted in two peripheral veins, and patients were coloaded with 10 mL/kg of crystalloid solution and 500 mL of colloid solution at the time of spinal anesthesia. Fluid preload was not applied to the patients before spinal anesthesia.

Spinal anesthesia was performed at the level of the L3 to 4 or L4 to 5 intervertebral spaces with the patient in the sitting position. A dose of 8.5-10 mg of 0.5% hyperbaric bupivacaine (depending on the patient's constitution) was injected through a 25-gauge Quincke needle. The patient was returned to the supine position with a left lateral tilt of 15°. An anesthesia nurse who was blinded to the study evaluated the level of sensory blockage with a cold test. Surgery was initiated after achieving spinal blockade to the level of T5.

The NIBP was measured every 2 minutes during the postspinal period. Hypotension was defined as an absolute value of SBP less than 100 mmHg or a decrease of <80% of the baseline value[2] or mean arterial pressure <65 mmHg[13]. Ephedrine was administered if the patient had symptoms suggesting cerebral hypoperfusion, such as dizziness, nausea, or vomiting, even if SBP was above 100 mmHg or mean arterial pressure was above 65 mmHg. These patients were classified as the hypotensive group. The patients were divided into two groups according to the development of hypotension or not. Episodes of hypotension were treated with boluses of ephedrine 10 mg. Bradycardia (HR <55 beats/min) was treated with 0.5 mg intravenous injection of atropine.

The anesthesiologist who performed the neuraxial block and monitored the patient throughout the operation was blinded to the ultrasound measurements of SCV-AV recorded pre-operatively.

Sample Size Calculation

The sample size required to estimate the percentage decrease in mean blood pressure in a multiple linear regression model was calculated with G Power. We assumed a medium effect size for multiple linear regression based on Cohen's f^2 (0.15); a sample size of 74 patients (α=0.05, 1-β=95%) was necessary. Thus, 90 subjects were included to cope with an expected loss of 20%.

Statistical Analysis

Statistical analyses were performed with SPSS 21.0 software (IBM Corp., Armonk, NY, USA). The conformity of the variables to the normal distribution was examined using the Kolmogorov-Smirnov test. The Independent Samples *t*-test was used as a statistical method for statistical significance between two independent groups for the variables found to have a normal distribution. Categorical data were analyzed by Chi-square test and given as number (%). A value of $p<0.05$ was considered statistically significant.

Results

Data from 82 out of 90 patients included in the study were collected. Eight patients were excluded from the study because SCV-AV was not visualized well. There were no complications or adverse events. Hypotension developed in 53 (64%) patients after spinal anesthesia. Eighty-two patients who were included in the study were divided into 2 groups: developing (n=53) and not developing hypotension (n=29).

Demographic data of patients in both groups were compared in Table I. Data are expressed as mean ± standard deviation (SD) or number of patiens (%). When demographic data were compared, no statistically significant difference was found between the groups.

The comparison of hemodynamic parameter findings between groups is summarized in Ta-

