



# Pre-anesthetic ultrasonographic assessment of the internal jugular vein for prediction of hypotension during the induction of general anesthesia

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## Abstract

**Purpose** Severe hypotension caused by anesthetic administration for anesthesia induction, which might cause ischemic stroke, myocardial injury, acute kidney injury and postoperative mortality, should be prevented. Anesthesiologists are familiar with ultrasound examination of the internal jugular vein (IJV). This study aimed to clarify whether ultrasonographic IJV evaluation just before induction could predict the occurrence of such hypotension.

**Methods** Adult patients undergoing surgery under general anesthesia were enrolled after excluding patients with cardiovascular disease or ASA-PS  $\geq$  III. Ultrasonographic IJV images were recorded in both the supine and 10° Trendelenburg positions immediately before induction. Using these images, IJV area (IJV-A), diameter and change rate with posture were measured. Hypotension during induction was defined as mean BP  $<$  60 mmHg or  $>$  30% decrease from baseline.

**Results** Hypotension during induction was observed in 37 of 82 patients. IJV-A in the Trendelenburg position was  $2.02 \pm 0.86$  and  $1.72 \pm 0.68$  in the hypotensive and non-hypotensive groups, respectively ( $P = 0.08$ ). Logistic regression analysis performed using age, use of calcium antagonists, angiotensin converting enzyme inhibitors/angiotensin receptor blockers, baseline mean BP and IJV-A in the Trendelenburg position as variables showed that IJV-A in the Trendelenburg position was an independent predictor of hypotension, with an adjusted odds ratio of 3.11 (95% CI 1.07–9.03,  $P = 0.04$ ). Area under the curve was 0.595 (95% CI 0.469–0.722) for IJV-A in the Trendelenburg position.

**Conclusion** IJV-A in the Trendelenburg position was an independent predictor of hypotension during induction. Further study is required to examine the diagnostic accuracy of IJV-A as a predictor for hypotension during induction.

**Keywords** Internal jugular vein · Ultrasonographic measurement · Hypotension · General anesthesia induction

## Introduction

Anesthetic administration at the time of general anesthesia induction causes vasodilation and/or suppression of cardiac function, which can lead to hypotension [1, 2]. Severe hypotension might be associated with hypoperfusion and ischemia of vital organs, resulting in postoperative organ injury, such as ischemic stroke, myocardial injury and acute

kidney injury, and postoperative mortality [3–7]. Hence, anesthesiologists should pay attention to the development of severe hypotension during general anesthesia induction. Underlying hypovolemia is known to be a major factor responsible for severe hypotension during anesthesia induction [8–10]. Therefore, assessment of intravascular volume deficit before anesthesia might help in predicting a critical decrease in blood pressure (BP) during induction, so that it can be preempted.

Recently, the usefulness of point-of-care ultrasonographic examination, performed by anesthesiologists in real time, for perioperative management has been reported [11–13]. Ultrasonographic studies have established the utility of measuring the inferior vena cava (IVC) or internal jugular vein (IJV) for evaluating intravascular volume status [14]. In particular, IVC diameter and collapsibility, obtained from ultrasonographic measurement, have been demonstrated to

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be predictors of hypotension after anesthetic administration [8, 15].

On the other hand, the utility of ultrasonographic evaluation of the IJV in non-invasive estimation of central venous pressure (CVP) has been previously reported [16–18]. Some studies have reported that intravascular volume or fluid responsiveness can be estimated using ultrasound IJV studies [14, 19]. In shock patients, the passive leg raising (PLR) test has been shown to be useful in assessing intravascular volume deficit or fluid responsiveness [20]. Similar to PLR, change in the IJV size with change in posture from the supine to Trendelenburg position might reflect intravascular volume status.

In addition, anesthesiologists are well-versed with IJV-imaging during ultrasound-guided central venous catheterization. Compared with IVC measurement by ultrasonography, IJV assessment is much simpler. Therefore, if preoperative ultrasound evaluation of the IJV can be used to predict the severe decrease in BP with induction of general anesthesia, it can provide very useful information for patients undergoing general anesthesia. However, only few studies have examined whether the status of the IJV can be used to predict the decrease in BP resulting from anesthetic infusion.

