The relationship between the collapsibility index of the internal jugular vein and spinal anesthesia-induced hypotension in cesarean section

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Original Article

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ABSTRACT

Objective: We aimed to investigate the sonographic assessments of internal jugular vein (IJV) to predict spinal anesthesia induced-hypotension in pregnant patients undergoing a cesarean section.

Design: A prospective, observational study

Setting: Bursa Yuksek Ihtisas Training and Research Hospital

Subjects: Seventy-nine American Society of Anesthesiologists physical status II, healthy pregnant women at term aged over 18 years who were scheduled for an elective cesarean section with spinal anesthesia were included in the study.

Intervention: Sonographic assessment of the IJV was made in the supine position with an estimated 15° left lateral table tilt before spinal anesthesia. Spinal anesthesia was performed for all patients. We administered 20 mL/kg crystalloid to patients as coloading. Collapsibility index (CI) [(dIIJVmax-dIJVmin)/dIJVmax × 100%], aspect ratio (height/width), and the maximum diameter of the IJV (dIJVmax) were measured preoperatively. The upper sensory level was assessed. Hypotension was defined as a more than 20% decrease in systolic blood pressure from the baseline level.

Main outcome measure: The relationship between spinal anesthesia-induced hypotension and dIJVmax, IJV-CI, and IJV aspect ratio.

Results: Seventy-three patients were analyzed. The incidence of hypotension was 60.3% (n=44). There were no significant differences in IJV-CI (50±1.6, 51±2), IJV aspect ratio (1.02±0.30, 1.11±0.50) and dIJVmax (1.00 ±0.36, 1.03±0.26) between developed hypotension group and undeveloped hypotension group. The upper sensory level was also not significantly different between the groups.

Conclusion: We found that dIJVmax, IJV aspect ratio, and IJV-CI were not predictive of spinal anesthesia-induced hypotension for cesarean section.

KEYWORDS: collapsibility index, hypotension, internal jugular vein, spinal anesthesia, ultrasound

Clinical trial registration: Australian New Zealand Clinical Trials Registry (Ref: ACTRN12618001067268)

INTRODUCTION

Hypotension is the most common complication of spinal anesthesia. If no precautions are taken, hypotension develops in 80-90% of patients [1,2]. Maternal symptoms such as nausea, vomiting, dyspnea, cardiac arrest, and collapse frequently accompany severe hypotension, and adverse effects on the fetus, including depressed Apgar scores, neonatal acidosis, and neurologic deficit have been correlated with the severity and duration of hypotension [1-3]. A patients susceptibility to intraoperative hypotension is influenced by a surgical patient's preoperative volume status that may change due to comorbidities, and preoperative treatments such as bowel preparation and fasting [4,5]. Knowing intravascular volume status is important for physicians. Measurement of central venous pressure (CVP), a traditional method, is invasive and often inaccurate [6]. In many clinical cases such as tricuspid regurgitation, heart failure, and right heart failure, hypovolemia and hypervolemia show pressure, and volume change within the intrathoracic systemic venous compartment. A change due to hypovolemia or hypervolemia also reflects in extrathoracic veins, primarily in the intraabdominal inferior vena cava (IVC) or extrathoracic internal jugular vein (IJV) [7,8].

Recently, it has been shown that sonographic determination of the diameter of the IVC and IJV is related to CVP and other hemodynamic parameters describing the patient's volume status [9,10]. IVC measurements are not possible in 10-15% of patients because of morbid obesity, pregnancy or excessive bowel gas [11,12]. IJV imaging is easier to perform than IVC visualization in pregnant patients and does not require transthoracic echocardiography. The present study investigated the use of IJV to predict spinal anesthesia-induced hypotension in pregnant patients undergoing a cesarean section.

SUBJECTS AND METHODS

Ethics approval

This was a prospective, observational, and single-center study of pregnant patients conducted between October 2017 and February 2018. The study protocol was approved by the Local Ethics Committee and the protocol for this clinical trial was registered at the Australian New Zealand Clinical Trials (ACTRN12618001067268). The study was conducted following the principles of the Declaration of Helsinki. Written informed consent was obtained from each patient.

Patients

Seventy-nine term pregnant women aged over 18 years, who were American Society of Anesthesiologists (ASA) status II and undergoing elective cesarean section with spinal anesthesia were included in the study. The patients with gestational age less than 37 weeks, chronic hypertension, multi-fetus pregnancy, preeclampsia, gestational diabetes, pre-pregnancy obesity, history of pregnancy-related complications and severe medical conditions such as pulmonary, liver, and kidney disease were excluded from the study. Patients with a baseline systolic blood pressure (SBP) higher than 150 mm Hg and mean blood pressure (MBP) lower than 70 mm Hg were also excluded.