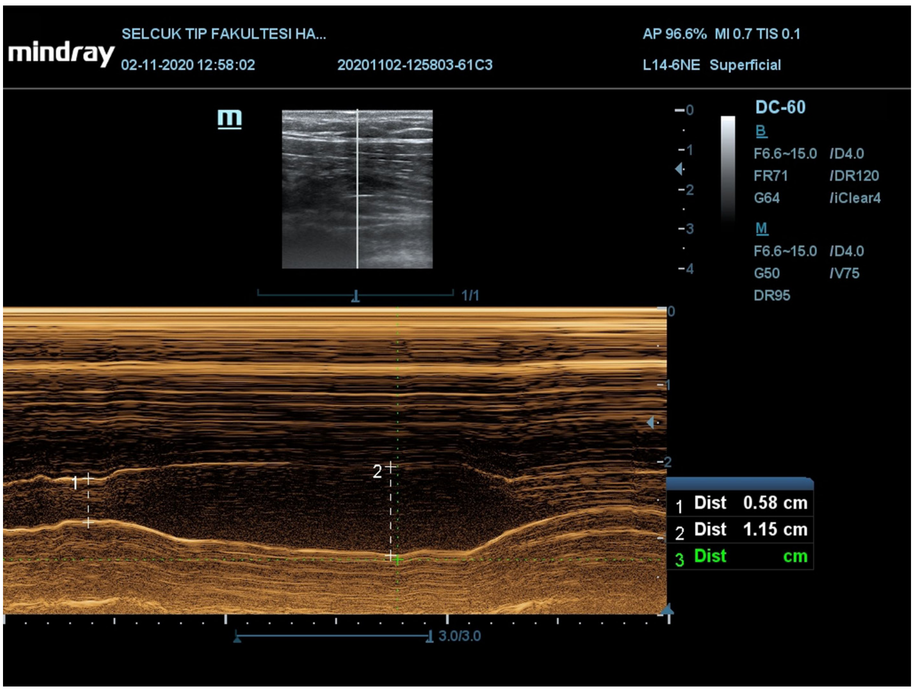

Figure 1. Ultrasonographic measurements during spontaneous breathing.

Table I. Comparison of demographic characteristics in patients who developed SAIH and patients who did not.

	SAIH (+) n=53	**SAIH (-) n=29**	***p***
Age (year)	29.6±5.3	29.8±6	<0.863
Height (cm)	161.3±6.4	163.0±5.6	<0.252
Weight (kg)	78.8±14.2	79.6±12.4	<0.781
BMI (kg/m^2)	30.2±5.1	30±5	<0.874
Gestational diseases	4 (7.5)	4 (13.8)	<0.362

SAIH (+) = Developed Spinal Anesthesia Induced Hypotension. SAIH (-) = Not developed Spinal Anesthesia Induced Hypotension. BMI = Body Mass Index. Values are mean ± standard deviation (SD) or number of patients. Significant difference between groups ($p<0.05$).

ble II. There were no significant differences in the baseline HR values between the two groups ($p=0.861$). Baseline MBP was significantly lower in patients who developed hypotension than those who did not (76.2±15.7 *vs*. 88.6±9.7, $p<0.001$).

Comparison of ultrasonographic measurements of subclavian/infraclavicular axillary vein between groups is summarized in Table III. There were no significant differences in the dSCV-AVinspiration-spontaneous breathing, dSCV-AVexpiration-spontaneous breathing, dSCV-AVinspiration-deep inspiration, dSCV-AVexpiration-deep inspiration, collapsibility index of SCV-AVspontaneous breathing, collapsibility index of SCV-AVdeep inspiration values between two groups ($p=0.830$, $p=0.887$, $p=0.187$, $p=0.620$, $p=0.979$, and $p=0.380$, respectively).

Discussion

The results showed that the SCV-AV collapsibility index failed to predict the development of SAIH during both spontaneous and deep inspirium.

Point-of-care ultrasonography has become a frequently used method in anesthesia practice recently to evaluate intravascular volume status. One of the most frequently evaluated veins for this purpose is the IVC[4]. IVC evaluation is generally considered a reliable way to determine both intravascular volume status[10,14]. Studies[8,11,15] have shown a correlation between ultrasonographic measurements of SCV and IVC in assessing intravascular volume status. In cases where IVC imaging is difficult (abdominal bloating, intestinal gas, morbid obesity, and tissue edema), SCV can be used conveniently. SCV imaging was preferred in this study due to the fact that IVC imaging would be limited owing to a large uterus in pregnant patients. Simultaneously, a shorter duration of SCV imaging compared with IVC was also a factor.

SCV is a vein with high compliance, and its size and dynamics are affected by the total volume of intravascular fluids and breathing. The fact that SCV is protected from unwanted external compressions by the upper tissues and the clavicles reduces the likelihood of vein collapse due to the pressure generated by the ultrasound probe in sonographic measurements. This feature also supports the use of SCV sonography to determine the intravascular volume status[16].

The literature has focused mostly on IVC for the estimation of preoperative volume status, and later studies[11] investigated the correlation between SCV and IVC. Kaptein et al[11] showed that the SCV collapsibility index in the semi-seated position had a compatibility with the IVC collapsibility index for spontaneous breathing. Previous studies[17,18] have documented that 0°, 30°, or 45° positions do not considerably affect the IVC collapsibility index, and the measurements are comparable. The SCV collapsibility index,

Table II. Comparison of hemodynamic data in patients who developed SAIH and patients who did not.