This study was conducted to clarify whether ultrasonographic IJV assessment in the supine and/or Trendelenburg positions just before induction of general anesthesia can predict the hypotension resulting from anesthetic administration. We hypothesized that a smaller IJV size or greater change in IJV size when changing from the supine to Trendelenburg position is reflective of inadequate intravascular volume, and might result in a significant fall in BP with anesthesia induction.

## Methods

### Materials

This study was approved by the Ethics Committee of Yokohama City University (Yokohama, Japan) (ID: B161000001) and written informed consent was obtained from each patient for study participation. The trial was registered with the University Hospital Medical Information Network Clinical Trials Registry (ID: UMIN000025130) on December 2, 2016.

This prospective single center study was performed between December 14, 2016 and August 14, 2018. Adult patients who underwent general anesthesia for elective surgery at Yokohama City University Hospital were enrolled. Patients with a history of heart failure, moderate or severe valvular heart disease, aortic disease, peripheral arterial disease, left ventricular ejection fraction less than 40% or American Society of Anesthesiologists' Physical Status (ASA-PS) III or worse were excluded.

## Methods

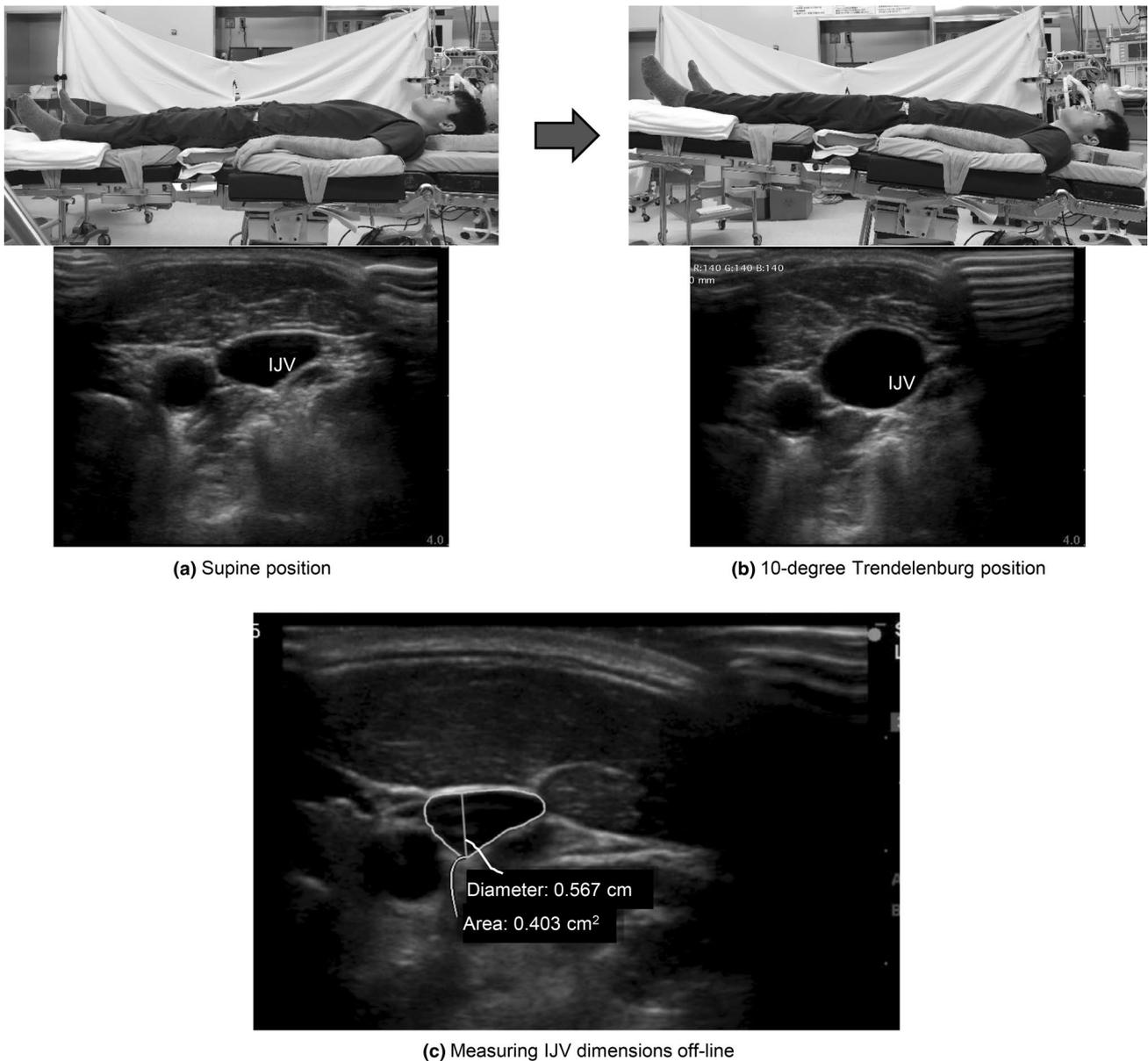
After patients entered the operating room, standard monitoring was performed. Baseline values of BP and heart rate (HR) in the supine position were measured non-invasively. The ultrasound probe (Linear transducer 6–15 MHz FUJIFILM Co., Tokyo, Japan) was placed horizontally to the right of the middle level of the thyroid cartilage with minimum pressure. Sufficient gel was applied to the probe so as not to push the IJV during the procedure. A clear and true transverse view of the right IJV was recorded for 15 s using SonoSite M-Turbo, SonoSite Edge or SonoSite Edge II (FUJIFILM Co., Tokyo, Japan). Then, after changing the patient's position to the 10° Trendelenburg position, similar ultrasonographic measurements were again performed (Fig. 1) [21]. During the measurements, respiration of each patient was spontaneous breathing. All the IJV measurements were performed in the same level, which is the right of the middle level of the thyroid cartilage, as described above. All measurements were performed by a single senior anesthesiologist.