IJV Ultrasonography (USG)

All measurements were performed in the operating room. Blood pressure and heart rate were measured in the supine position with an estimated 15° left lateral table tilt to minimize aortocaval compression by the uterus. After a stabilization interval of 3-5 min, baseline blood pressure measurements were made at least 3 times and averages were recorded. We used the non-invasive oscillometric method with an appropriately sized cuff. The anteroposterior IJV diameter was measured using M-mode during a respiratory cycle in the supine position with an estimated 15° left lateral table tilt. The USG examination was performed with a 15-MHz linear transducer probe (Esaote®MyLab 30, Florance, Italy). Right IJV measurements were obtained at the level of the cricoid cartilage using the method described by Keller *et al*. [13]. USG probe was used to avoid changes in vein diameter unrelated to respiratory variation and to collapse IJV and distinguish it from the carotid artery gentle pressure by the ultrasonography probe was used. Then the pressure was relieved to the USG probe-skin interface. For true measurement, attention was given to avoid the influence of probe compression on IJV dimensions during the USG examination and in order to avoid the interference of probe to-vein angle, the IJV evaluation was performed by positioning the probe perpendicular to the skin and oriented orthogonally to the IJV short-axis diameter [14]. USG measurements including the maximum diameter of the IJV (dIJVmax) at the end of expiration during spontaneous respiration, collapsibility index (CI), and aspect ratio were recorded. The IJV CI (%) was calculated as [(dIJVmax – dIJVmin)/dIJVmax] x 100% [15]. IJV aspect ratio was defined as its height (anterior-posterior diameter) divided by its width [13]. All of the USG images were made by the primary investigator, who had similarly performed >30 cases before starting the study.

Anesthesia Management

Single-shot spinal anesthesia was then performed in the sitting position at L_{3-4} or L_{4-5} using a 25-G Quincke needle. A dose of either 10 mg (height <160 cm) or 12 mg (height ≥ 160 cm) of 0.5% hyperbaric bupivacaine was injected over 30 s with the orifice-directed cephalad. Immediately after the injection, the patient was returned to the supine tilted position, and blood pressure and heart rate measurements were taken. We administered 20 mL/kg crystalloid (Ringer lactate®, Polifarma, Istanbul, Turkey) to patients as coloading. The sensory level was assessed using the pinprick test. Surgery started after attaining an upper sensory level of T_6 or higher. Hypotension was defined by a more than 20% decrease in SBP from the baseline level. The SBP and MBP reading before IJV USG were defined as a baseline. Systolic BP was recorded every 3 minutes throughout the study period and ephedrine 5, and 10 mg boluses were administered when the systolic blood pressure decreased below 80% (hypotension), and 70% (severe hypotension) of the baseline value, respectively. The patients were divided into two groups who developed hypotension and developed no hypotension.

Outcomes

The primary outcome was the relationship between spinal anesthesia-induced hypotension and dIJVmax, IJV-CI, and IJV aspect ratio. The secondary outcomes were the number of patients requiring ephedrine and upper sensory level.

Statistical Analysis

A pilot study of 15 patients detected a decrease in SBP. The analysis indicated a sample size of 73 patients was needed to provide 80% power and a 5% level of significance to detect a 33% effect size. The Shapiro-Wilk test was used as a normality test. Continuous variables were compared using Student's t-test, and the Mann-Whitney U test was used when the data were not normally distributed. Categorical variables were compared using Pearson's Chi-square test and Fisher's exact test. Paired data were analyzed using the paired t-test, and the Wilcoxon signed-rank test was used when data were not normally distributed. For responses at different time points, percent changes were calculated according to baseline measurements. These percent changes were compared using the Mann-Whitney U test for two groups and the Kruskal-Wallis test for more than two groups. Correlations between variables were tested using Pearson and Spearman correlation coefficients. A p-value <0.05 was considered significant. All statistical analyses were performed using the IBM SPSS ver. 23.0 software package.

RESULTS

One hundred twenty patients were screened in the study; 47 patients were excluded. Data from the remaining 73 patients were analyzed. Full details of patients included the study in the flow chart of the study in Figure 1.

