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Original Article

Ultrasonographic measurement of the internal jugular vein as a predictor of hypotension following the induction of anesthesia

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Abstract: Purpose: The aim of this study was to investigate the reliability of preanesthetic ultrasound measurements of the internal jugular vein (IJV) in predicting hypotension after the induction of general anesthesia. Methods: A total of 40 patients who underwent elective surgery under general anesthesia were enrolled in this prospective study. Before the induction of anesthesia, sonographic measurements of the IJV were performed both in the supine and Trendelenburg positions. The blood pressure values were measured every minute after the induction. The patients were then classified into hypotension and non-hypotension groups. The association between the sonographic measurements and the postinduction hypotension were analyzed. Results: Twenty-four (60%) patients developed postinduction hypotension. In a univariate analysis, the max (P=0.007) and min (P=0.20) IJV diameters in the supine position, the max IJV diameter (P=0.027), and the collapsibility index (P=0.029) in the Trendelenburg position were significantly different between the groups. In a logistic regression analysis, the collapsibility index in the Trendelenburg position was found to be an independent predictor of postinduction hypotension. An ROC curve analysis showed that the collapsibility index in the Trendelenburg position had a sensitivity of 62% and a specificity of 62% to predict postinduction hypotension at a cut-off point less than 19.9%. Conclusion: The collapsibility index of IJV in the Trendelenburg position seems to be an alternative predictor of postinduction hypotension.

Keywords: Induction of anesthesia, internal jugular vein, postinduction hypotension, ultrasonography

Introduction

Hypotension following the induction of anesthesia is common in routine practice. Although postinduction hypotension is most often mild or transient, it is an independent risk factor for the development of serious complications such as ischemic stroke, acute myocardial infarction, heart failure, acute kidney failure, prolonged hospitalization, and increased postoperative mortality, especially when severe or prolonged [1-5]. This condition usually depends on vasodilation and the depression of cardiac functions caused by anesthetic drugs administered during induction; however, it has more clinical significance in hypovolemic patients [1, 6, 7]. Therefore, assessing the intravascular volume before anesthesia plays a key role in preventing or minimizing such hypotensive events.

Although central venous catheterization is an effective method for predicting intravascular volume status, its invasiveness and possible serious complications limit its wide use in routine anesthesia practice. In recent years, the use of ultrasonography has gained popularity for its ability to determine intravascular volume status. In this line, the effectiveness of sonographic measurements of the inferior vena cave (IVC) has been reported in previous studies [9-12]. More recently, sonographic evaluation of the internal jugular vein (IJV), which is easier and shorter than IVC sonography, has been shown to be effective in the prediction of intravascular volume [8]. To our knowledge, there is only one study investigating the effectiveness of IJV sonography in predicting hypotension after the induction of general anesthesia [13]. However, the collapsibility index, defined as the change in IJV diameter associated with the respiratory cycle, has not been studied yet.

In this work, we aimed to investigate the reliability of preanesthetic ultrasound measurements of the IJV, including the collapsibility index, in predicting hypotension after the induction of general anesthesia.

Materials and methods

General data

This prospective study was approved by the Institutional Ethics Committee (permit no/date: 42/10.12.2019). Forty patients who underwent elective surgery under general anesthesia at Osmangazi University Hospital were included in the study. The patients were preoperatively informed about all the steps of the procedures, and their written informed consent forms were taken. Patient characteristics including age, gender, and their American Society of Anesthesiologist (ASA) scores, the procedural data, the anesthetic techniques, and the perioperative complications related to anesthesia were recorded. The exclusion criteria included being under 18 years old, ASA scores of 3-4, having any significant hepatic, renal, cardiovascular, or respiratory disease, the presence of a left ventricular ejection fraction less than 40%, and an allergy to the study medications.