	SAIH (+) n=53	**SAIH (-) n=29**	***p***
Baseline HR (beats/min)	95.3±14.2	94.6±16.1	<0.861
Baseline MBP (mmHg)	76.22±15.73	88.62±9.70	**<0.001**

SAIH (+) = Developed Spinal Anesthesia Induced Hypotension. SAIH (-) = Not developed Spinal Anesthesia Induced Hypotension. MBP = mean blood pressure. HR = heart rate. Values are mean ± standard deviation (SD).

Table III. Comparison of preoperative subclavian/infraclavicular axillary vein ultrasound measurements in patients who developed SAIH and patients who did not.

	SAIH (+) n=53	SAIH (-) n=29	*p*
dSCV-AVinspiration-spontaneous breathing (cm)	0.51±0.23	0.50±0.25	<0.830
dSCV-AVexpiration-spontaneous breathing (cm)	0.90±0.21	0.89±0.22	<0.887
dSCV-AVinspiration-deep inspiration (cm)	0.29±0.13	0.33±0.16	<0.187
dSCV-AVexpiration- deep inspiration (cm)	0.85±0.21	0.87±0.24	<0.620
CI of SCV-AVspontaneous breathing (%)	44.25±19.03	44.37±23.48	<0.979
CI of SCV-AVdeep inspiration (%)	64.62±15.15	61.54±15.00	<0.380

SAIH (+) = Developed Spinal Anesthesia Induced Hypotension. SAIH (-) = Not developed Spinal Anesthesia Induced Hypotension. dSCV-AV = Diameter of the subclavian vein or infraclavicular axillary vein. CI of SCV-AV = Collapsibility index of the subclavian vein or infraclavicular axillary vein. Values are mean ± standard deviation (SD).

on the other hand, is affected to a larger extent by the position. In fact, 0° supine is the position where the correlation between SCV and IVC is the weakest, whereas the 45° sitting position is where the correlation is the strongest. Therefore, in evaluating the relative intravascular volume with SCV, the semi-seated position between 30° and 45° is reported to be the ideal position. Using this ideal position may not be extremely suitable for maintaining the hemodynamics of pregnant women because the 15° left lateral position is recommended to prevent hypotension due to aortocaval compression in pregnant women. In the present study, ultrasonographic measurements were performed in this position, and the 30°-45° semi-seated position was not preferred.

In the literature, SCV has not yet been evaluated in studies to predict SAIH, and IVC has been the focus. Ceruti et al[9] measured the IVC collapsibility index before spinal anesthesia and reported no correlation between the decrease in mean blood pressure after spinal anesthesia and the IVC collapsibility index. In another study[12], IVC was evaluated in both the supine position and 15° left tilt position in 40 pregnant women, and the IVC collapsibility index was reported not to be a predictor of SAIH. In these studies, the IVC collapsibility index was evaluated only during normal

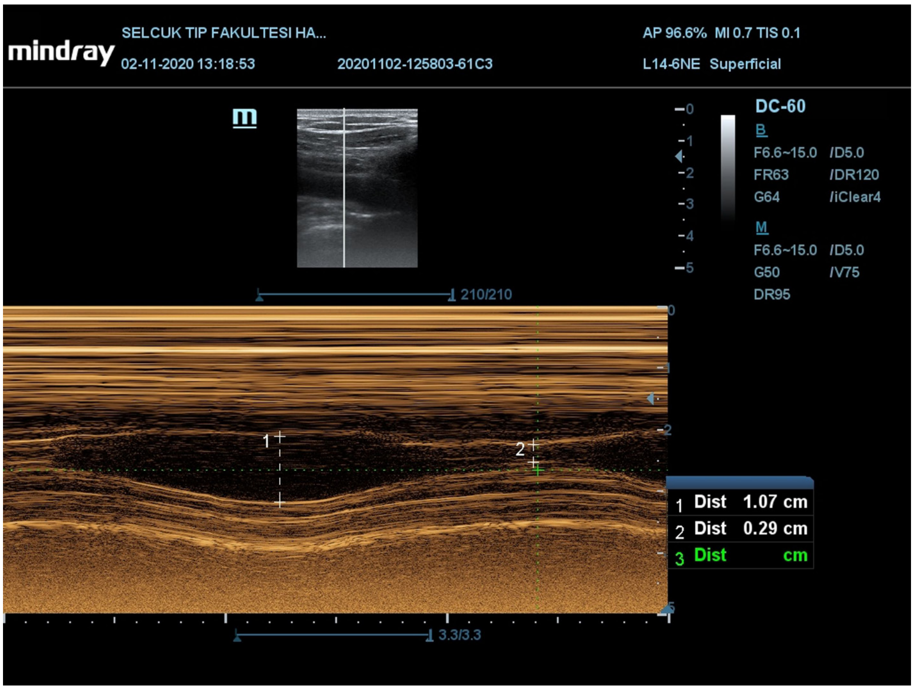

Figure 2. Ultrasonographic measurements during deep inspiration.

