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Evaluation of the Corrected Carotid Flow Time and the Inferior Vena Cava Collapsibility Index in Predicting Post-spinal Anesthesia Hypotension in Geriatric Patients

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ABSTRACT

Background: we aim to compare the efficacy of the ultrasonographic assessment of the corrected carotid flow time (CFTc) with that of the inferior vena cava collapsibility index (IVCCI) in predicting post-spinal anesthesia hypotension (PSAH) in geriatric patients.

Methods: This prospective observational study was conducted at Fayoum University Hospital on 282 geriatric patients who underwent elective surgeries. Before spinal anesthesia, patients were positioned supine with their head tilted to the opposite side of the operator. Ultrasound measurements of CFTc was obtained using a high-frequency linear probe while IVCCI was assessed with a low-frequency curvilinear probe. The primary outcome was the receiver operating characteristic (ROC) curve for CFTc and IVCCI values in predicting PSAH in geriatric patients.

Results: The incidence of PSAH among patients was 16.3%. The mean CFTc was 300.34 ± 19.65 msec, and the mean IVCCI was $27.89 \pm 5.87\%$. According to ROC curve analysis, CFTc and IVC collapsibility index were not significant predictors of PSAH, with AUCs of 0.506 (95% CI: 0.446 to 0.566 and p-value: 0.90) and 0.51 (95% CI: 0.455 to 0.574 and p-value: 0.737), respectively.

Conclusion: Neither CFTc nor IVCCI can be used independently as reliable predictors of PSAH in geriatric patients. Their role in predicting PSAH in the elderly appears limited and further research is needed to explore more comprehensive predictive tools for PSAH in this age group.

Clinical trial registration: ClinicalTrials.gov, NCT0575953, unique protocol ID; D316

Introduction

The most frequent adverse event connected to spinal anesthesia is post-spinal anesthesia hypotension (PSAH), with an incidence of 15% to 30% [1]. Hypotension is defined as a drop in systemic blood pressure to levels considered low. Blood pressure readings below 90/60 are generally recognized as hypotensive even though there is no widely accepted standard value for this condition [2]. The cause of hypotension is reduced systemic vascular resistance, which results from sympathetic inhibition and reduced cardiac output (CO) due to decreased venous return [3]. PSAH may be accompanied by dizziness, vomiting, nausea, cardiac arrhythmias, syncope, and cardiac arrest. Intraoperative hypotension causes an increased incidence of postoperative mortality. That is why it is important to be able to predict PSAH and take appropriate precautions to prevent undesirable consequences [4].

The term "geriatrics" relates to the medical treatment of elderly people. Although there isn't a specific age to define elder age, the phrase "above age 65" is frequently used [5,6]. Before the age of 30, most age-related biological processes reach their peak, and they thereafter fall linearly and gradually [7,8]. This reduction may be crucial under stress, but it often has little to no impact on daily activities. As a result, diseases rather than natural aging are the main reason for functional decline as people age [9]. Evaluation of older patients often differs significantly from those of younger patients due to age related physiological changes. History-taking and physical examinations may need to be done separately for elderly patients, especially those who are frail or very old [10,11].

The prevention of PSAH via intravenous fluid loading is an older method. Fluid boluses fail to adequately increase cardiac volume in about 50% of individuals with hemodynamically unstable conditions [12]. In fluid non-responsive patients, the empirical fluid loading has no value and may cause deterioration of the patient's condition [13]. There is no definitive tool to predict PSAH, so it is difficult to differentiate the patients who need vasopressors from those who need fluid boluses. There are numerous dynamic and static indices of fluid responsiveness, and their performance varies in different settings [14,15].

There has been ongoing research for simple, reliable, and non-invasive methods for predicting PSAH [16]. Different non-invasive methods have been used to predict PSAH, such as transthoracic bioimpedance and transthoracic echocardiography (TTE) [17]. However, TTE needs high operator efficiency and is time-consuming, and transthoracic bioimpedance is expensive and not available. On the other hand, IVCCI and corrected carotid flow time (CFTc) assessment sonographically are time-efficient, easy to perform, available, and found to be indicators of fluid responsiveness when used to identify changes in CO [18-20].

By using ultrasonography to guide the measurement of the IVC's diameter, the intravascular volume can be indirectly determined [21]. In patients scheduled for elective surgery, measuring the preoperative IVCCI serves as a dependable indicator of the likelihood of developing hypotension within 30 minutes after receiving spinal anesthesia [22]. CFTc is the carotid systole time, with heart rate correction applied [23]. This simple measurement may be correlated with intravascular volume. Fluid administration or intake causes a rise in CFTc, while volume elimination during dialysis or blood donation causes a reduction in CFTc [24]. However, no studies have used and compared CFTc and IVCCI to predict PSAH. So, we hypothesized that CFTc and IVCCI measurements are methods that help in predicting the occurrence of PSAH in geriatric patients. Therefore, in this study, we compared the efficacy of the ultrasonographic assessment of the corrected carotid flow time with that of IVCCI in predicting PSAH in geriatric patients.