After the pre-anesthetic ultrasonographic examinations, general anesthesia was induced with 1.5 mg/kg propofol and 3 mcg/kg fentanyl, followed by rocuronium (0.6 mg/kg) to facilitate endotracheal intubation. The dose of fentanyl was calculated using ideal body weight and those of propofol and rocuronium were calculated using actual body weight. Mask ventilation was started when spontaneous breathing stopped due to propofol administration. BP and HR were measured every minute for 5 min after propofol administration.

After pre-intubation measurements for 5 min, the trachea was intubated. The infusion rate of crystalloid fluid was fixed at approximately 10 mL/h per actual body weight during the study period. Ephedrine (4 mg) or phenylephrine (0.05 or 0.1 mg) was administered when systolic BP was 80 mmHg or less. Tidal volume and respiratory rate during mask ventilation were determined by the attending anesthesiologist.

Mean BP less than 60 mmHg or greater than 30% decrease from baseline before intubation was defined as significant hypotension, and patients who developed hypotension were classified as the hypotensive group [8]. Data collected from the patients' medical and anesthesia records and ultrasonographic IJV measurements were compared between the hypotensive group and the group that did not develop hypotension (non-hypotensive group).

Using the recorded ultrasonographic images, the maximum area of the IJV (IJV-A) and maximum IJV diameter (IJV-D) in the supine and Trendelenburg positions were measured off-line using OsiriX MD software (Pixmeo Sarl Co., Bernex, Switzerland). We adopted the value that the area or diameter was biggest during the measurement for 15 s. The rate of change in IJV dimensions with



$$\text{IJV change rate with posture} = \frac{\text{IJV measurement in Trendelenburg position} - \text{IJV measurement in supine position}}{\text{IJV measurement in Trendelenburg position}}$$

**Fig. 1** Patient's position and ultrasonographic images in the supine position (a) and 10° Trendelenburg position (b). Measuring internal jugular vein dimensions off-line (c). Using the recorded ultrasonographic images, the maximum area and diameter of the IJV in the

supine and Trendelenburg positions were measured off-line using OsiriX MD software (Pixmeo Sarl Co., Bernex, Switzerland). *IJV* internal jugular vein

change in posture (IJV-A change and IJV-D change) was defined as the value obtained by dividing the difference between the values in the Trendelenburg and supine positions by the value in the Trendelenburg position (Fig. 1). Additionally, data on preoperative medications [calcium-channel antagonists (CA), angiotensin converting enzyme inhibitors or angiotensin receptor blockers (ACE-I/ARB), Beta adrenergic receptor blockers, and diuretics] were

obtained from the patients' medical records, since hypotension is common after general anesthesia induction in patients who routinely use CAs or ACE-I/ARBs [22–24].