breathing, and deep inspirium was not evaluated. In the present study, measurements were made in both normal breathing and deep inspirium. The physiological mechanism underlying this evaluation is that the intrathoracic pressure is negative during breathing, thereby increasing venous return to the heart. Thus, increased blood flow to the heart from central veins such as the IVC and superior vena cava causes these great veins to collapse. We hypothesized that deep inspiration would increase this collapse state; therefore, we evaluated its ability to predict the decrease in the mean arterial pressure[19]. However, no correlation was found between the SCV-AV collapsibility index and SAIH during deep inspirium. This may be due to the simultaneous loading of large amounts of fluid with spinal anesthesia.

Patients with a high collapsibility (i.e., IVC collapsibility index >50-70%), are more likely to be hypovolemic. In hypovolemia, the cut-off value for the collapsibility index is >50% for IVC compared with >39% for SCV[11]. Similarly, the cut-off value for the SCV collapsibility index for hypovolemia was reported as >40% by Kent et al[8] and >39% by Munir et al[20]. In our study, the collapsibility index was found to be much higher. There may be several reasons for this; the change in vascular tone balance due to the increase in prostaglandin and nitric oxide synthesis, which have vasodilator properties, in pregnant women may have caused an increase in the collapsibility index[12]. Another reason for the high collapsibility rate in the present study may be venous pooling due to aortocaval compression and the associated low preload. Although the patients were placed in a 15° left tilt position to prevent supine hypotension, this position may have been insufficient to prevent aortocaval compression. A magnetic resonance imaging study comparing 15° and 30° left tilt positions reported that 30° was more effective than 15° in eliminating the compression of vena cava[21].

While basal MBP was found to be significantly associated with SAIH in the present study, there was no significant correlation between basal HR and SAIH. There are contradicting views on this subject in the literature; while preoperative basal HR and MBP are reported as predictors of SAIH in several studies[22,23], other studies[24,25] state the opposite.

Choi et al[19] conducted a study on patients undergoing cholecystectomy and reported that SCV could not be adequately imaged in 2.5% of patients. In the present study, this rate was found to be higher (8.8%). Larger breasts and increased adipose tissue in pregnant women may have negatively affected the image quality. At the same time, image loss occurred more frequently during the deep inspirium stage, which caused the vein to become excessively collapsed. This can be considered an indication that patients were hypovolemic.

Limitations

Our study has some limitations. SCV-AV measurement was not performed again in the post-spinal period to compare the pre- and post-spinal results. However, because we needed to focus on hypotension after spinal anesthesia and wished to avoid more confounding factors (patient's position, abdominal pressure when delivering the baby, and removal of the compression on the vena cava with birth), we did not measure post-spinal SCV-AV.

Conclusions

Preoperative SCV-AV collapsibility index cannot be used to predict SAIH in pregnant women undergoing elective cesarean section. This is the first study in the literature that evaluated the SCV-AV collapsibility index in pregnant women. Further studies are required to determine the SCV collapsibility index specific to pregnant women.

Conflict of Interest
The authors declare that they have no conflict of interests.

Informed Consent
Written informed consent was obtained from the study participants.

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Ethics Approval
This study was conducted in accordance with the principles of the Declaration of Helsinki. Ethics Committee Approval was obtained from the Selçuk University Local Ethics Committee (2020/426).

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Authors' Contributions

Emine Aslanlar: concept, design, supervision, data collection, literature search, writing manuscript, critical review, analysis and interpretation, and resources. Mehmet Sargin: concept, design, critical review, materials and editing. Durmuş Ali Aslanlar: analysis and interpretation, manuscript writing, Özkan Önal: design, supervision, critical review, and editing.

ORCID ID

Emine Aslanlar: 0000-0003-3849-9137
Mehmet Sargın: 0000-0002-6574-273X
Durmuş Ali Aslanlar: 0000-0002-6932-2767
Özkan Önal: 0000-0002-5574-1901

Data Availability

Data information can be obtained from the author upon request.

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