Anesthesia management

In all the patients, the fasting times were set as at least eight hours before surgery. The patients did not have any premedication. The standard monitoring included noninvasive blood pressure, a five-lead electrocardiogram (ECG), pulse oximetry, end-tidal carbon dioxide, and minimum alveolar concentration (MAC) values. In a supine position, the baseline systolic (SBP), diastolic (DBP) and mean arterial blood (MAP) pressures, and heart rate (HR) were measured non-invasively. A saline infusion (10 ml/kg/h) was started by opening the appropriate vascular access. Subsequently, an ultrasonographic examination was performed. After the sonographic procedure, anesthesia was started immediately by another anesthesiologist. The induction of anesthesia was performed using intravenous (IV) remifentanil (0.5 mcg/kg) with lidocaine (0.5 mg/kg) plus thiopental sodium (4-6 mg/kg) in 4 L/min air (50%) and oxygen (50%). A neuromuscular blocker (rocuronium, 0.6 mg/kg) was given to all patients. After adequate neuromuscular blockade, the patients were entubated 3 minutes after anesthesia induction. Blood pressure and HR were collected just before the induction (i.e. baseline) and then after the induction but before the surgical incision. The blood pressure and HR values were measured every minute during this period. A MAP less than 65 mmHg or more than a 20% decrease compared to the baseline level was defined as postinduction hypotension [14]. The patients were then classified into the hypotension or non-hypotension group, according to this definition. Ephedrine (5 mg) was administered to the patient when the MAP dropped below 60 mmHg, and atropine (0.5 mg) was given when the HR dropped below 50 per minute. The anesthesia was maintained using remifentanil infusion (0.05-0.1 mcg/kg with titration) plus inhalation sevoflurane (2-3%) in 4 L/min air (50%) and oxygen (50%). After the surgical procedure, the patients were followed up in the recovery unit for at least 30 minutes. No hemodynamic data following the start of the surgery was included in the data analysis.

Sonographic examinations

All patients were spontaneously breathing during the sonographic examinations. The measurements were performed using a single ultrasound machine operated by a single senior anesthesiologist. A clear transverse view of the right IJV was recorded for fifteen seconds, with a linear ultrasound probe placed horizontally to the right of the middle level of the thyroid cartilage with minimal pressure. Variations in the IJV diameter with respiration were assessed using M-mode imaging (**Figure 1A**, **1B**). The following three values were recorded: 1. Maximum (max) and minimum (min) IJV diameter values (at the end of the expirium and inspirium, respectively); 2. Collapsibility index (%) = [(max IJV diameter - min IJV diameter)/max IJV diameter] × 100; 3. max IJV area.

Thereafter, the position was changed to the Trendelenburg position (10^0), and similar sonographic measurements were again performed. In addition, the following values were calculated using data obtained from both patient positions (supine and Trendelenburg): 1. Change in the IJV diameter (%): [(Trendelenburg max IJV diameter-Supin max IJV diameter)/Trendelenburg max IJV diameter]; 2. Change in the IJV area (%): [(Trendelenburg max IJV area-Supin max IJV area)/Trendelenburg max IJV area].