### Sample size estimation

In a previous study [8] that maximum IVC diameter and IVC collapsibility index, assessed using preoperative

ultrasonography, could predict hypotension after the induction of general anesthesia, hypotension was observed in 46.7% of patients, and the area under the curve (AUC) in receiver operating characteristics (ROC) curve analysis of maximum IVC diameter was 0.76 and AUC of the ROC curve of IVC collapsibility index was 0.9. Based on these results, assuming an AUC of the ROC curve of 0.7 and calculating sample size with a power of 90%, 82 patients were deemed necessary as participants in this study. Hence, considering potential failure of ultrasonographic measurements, 100 patients were included in this study.

## Statistical analysis

All statistical analyses were performed with EZR software (Saitama Medical Center, Jichi Medical University, Saitama, Japan) [25], which is a graphical user interface for R (The R Foundation for Statistical Computing, Vienna, Austria). Results were expressed as mean  $\pm$  standard deviation, median (interquartile range) or numbers (percentage).

Student's *T* test for normally distributed parametric data, Mann-Whitney *U* test for continuous variables without normal distribution and Pearson's Chi-square test for categorical variables were used for analysis. Multiple logistic regression analysis was performed using age, CA usage, ACE-I/ARB usage and mean BP before induction (baseline mean BP) as variables [22–24, 26]. In addition, variables for which the *P* value was less than 0.1 were simultaneously adopted, and

adjusted odds ratios were calculated. To evaluate the diagnostic capability of ultrasonographic IJV measurements, the ROC curve was drawn and the cut off value was calculated. The gray zone was the third partition which could not decide positive or negative [27]. It was defined as the range between the value less than 90% sensitivity and one less than 90% specificity. In fact, it indicated the inconclusive range of the values of ultrasonographic IJV measurements.

*P* values less than 0.05 were considered indicative of statistically significant differences.

## Results

Eighty-two of the 100 patients were analyzed. Eleven patients were excluded because of inappropriate ultrasonographic data. In three patients, the general anesthetic induction method was changed, two patients could not be placed in the Trendelenburg position and two were excluded due to protocol violation.

Thirty-seven (45.1%) of the 82 patients developed significant hypotension after anesthetic administration. Table 1 shows the patient's characteristics, BP and HR before induction in the two groups. Mean patient age was 70 (63–75) years in the hypotensive group and 52 (43–61) years in the non-hypotensive group, indicating that patients in the hypotensive group were significantly older ( $P < 0.01$ ). There were no significant differences in sex, height, weight and body

**Table 1** Patient baseline data

	All patients	Hypotensive group	Non-hypotensive group	<i>P</i> value
<i>n</i> (%)	82	37 (45.1)	45 (54.9)	
Age (years)	61 (49–70)	70 (63–75) <sup>a</sup>	52 (43–61)	<0.01
Sex (female)	46 (56.1%)	21 (56.8%)	25 (55.6%)	1
Height (cm)	161.7 (9.66)	160.1 (10.2)	162.9 (9.08)	0.19
Weight (kg)	62.1 (53.8–70.7)	61.8 (51.8–68.6)	63.8 (53.9–72.2)	0.46
Body mass index (kg/cm <sup>2</sup> )	23.1 (21.0–26.4)	23.1 (20.9–26.2)	23.0 (21.2–26.6)	0.96
Antihypertensive medication				
Calcium-channel antagonist	14 (17.1%)	13 (35.1%) <sup>a</sup>	1 (2.2%)	<0.01
Angiotensin-converting enzyme inhibitor and/or angiotensin-receptor blocker	16 (19.5%)	15 (40.5%) <sup>a</sup>	1 (2.2%)	<0.01
$\beta$ -Adrenoreceptor blocker	5 (6.1%)	3 (8.1%)	2 (4.4%)	0.82
Diuretic	1 (1.2%)	1 (2.7%)	0 (0%)	0.92
Baseline blood pressure (mmHg)				
Systolic	140.4 (19.8)	143.4 (20.8)	138.0 (18.8)	0.22
Diastolic	81.5 (73.0–88.8)	83 (70–88)	81 (73–90)	0.73
Mean	98 (89.3–106)	102 (88–106)	95 (91–106)	0.73
Baseline heart rate (bpm)	70.9 (11.2)	70.8 (9.57)	70.9 (12.5)	0.98