The characteristics of patients are summarized in Table 1. After spinal anesthesia, hypotension developed in 44 (60.3%) patients according to the study criteria. Thirty-seven (50.68%) patients received ephedrine (14.32±7.67 mg) for severe hypotension lasting more than 2 min. When the patient's heart rate was below 50, one patient received atropine for bradycardia. The upper sensory level was not significantly different between the groups (Table 1, p>0.05). There were no significant differences in IJV-CI, IJV aspect ratio, and dIJVmax between the groups (Table 1). Receiver operating characteristics (ROC) curve analysis for predicting hypotension was not calculated because there were no significant differences in measurements.

The logistic regression analysis for spinal anesthesia-induced hypotension is shown in Table 2. We did not find significant independent predictive factors of hypotension. There were no significant correlation in SBP 20% decrease with IJV-CI, IJV aspect ratio, and dIJVmax (Figure 2).

DISCUSSION

Determining the initial volume status of patients and administering a prophylactic vasopressor is important to prevent hypotension in patients who are undergoing cesarean section with spinal anesthesia. Sonographic measurement of the diameter of the IJV or IVC is related to CVP and other hemodynamic parameters describing the patient's volume status and is important to anesthesiologists in an opportunity to predict hypotension. We investigated whether preoperative USG measurements of IJV could predict spinal anesthesia-induced hypotension in pregnant patients undergoing a cesarean section. In the current study, hypotension was developed in 44 patients (60.3%). We found that dIJVmax, IJV aspect ratio, and IJV-CI were not predictive of spinal anesthesia-induced hypotension.

There are different definitions for hypotension [3]. We chose as a more than 20% decrease in SBP from the baseline level like Tawfik *et al*.'s [16] study. Applying these different definitions to a cohort of women having an elective cesarean section with neuraxial blocks gave incidences for hypotension varying between 7.4% and 74.1% [3]. In our study, the incidence of spinal anesthesia-induced hypotension was 60.3% in cesarean section, similar to the literature.

Although sonographic assessment of the IVC has been investigated in anesthesia and intensive care unit to evaluate the volume status and predict fluid responsiveness, there are only a few studies about pregnant women [16,17]. Comparison of literature about the anesthesia-induced hypotension and sonographic parameters of the IVC or IJV were summarized in Table 3. To our knowledge, no studies have been investigated the relationship between IJV-CI and spinal anesthesia-induced hypotension on pregnant women.

Hernandez *et al*. [18] researched the IVC diameter in response to 1 L of intravenous hydration in term pregnancy with epidural analgesia for normal vaginal delivery. They found that hydration was not accompanied by any significant change in HR, MBP, or IVC-CI. With the initiation of epidural anesthesia, the MBP decreased significantly from 88 to 80 mm Hg, but the HR and IVC-CI remained unchanged. In their study [18], there was no difference in IVC-CI. However, the rate of hypotension is lower in epidural analgesia compared with spinal analgesia. MBP values are higher than 60 mm Hg in their both groups. They reported that the IVC diameter might prove useful in obstetric states in which rapid confirmation of intravascular volume changes is important for guiding therapy, such as obstetric hemorrhage, management of dialysis in chronic kidney disease, severe cardiac disease, and oliguria from various causes [18].

Zhang *et al*. [5] demonstrated that preoperative USG measurement of the IVC-CI was a reliable predictor of hypotension after induction of general anesthesia. In our study, preoperative ultrasound measurements of dIJVmax, aspect ratio, and IJV-CI were not a predictor of spinal anesthesia-induced hypotension for cesarean section.

Ceruti *et al*. [17] evaluated IVC USG-guided volume optimization to prevent postspinal hypotension in non-obstetric surgery. The authors found that the IVC-CI was correlated with the amount of fluid administered (R^2= 0.32), but could not be used to predict spinal anesthesia-induced hypotension. We performed IJV imaging in obstetric patients without using volume management according to USG, unlike Ceruti *et al*.'s [17] study, and we found no significant relationship between IJV-CI and hypotension.

Tawfik *et al*. [16] searched maternal hemodynamics using a combination of 500 mL crystalloid coload and 500 mL colloid preload versus 1000 mL crystalloid coload. They assessed the IVC at baseline and at the following time points after spinal anesthesia. Their specific administered fluid strategies don't significantly influence the incidence and severity of hypotension. When hypotension develops in spite of fluid administration, vasopressors are still required [16]. The degree of systemic vascular resistance is also an important role of spinal anesthesia-induced hypotension as well as preoperative volume status. We think that further studies are needed to investigate the degree of systemic vascular resistance.