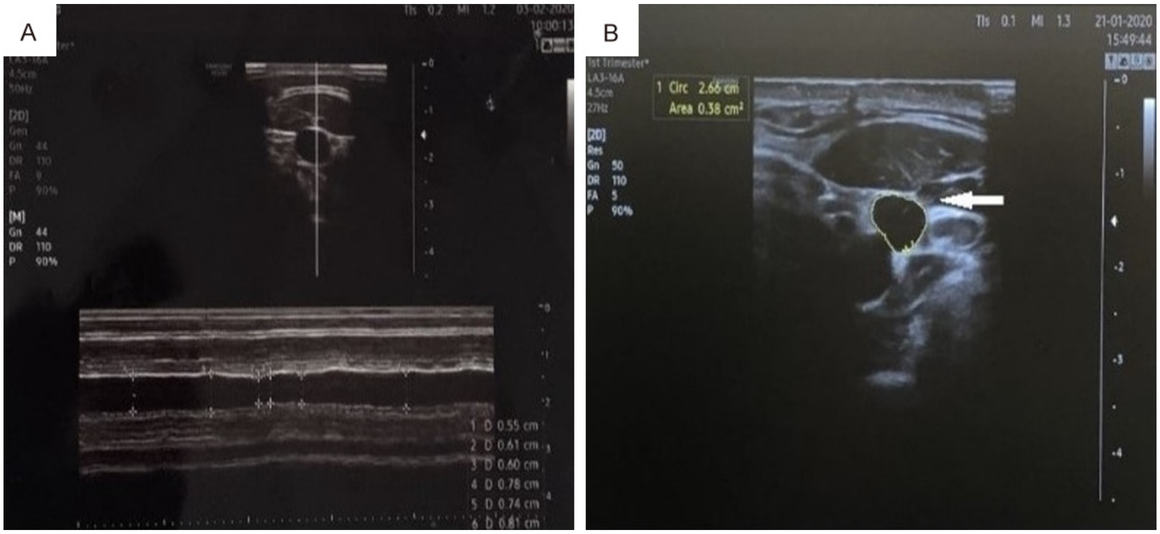

Figure 1. Sonographic M-mode images of (A) maximum and minimum IJV diameter values during the respiratory cycle (at the end of expirium and inspirium, respectively) (B) maximum IJV area (white arrow).

Statistical analysis

No previous study has investigated the IJV collapsibility index for the determination of postinduction hypotension. Therefore, a similar study investigating the efficacy of the IVC collapsibility index was taken as a reference study for calculating the sample size [10]. Based on the power analysis using a two-sample t-test, a sample size of 11 patients per group was required to achieve a power of 96% with a significant level of 5% for evaluating the differences between the groups with or without postinduction hypotension.

The data analysis was done using SPSS 23.0 software (Chicago, Il., USA). The descriptive analyses are presented as the number/percentage or mean/percentage, respectively for the categorical and continuous variables. Mann Whitney U tests, Fisher's exact tests, and chi-square tests were used to evaluate the differences among the groups. In addition, receiver operating characteristic (ROC) curves were used to assess the diagnostic capabilities of the ultrasonographic IJV measurements. A *P* value less than 0.05 was accepted as significant.

Results

Baseline patient characteristics

A total of 40 patients (30 females and 10 males) with a mean age of 39.7 (range, 20-68) years old were enrolled in the study. The mean weight and height were 69.4±12.9 kg and 166±7.9, respectively. The mean BMI of the whole study cohort was 25±4.4 kgm^{-2} (18.9-35.4). Preoperatively, the patients were classified as ASA 1 (19, 47.5%) or ASA 2 (21, 52.5%). The mean fasting time was 12.9±1.3 hours (10-15).

After the administration of the induction of anesthesia, 24 (60%) patients developed significant hypotension. The baseline characteristics were then compared between the hypotensive and non-hypotensive groups (**Table 1**). A significant difference in age was found between the groups, indicating that patients who had developed post spinal hypotension were older (P=0.006). There were also significant differences in BMI (P=0.029), SBP (P<0.01) and MAP (P<0.007) between the two groups.

Ultrasonographic measurements of IJV

The max/min IJV diameters and max/min IJV areas were measured in the supine and Trendelenburg positions. Changes in IJV diameters and areas according to the posture were also measured. Thereafter, all the ultrasonographic measurements were compared between the hypotensive and non-hypotensive groups (**Table 2**). The max (P=0.007) and min (P=0.20) IJV diameters in the supine position, the max IJV diameter (P=0.027), and the collapsibility index (P=0.029) in the Trendelenburg

Table 1. A comparison of the baseline characteristics in the hypotensive and non-hypotensive groups