Normally distributed data are presented as mean (standard deviation). Non-normally distributed data are presented as median (interquartile range)

<sup>a</sup>Significant difference compared with the non-hypotensive group

mass index between the two groups. There was a significantly larger number of preoperative CA users in the hypotensive than the non-hypotensive group, at 13 (35.1%) of 37 and 1 (2.2%) of 45 patients, respectively ( $P < 0.01$ ). More patients using ACE-I/ARBs preoperatively were also seen in the hypotensive group [15 (40.5%) of 37 in the hypotensive group and 1 (2.2%) of 45 in the non-hypotensive group ( $P < 0.01$ )]. Beta adrenergic receptor blocker and diuretic usage did not differ between the two groups. There were no significant differences in systolic, diastolic and mean BP and HR before the induction of general anesthesia.

Ultrasonographic IJV measurements are shown in Table 2. Minimum, maximum and mean values (standard deviation) of IJV-A in the entire cohort in the supine position were 0.09, 3.12 and 1.29 (0.68)  $\text{cm}^2$ , respectively, and those in the Trendelenburg position were 0.15, 4.88 and 1.85 (0.78)  $\text{cm}^2$ , respectively. Similarly, minimum, maximum and mean values (standard deviation) of IJV-D in the supine position were 0.23, 1.75 and 0.93 (0.31) cm, respectively, and those in the Trendelenburg position were 0.34, 1.84 and 1.21 (0.27) cm, respectively. Individual differences were observed in the size of the IJV. Six (three in the hypotensive group and three in the non-hypotensive group) had smaller IJV-As in the Trendelenburg position than those of the supine position, and three (all in the non-hypotensive group) had smaller IJV-Ds in the Trendelenburg position than those of the supine position. IJV-A in the Trendelenburg position was 2.02 (0.86)  $\text{cm}^2$  in the hypotensive group and 1.72 (0.68)  $\text{cm}^2$  in the non-hypotensive group, indicating a tendency to be larger in the hypotensive group, although the difference was not significant ( $P = 0.08$ ). There were no significant differences in IJV-A in the supine position, IJV-D in both positions, and changes in IJV-A and IJV-D with change in position.

Multiple logistic regression analysis was performed using age, CA, ACE-I/ARB, baseline mean BP and IJV-A in the

Trendelenburg position as variables. Since the  $P$  value of IJV-A in the Trendelenburg position was less than 0.1 in univariate analysis, IJV-A in the Trendelenburg position was simultaneously adopted as a variable. The adjusted odds ratios are shown in Table 3. IJV-A in the Trendelenburg position was found to be an independent predictor of hypotension with an adjusted odds ratio of 3.11 [95% confidence interval (CI) 1.07–9.03;  $P = 0.04$ ].

The AUC of IJV-A in the Trendelenburg position was 0.595 (95% CI 0.469–0.722), and the cut off value was 1.475  $\text{cm}^2$  (sensitivity: 75.7%, specificity: 44.4%). The AUCs of IJV parameters are shown in Table 4. Considering the AUC of IJV-A in the Trendelenburg position which was an independent predictor as a reference value, it was compared with the AUCs of other IJV parameters. Any AUCs of IJV parameters were not significantly different from the AUC of IJV-A in the Trendelenburg position. The gray zone of IJV-A in the Trendelenburg position was between 0.92 and 2.61  $\text{cm}^2$  and included 74.4% of the patients (Table 4).