Of the possible strategies of fluid administration during spinal anesthesia for cesarean delivery, crystalloid preload has been demonstrated to have minimal or no effect in reducing the incidence and severity of hypotension, and the other strategies (colloid preload and crystalloid or colloid coload) seem to be comparably effective [19]. We used 20 mL/kg crystalloid coload and no preloading for our patients. Future clinical research should focus on the effectiveness of preloading before spinal anesthesia and the relationship between CI and hypotension.

Keller *et al*. [13] suggested that the IJV aspect ratio can be useful for identifying patients with a low CVP in spontaneously breathing patients. They found that IJV aspect ratio < 0.75 in predicting a CVP < 10 mm Hg [13]. The IJV aspect ratio was assessed easily and was found over 0.75 in our two groups. If compared to the study of Keller *et al*. [13], all patients' CVP could be accepted over 10, because the IJV aspect ratio was found over 0.75 in our study. We did not include patients who had pathologic volume depletion or excess and therefore did not assess the assessment of IJV in these situations.

Kuwata *et al*. [20] investigated the efficacy of pleth variability index (PVI) and perfusion index (PI) to estimate maternal volume status. They demonstrated that PVI and PI change after spinal anesthesia were good predictors of spinal anesthesia-induced hypotension in patients undergoing a cesarean section. According to the literature, only 34% of anesthesiologists in America and Europe used cardiac output monitoring in high-risk surgery [21]. For this reason, many anesthesiologists use a very simple hemodynamic monitoring level (for example, blood pressure, HR) and therefore the inclusion of the ultrasonographic assessment of IVC or IJV helps to identify patients who need fluid optimization. We have no cardiac output monitoring in our study.

Bauman *et al*. [22] demonstrated that IVC-CI and IJV-CI were correlated in the setting of spontaneous breathing. However, IVC-CI and IJV-CI were not correlated during increased thoracic pressure or increased intraabdominal pressure. Our measurements were made in spontaneous breathing. Kent *et al*. [23] verified positive correlations between IJV-CI versus IVC-CI (R^2= 0.38). We preferred to use IJV in pregnant patients because of the easier imaging than IVC.

Our study has some limitations. Our primary limitations were that not using invasive blood pressure measurement, and we did not include invasive hemodynamic parameters such as PVI, PI, cardiac output and CVP. We did not evaluate the change in IJV diameters after spinal anesthesia, crystalloid coload, and at the time developed hypotension. We cannot generalize our results because of the different definitions of hypotension; our results might change depending on the definitions used. Other limitations were no evaluation of IVC synchronously.

CONCLUSION

We found that dIJVmax, IJV aspect ratio, and IJV-CI were not predictive of spinal anesthesia-induced hypotension in cesarean section. IJV-CI could be an alternative option to when IVC-CI is unable to access because it is relatively easier and faster to obtain than IVC-CI measurements in term pregnant patients. Future research is needed to determine the relationship between IJV measurements and spinal anesthesia-induced hypotension in obstetric patients with invasive hemodynamic parameters.

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I and all authors have no conflict of interest

Author contribution:

DK; Study design, literature review, article writing.

CB; Study design, literature review, article writing.

CY; Study design, literature review, article writing.

SEO; Study design, literature review, article writing.

GO; Analysis,and article writing.

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Table 1: Comparison of patients characteristics between patients who developed and undeveloped hypotension after spinal anesthesia

Variables	Developed Hypotension		p
	Yes (n=44)	No (n=29)	
Age, years	30.66 ± 5.39	30.38 ± 4.13	0.813
Height, cm	160.23 ± 5.46	162.24 ± 4.80	0.111
Weight, kg	78.73 ± 13.65	79.90 ± 12.35	0.711
dIJVmax, cm	1.00 ± 0.36	1.03 ± 0.26	0.741
Collapsibility index, %	50 ± 1.6	51 ± 2	0.764
Aspect ratio	1.02 ± 0.30	1.11 ± 0.50	0.373
Upper sensory level	T4 (2-6)	T5 (3-6)	0.061
The amount of crystalloid consumption intraoperatively, ml	1734.78 ± 360.13	1690.90 ± 367.05	0.251
Baseline SBP, mmHg	136.04 ± 13.27	133.14 ± 13.55	0.367
Baseline MBP, mmHg	97.16 ± 12.24	93.41 ± 11.17	0.190
Baseline HR, beats/min	96.90 ± 15.65	90.34 ± 14.83	0.078
SBP % decrease	-0.18±0.12	-0.12 ± 0.09	**0.016**

dIJVmax: maximum diameter of the internal jugular vein, SBP: sistolic blood pressure, MBP: mean blood pressure, HR: heart rate