	Hypotensive group (n=24)	Non-hypotensive group (n=16)	P
Age (y)	44.6±14.9 (20-68)	32.5±8.7 (21-52)	0.006
Gender (F/M)	20 (83.3%)/4 (16.7%)	10 (62.5%)/6 (37.5%)	0.159
Weight (kg)	71.7±13.5 (50-98)	66±11.5 (47-83)	0.345
Height (cm)	165±7.6 (150-182)	167.3±8.4 (153-184)	0.370
BMI (kg/cm^2)	26.1±4.5 (19.1-34.8)	23.4±3.9 (18.9-35.4)	0.029
Fasting time (h)	12.8±1.5 (10-15)	13.1±1.1 (12-15)	0.633
Baseline BP (mmHg)			
Systolic	132.1±11.8 (96-151)	119.3±9 (105-143)	<0.01
Diastolic	78.5±11.2 (51-101)	72.5±9.9 (59-90)	0.095
Mean	97.5±11.4 (71-119)	89.5±8.1 (80-106)	0.007
Baseline HR (bpm)	85.6±19.7 (54-133)	82.1±11.1 (64-103)	0.795
ASA (ASA 1/ASA 2)	8 (33.3)/16 (66.7%)	11 (68.8%)/5 (31.2%)	0.079

Data are presented as n (%) for gender and ASA; mean ± SD for other variables. y: year, F: female, M: male, kg: kilogram, cm: centimeter, h: hour.

Table 2. A comparison of the sonographic data in the hypotensive and non-hypotensive groups

	Hypotensive group (n=24)	Non-hypotensive group (n=16)	P
Supine position			
maxIJV diameter (mm)	8.7±2.3 (5.3-13)	6.5±1.8 (3.3-10.3)	0.007
minIJV diameter (mm)	6.3±2.1 (3.5-10.9)	4.6±1.5 (2.4-8.5)	0.020
maxIJV area (mm^2)	78.6±32.9 (27-145)	64.3±23.1 (32-99)	0.304
collapsibility index (%)	28.6±12.8 (9.5-57.1)	28.7±9.6 (17.4-52.8)	0.859
Trendelenburg position			
maxIJV diameter (mm)	10.4±2.6 (6-15.7)	8.4±1.9 (3.8-13.9)	0.027
minIJV diameter (mm)	7.5±2.1 (3.7-11)	6.8±1.6 (3-11.1)	0.149
maxIJV area (mm^2)	106.1±44.1 (48-191)	84.9±29.1 (44-143)	0.120
collapsibility index (%)	26.8±11.1 (9.6-55.9)	19.5±6.5 (12.7-34.4)	0.029
Change in IJV diameter (%)	15.9±11.3 (1.1-43.2)	23.3±13.9 (4-48.7)	0.126
Change in IJV area (%)	24.6±15 (3-60.2)	21.8±18.8 (1-59.4)	0.374

IJV: internal jugular vein, mm: millimeter.

Table 3. A multiple logistic regression analysis of the postinduction hypotension

	β (SE)	Exp (β)	95% CI	P
maxIJV diameter (supine)	0.295 (0.65)	1.343	0.37-4.79	0.650
minIJV diameter (supine)	0.624 (0.60)	1.867	0.57-6.06	0.299
maxIJV diameter (Trendelenburg)	-0.287 (0.34)	0.751	0.38-1.46	0.399
Collapsibility index (Trendelenburg)	0.145 (0.06)	1.156	1.01-1.31	0.028
Constant	-5.797 (2.19)			

SE = Standard error, Exp (β) = Odds ratio, CI = Confidence interval.

position were found to be significantly different between the groups.

The four sonographic variables (max and min IJV diameters in the supine position, the max IJV diameter and the collapsibility index in the Trendelenburg position) which were statistically significant in the univariate analysis then underwent a multiple logistic regression analysis (**Table 3**). The collapsibility index in the Trendelenburg position was found to be an independent predictor of postinduction hypotension (P= 0.028).