**Table 3** Adjusted odds ratios calculated by logistic regression analysis

	Adjusted odds ratio (95% confidence interval)	$P$ value
Age	1.08 (1.02–1.15)	<0.01
Calcium-channel antagonist	11.6 (0.91–146.0)	0.06
Angiotensin-converting enzyme inhibitor and/or angiotensin- receptor blocker	29.3 (2.41–357.0)	<0.01
Baseline mean blood pressure	0.91 (0.85–0.98)	<0.01
IVJ area in the Trendelenburg position	3.11 (1.07–9.03)	0.04

IVJ internal jugular vein

**Table 2** Ultrasonographic data

	All patients ( $n = 82$ )	Hypotensive group ( $n = 37$ )	Non-hypotensive group ( $n = 45$ )	$P$ value
IVJ area				
Supine ( $\text{cm}^2$ )	1.29 (0.68)	1.40 (0.73)	1.21 (0.64)	0.21
Trendelenburg position ( $\text{cm}^2$ )	1.85 (0.78)	2.02 (0.86)	1.72 (0.68)	0.08
Change rate with posture (%)	31.0 (22.2)	33.3 (21.9)	29.2 (22.6)	0.41
IVJ diameter				
Supine (cm)	0.93 (0.31)	0.93 (0.30)	0.94 (0.32)	0.87
Trendelenburg position (cm)	1.21 (0.27)	1.22 (0.26)	1.20 (0.28)	0.74
Change rate with posture (%)	23.6 (15.9)	25.4 (15.1)	22.2 (16.6)	0.37

Data are represented as mean (standard deviation)

There were no significant differences between the hypotensive and non-hypotensive groups in these ultrasonographic data

IVJ internal jugular vein

**Table 4** The areas under the curve in receiver operating characteristics curve analysis and the gray zone

	AUC (95% confidence interval)	<i>P</i> value	Gray zone
<b>IJV area</b>			
Supine	0.595 (0.467–0.722)	0.98	0.33–2.05 cm <sup>2</sup> (81.7%)
Trendelenburg position	0.595 (0.469–0.722)	–	0.92–2.61 cm <sup>2</sup> (74.4%)
Change rate by posture	0.542 (0.416–0.669)	0.59	2.2–58.3% (80.5%)
<b>IJV diameter</b>			
Supine	0.506 (0.378–0.635)	0.1	0.51–1.30 cm (79.3%)
Trendelenburg position	0.548 (0.418–0.678)	0.13	0.88–1.53 cm (80.5%)
Change rate by posture	0.553 (0.427–0.679)	0.67	7.5–42.7% (75.6%)

Considering the AUC of IJV area in the Trendelenburg position which is an independent predictor as a reference value, it was compared with the AUCs of other IJV parameters. *P* values for comparison of the AUC are shown

The percentage of the patients included in the gray zone is shown in parentheses

AUC area under the curve, IJV internal jugular vein

A negative correlation was found between IJV-A in the supine position and change in IJV-A ( $r = -0.58$  95% CI  $-0.71$  to  $-0.42$ ;  $P < 0.01$ ).

## Discussion

This study showed that IJV-A in the Trendelenburg position before the induction of general anesthesia, measured by ultrasonography, is a predictor of hypotension during induction. In contrast to previous studies, an increment in IJV-A in the Trendelenburg position increases the risk of hypotension during induction [16, 17]. However, the diagnostic accuracy was too low to apply the cut off value clinically. Because of the wide gray zones, ultrasonographic IJV measurements might not be clinically important for the predictors of hypotension during induction in our study.

Several reports have described the utility of ultrasonographic IJV measurements in predicting CVP, intravascular volume and fluid responsiveness [14, 16–19]. Prekker et al. reported in 67 spontaneously breathing patients that IJV aspect ratio less than 0.75 was predictive of CVP less than 10 mmHg, although its predictive ability was inferior to that of IVC diameter [17]. Avcil et al. studied 37 non-ventilated and 36 ventilated patients, and found that the maximum and minimum diameters of the IJV measured ultrasonographically showed moderate correlation with CVP, and a maximum IJV diameter of 1.01 cm or less, minimum IJV diameter of 0.71 cm or less and IJV area of 0.91 cm<sup>2</sup> or less predicted a CVP of 5 mmHg or less with high sensitivity [16]. In our study, IJV area in both groups were larger than 1.2 cm<sup>2</sup> in the supine position. Our study participants were relatively healthy and were assumed to have normal CVPs. Nevertheless, about half of the patients developed hypotension after anesthetic administration. Our results suggest that

CVP values in normal range do not correlate with hypotension during induction.