Table 2: Logistic Regression analysis results of patients for hypotension after spinal anesthesia

Variables	B	p	OR	95% CI for OR	
				Lower	Upper
Age, years	0.050	0.415	1.051	0.932	1.186
Height, cm	-0.059	0.309	0.942	0.841	1.057
Weight, kg	-0.015	0.525	0.985	0.939	1.032
Gestational age (week)	-0.381	0.325	0.683	0.320	1.460
Upper sensory level	-0.632	0.085	0.532	0.259	1.091
dIJVmax (cm)	-0.362	0.719	0.696	0.097	5.001
Collapsibility index	-1.110	0.511	0.330	0.012	9.016
Aspect ratio	-0.425	0.586	0.654	0.142	3.013
Baseline SBP	0.001	0.978	1.001	0.942	1.063
Baseline MBP	0.034	0.338	1.035	0.965	1.111

CI:Confidence Interval OR: Odds ratio

dIJVmax: maximum diameter of the internal jugular vein, SBP: sistolic blood pressure, MBP: mean blood pressure

Table 3: Comparison of literature about the anesthesia induced hypotension and sonographic measurements of the IVC or IJV

Authors	**n**	**Anesthesia Technique**	**Patients**	**Research Parameters**	**Comments**
Zhang *et al.*[5]	90	General anesthesia	Non-obstetric	IVC Diameter, Collapsibility	IVC-CI was a reliable predictor of hypotension after induction of general anesthesia
Ceruti *et al.*[17]	160	Spinal anesthesia	Non-obstetric	IVC Collapsibility	The IVC-CI was correlated with the amount of fluid administered IVC-CI could not be used to predict postspinal anesthesia hypotension
Tawfik *et al.*[16]	198	Spinal anesthesia	Obstetric	IVC Collapsibility	The IVC can be reliably viewed in the long axis using the subcostal window in parturients before and during cesarean delivery The maximum and minimum IVC diameters and the IVC-CI can be used to assess the volume status
Kuwata *et al.*[20]	50	Spinal anesthesia	Obstetric	Pleth variability index, Perfusion index	Pleth variability index after spinal anaesthesia was a good predictor of spinal anaesthesia-induced hypotension Perfusion index change after spinal anaesthesia has the potential to predict hypotension.
Hernandez *et al.*[18]	24	Epidural analgesia	Obstetric	IVC Diameter Collapsibility	They found that hydration was not accompanied by any significant change in CI.
Current study	73	Spinal anesthesia	Obstetric	IJV Diameter Collapsibility Aspect ratio	dIJVmax, IJV aspect ratio, and IJV-CI were not predictive of hypotension induced spinal anesthesia

IVC: Inferior vena cava, IJV: internal jugular vein, CI: Collapsibility index, dIJVmax: maximum diameter of the internal jugular vein