An ROC curve analysis was used to evaluate the diagnostic ability of the collapsibility index in the Trendelenburg position for predicting the postinduction hypotension. The collapsibility index in the Trendelenburg position had a sensitivity of 62% and a specificity of 62% to predict the postinduction hypotension at a cutoff point of less than 19.9%. The AUC was 0.704 (**Figure 2**).

Discussion

Despite various preventive methods such as prophylactic intravenous fluid replacement and vasopressor administration, postinduction hypotension remains an important challenge in anesthesia management due to its potential severe consequences [15, 16]. This condition is not rare and has an incidence ranging from 8% to 60%, possibly depending on the variable

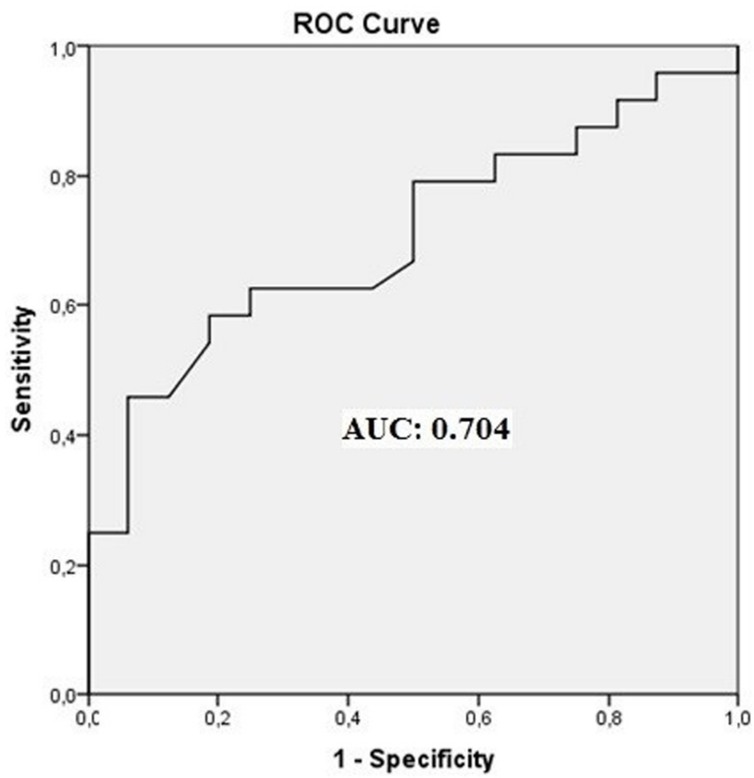

Figure 2. Receiver operating characteristic (ROC) curve analysis of the ability of the IJV collapsibility index in the Trendelenburg position as a predictor of postinduction hypotension. The area under the ROC curve (AUC) is 0.704.

definitions [17, 18]. In this respect, the relatively higher incidence in our study was generally consistent with the literature. In the present study, the patients who developed postinduction hypotension were statistically older than those in the non-hypotensive group, similar to what's reported in the literature [6]. In addition to older age, higher BMI and baseline blood pressure values were found to be associated with hypotension after the induction of anesthesia. Considering that body weight and tendency to high blood pressure increase with age, we think that this kind of relationship is an expected situation.