Broilo et al. analyzed respiratory variations in IVC diameter in 39 ventilated patients with hemodynamic instability [19]. They showed that respiratory variation in IVC is a marker for evaluation of fluid responsiveness, and demonstrated the correlation between respiratory variation of IVC diameter and that of IJV diameter. They concluded that respiratory variation in IJV diameter would be an indirect indicator for assessing fluid responsiveness. However, respiratory variation was not examined in this study, because it was difficult to detect respiratory variations in spontaneously breathing patients, especially in the Trendelenburg position.

In our study, IJV-A in the Trendelenburg position in the hypotensive group was larger than that in the non-hypotensive group. However, as described above, as IJV area and diameter were smaller, CVP was lower and fluid responsiveness was larger, which were the opposite of our results. A possible reason for this result could be that in patients with larger IJV area, the higher sympathetic tone just before induction resulted in a temporary shift in a large amount of blood to the IJV. Therefore, it was suggested that the subsequent reduction in sympathetic tone following anesthesia induction resulted in a greater fall in BP. Previous reports showed that venous constriction due to administration of noradrenaline or phenylephrine increases venous return and cardiac preload [28, 29]. In the present cohort, it might be possible that increased sympathetic tone due to anxiety and mental tension instead of vasoconstrictors increased preload. As the other possible reason, the IJV size could not reflect intravascular volume. Patients with ASA-PS I and II who undergo elective surgery might be considered to have a relatively normal intravascular volume, and hence, the difference in volume between the two groups might not have been significant. In such a cohort, the IJV size might be affected by the venous

compliance and surrounding tissue pressure rather than the venous pressure. Nassar et al. reported that in 9 of 51 participants, the IJV area was smaller in the Trendelenburg position than in the supine position, and they considered this result to be due to the contraction of IJV caused by sympathetic activation [30]. In our study, IJV-As of six patients and IJV-Ds of three patients were smaller in the Trendelenburg position than in the supine position. Therefore the contraction of IJV might have occurred. This may be the reason why IJV change rate did not become a predictor. And moreover this might suggest that occurrence of hypotension during induction of general anesthesia depends on factors other than intravascular volume. Although the exact reason why IJV-A in the Trendelenburg position in the hypotensive group was larger than that in the non-hypotensive group was unclear, the mechanism could be multifactorial, as described above. Further study to examine the relationship between preoperative diastolic dysfunction and IJV area should be conducted.

The reasons why the results of this study were different from those of other studies on ultrasonographic IVC measurements was unclear. The possible explanation might be that our participants had almost normal intravascular volume. The IJV was farther from the heart than the IVC, and the presence of the jugular vein valve might also have affected the results, although we could not find literature support for those. In future, both the IJV and IVC should be measured simultaneously using ultrasonography, and the relationship between the measurements and hypotension during anesthesia induction should be studied.

There are several limitations to our study. The anesthesiologist who performed ultrasonographic IJV measurements was not blinded to the hemodynamics during anesthesia induction. In this study, anesthetic administration for general anesthesia was specified in advance. Moreover BP and HR, which were measured by the automatic sphygmomanometer and electrocardiograph, were automatically recorded in the electronic anesthesia record. Thus, we thought that the bias was minimal. IJV parameters would reflect intravascular volume status such as stroke volume and cardiac output. However the association between intravascular volume and BP might be complex. In future, ultrasonographic IJV measurements should be compared with dynamic parameters including pulse pressure variation and stroke volume variation which are traditionally used to assess intravascular volume status. Patient age was higher in the hypotensive group and there were more patients who regularly used CAs or ACE-I/ARBs compared with the non-hypotensive group. To eliminate these confounding factors, multiple logistic regression analysis was performed. If the subjects are limited to elderly patients or those stratified according to regular medication, it might help determine highly accurate predictors of hypotension during induction, including their cut off values.

In conclusion, maximum area of the IJV in the Trendelenburg position, measured by ultrasonography before the induction of general anesthesia, is an independent predictor of hypotension during the induction of general anesthesia. The large IJV area in the Trendelenburg position increases the risk of hypotension during induction. However, its diagnostic accuracy is too low to allow prediction by this value alone. The finding of our study would prevent the anesthesiologists from misleading that the large IJV area hardly occurs hypotension during induction. Further study is required to examine the diagnostic accuracy of IJV area as a predictor of hypotension during induction.

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