Figure 1: Flow chart of the study

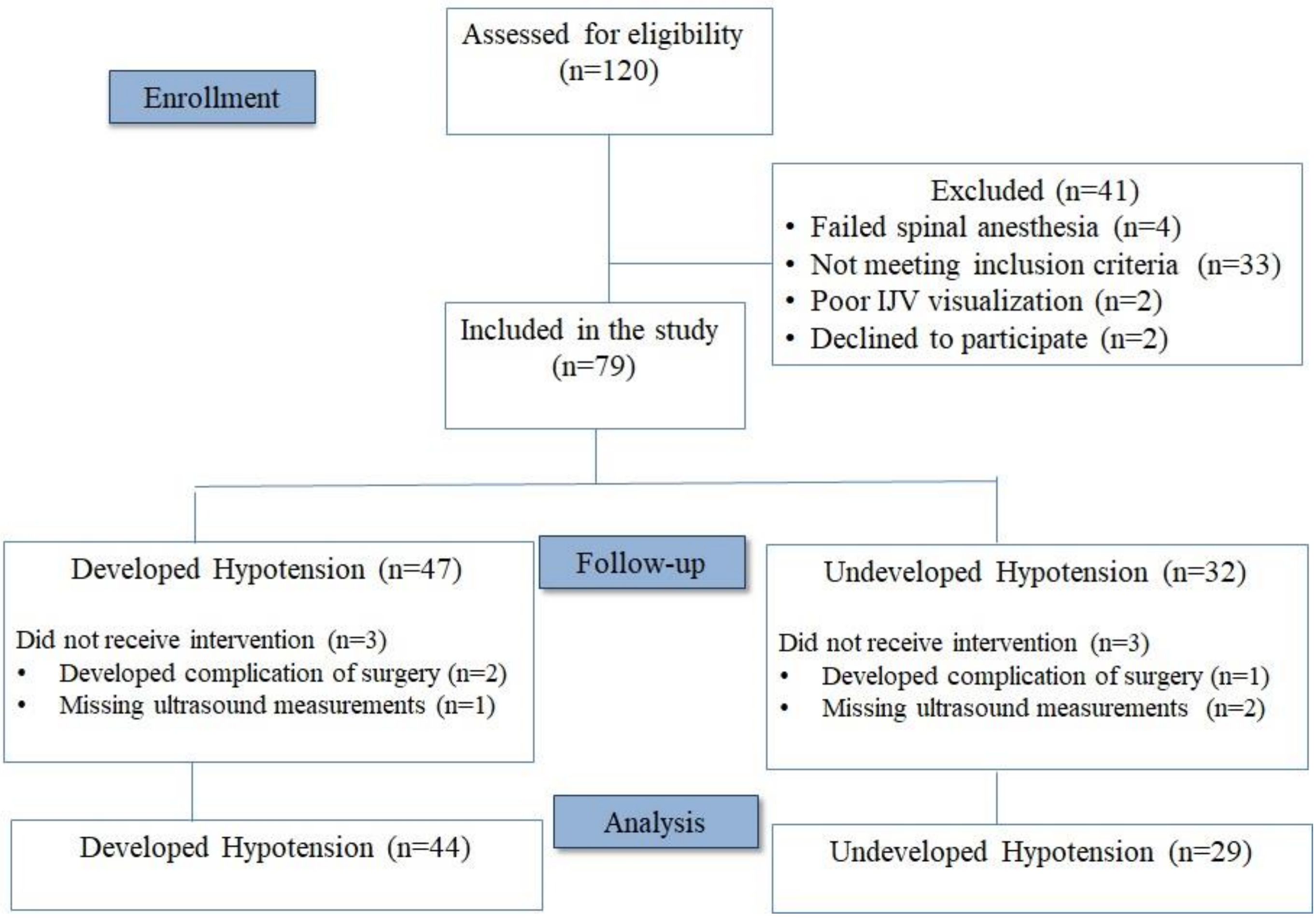

Figure 1: Flow chart of the study

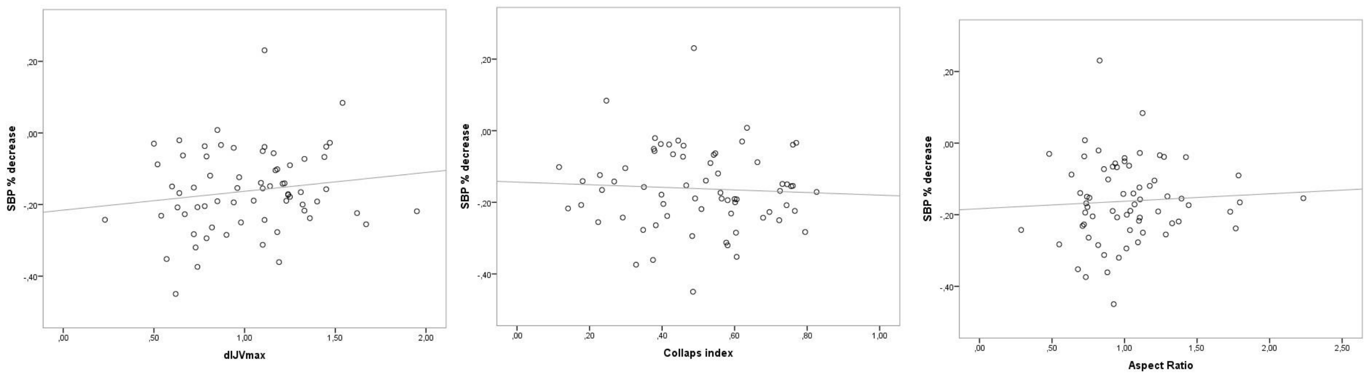

Figure 2: Correlation in SBP 20% decrease with IJV-CI, IJV aspect ratio, and dIJVmax.