Because underlying hypovolemia is an important causative factor for the occurrence of induction-related hypotension, the preanesthetic determination of this situation is of great importance to prevent potential complications. Most of the preanesthetic patients have latent hypovolemia, described as a clinical entity with a decrease in circulating blood volume without significant hemodynamic changes or organ dysfunction [19]. At this point, several studies have demonstrated the utility of sonographic measurements of IJV in predicting fluid responsiveness, central venous pressure, and intravascular volume [12, 20, 21]. In a study conducted on both ventilated and non-ventilated patients, both minimum and maximum IJV diameters showed moderate correlation with central venous pressure [20]. In another study, an IJV aspect ratio less than 0.75 was predictive of central venous pressure in spontaneously breathing ICU patients [22]. On the other hand, Okamura et al. found in their work that there were no significant differences in the IJV diameters between patients who developed hypotension after the induction of anesthesia and those without postinduction hypotension [13]. It should be stated here that the patient characteristics were different in the two studies. The patients in Okamura's study were relatively healthy, with the exception of having abnormal central venous pressures, similar to our study group. However, we found that the maximum IJV diameters in both positions were significantly larger in the hypotensive patients compared with the non-hypotensive patients. To us, this finding was compatible with the characteristics of the patients with hypotension since they were older and had higher BMI than non-hypotensive patients. However, we suggest that the lack of significance differences in the logistic regression analysis may limit the use of IJV diameters even though they were statistically significant in the univariate analysis.

The maximum area of IJV at the end of the expirium is also another sonographic parameter evaluated in the previous studies. In a study conducted on ICU patients, a 0.91 cm^2 cut-off value of the IJV area was found to predict a central venous pressure ≤5 mmHg with high sensitivity [20]. In our study, the IJV areas in the two positions were larger in the hypotensive patients than in the non-hypotensive group, without any significant differences. This finding is consistent with the finding reported in the study by Okamura et al. [14]. We suggested that this might be related to the relatively good health of the study group. That's why, an increased sympathetic tone due to increased anxiety and mental tension might have caused less IJV area. Increased sympathetic tonus also might have prevented hypotension after the induction of anesthesia by increasing preload. This is because all the patients in our and Okamura's studies underwent elective surgery and had ASA 1 or ASA 2 scores, indicating relatively normal intravascular volume. Hence, there might be no significant difference in the IJV area between the two groups. In addition, the relatively small number of patients may have influenced the statistical results.

The most important difference of the present study from the study by Okumura, which is the only study evaluating the utility of IJV ultrasonography for post-induction hypotension, is the determination of the predictive value of the collapsibility index. As is known, the collapsibility index has been shown as a reliable indicator of intravascular volume status in recent studies [10, 23, 24]. Haliloğlu et al. found that the IJV collapsibility index, a reasonable adjunct to the IVC collapsibility index, is a precise and easily-acquired parameter of fluid responsiveness in patients with sepsis [25]. In another study, the IJV collapsibility index was recommended as a first-line approach for the bedside non-invasive assessment of central venous pressure and fluid status in critical ICU patients [26]. Our study is the first showing the IJV collapsibility index in the Trendelenburg position is an independent risk factor for the occurrence of post-induction hypotension, with a cut-off point less than 19.9%. The cut-off value in our study was lower than those reported from other studies. For instance, Haliloğlu et al. reported a cut-off value of 36% in their study. Similarly, an IJV collapsibility index cut-off value greater than 39% was shown to be strongly associated with overall patient hypovolemia [27]. However, it should be noted that those studies were conducted on critically ill patients, meaning that there were significant differences in the patient health statuses.

There are several limitations to this study. First, the fact that it was carried out in a single center may limit the generalizability of the results. Second, a relatively, not statistically, small number of patient groups may be another limitation, which makes it difficult to interpret the subgroup findings. Third, the study population consisted of participants with ASA 1 or ASA 2 scores. Therefore, the results cannot be generalized to other patient groups with poorer health statuses. However, its prospective nature and the standard anesthetic and surgical protocols were the strengths of this study. We also believe that this study may provide a significant scientific contribution to the literature because it's the first study to demonstrate the IJV collapsibility index for predicting induction-related hypotension.

Conclusion

Maximum IJV diameters in the supine and Trendelenburg positions are higher in patients who developed hypotension after the induction of anesthesia in comparison to those without postinduction hypotension. Despite the lower sensitivity and specificity rates, the IJV collapsibility index in the Trendelenburg position seems to be an alternative predictor of postinduction hypotension.

Disclosure of conflict of interest

None.

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