Methods

We conducted a prospective observational study on geriatric individuals undergoing elective operations after receiving approval from the Ethical and Scientific Committee of Fayoum University Hospital (D316). Written informed consent was obtained from the participants or their surrogates to be involved in the study. The study was registered at ClinicalTrials.gov (NCT0575953). The study took place at Fayoum University Hospital in Fayoum, Egypt, and included patients over 65 years old who were undergoing elective surgeries with spinal anesthesia. BMI greater than 35 kg/m², contraindications for spinal anesthesia, cerebrovascular disease, carotid stenosis, ejection fraction less than 40% (low left ventricular function), regular dialysis, previous neck surgery, severe valvular heart disease, or fulminant hepatic failure were the exclusion criteria.

On the operation day, intravenous access was established, and anthropometric data (weight, height, and BMI) and demographic (age, sex) were recorded. Detailed medical history, including diagnoses of diabetes mellitus, hypertension, current medications, and previous surgeries, was also documented. Routine preoperative assessments included a full laboratory workup, and an electrocardiogram and echocardiogram were performed if indicated. In some cases, a carotid duplex was conducted to evaluate vascular status. No premedication was administered. Patients were positioned supine in the operating room and monitored using standard equipment, including a five-lead electrocardiogram, pulse oximeter, and non-invasive blood pressure cuff.

Intervention Protocol

Before administering spinal anesthesia, the patient's head was tilted away from the operator. A high-frequency linear ultrasound (US) probe (HFL_50, 15–6 MHz, Phillips) was located vertically on the patient's neck, with the marker directed toward the head. To capture a long-axis B-mode image of the right common carotid artery, the probe was aligned at the thyroid cartilage lower border. It was positioned centrally over the vessel lumen, roughly 2 cm before the bifurcation of the carotid artery.

Blood flow waveforms of carotid artery were then recorded, along with a pulsed wave Doppler trace of arterial flow. The cycle time was determined by counting the number of heartbeats at the start of the systolic upstroke, using the caliper tool on the ultrasound machine. The flow time was measured by measuring the interval (in tenths of milliseconds) among the dicrotic notch and the systolic upstroke. The corrected carotid flow time (CFTc) was then derived using Wodey's formula, which adjusts for heart rate. To ensure accuracy, the calculation was performed on a single cardiac cycle after achieving stability over several consecutive cycles. Wodey's formula is defined as:

Corrected Carotid Flow Time (CFTc) = Carotid Flow Time + 1.29 × (heart rate – 60) [25].

The IVC was scanned using a portable ultrasound device equipped with a low-frequency curvilinear probe (LFC_50, 6-15MHZ, Phillips) in the subxiphoid region (paramedian long-axis viewnear the common hepatic vein's junction with the IVCA two-dimensional image was captured at the junction where the inferior vena cava (IVC) enters the right atrium. M-mode ultrasound was then used to measure variations in the IVC diameter at the time of both expiration and inspiration. The procedure was conducted (2-3 cm) away from the right atrium/IVC junction. The M mode of US was utilized to assess the and IVC's minimum (IVCDMin), and IVCCI was calculated using the formula:

$$\frac{\text{Maximum IVCD} - \text{Minimum IVCD}}{\text{Maximum IVCD}} \times 100.$$

An attending anesthesiologist administered spinal anesthesia utilizing a 25-gauge Quincke spinal needle at the L4/5 or L3/4 vertebral interspace, with the participant seated. The anesthesiologist selected doses of 0.5% hyperbaric bupivacaine (10 to 15 mg) and fentanyl (0 to 15 mg). After the injection, the patient was repositioned to a supine position. After 10 minutes, the sensory block was assessed using cold and pinprick tests. Non-invasive blood pressure was recorded every three minutes during the first fifteen minutes and then every 10 minutes for the first hour of surgery.

The primary outcome was the area under the receiver operating characteristic (ROC) curve for the IVCCI and the CFTc in predicting PSAH in geriatric patients. Secondary outcomes included the determination of the cut-off value, negative and positive predictive values, sensitivity, and specificity of CFTc and IVCCI for PSAH, along with measurements of mean arterial pressure (MAP) and heart rate (HR) every three minutes for the first fifteen minutes and then every ten minutes for the first hour after anesthesia. Additional secondary outcomes were the incidence of PSAH, HR and MAP comparisons between patients with and without PSAH, the ephedrine dosage required to treat PSAH, and the correlation of PSAH with CFTc and IVCCI.

Sample Size Calculation

The sample size needed to compare two ROC curves with expected areas under the curve of 0.754 and 0.85 was calculated using the MedCalc program. Assuming an error of 0.01 and a power of 80%, a minimum of 270 patients, plus an additional 5% to account for potential dropouts, was required, resulting in a total of 282 patients. This sample size would allow detection of a 0.25 AUC difference depending on previous similar research and assuming the number of PSAH patients is similar to that of non-hypotensive patients [25,26].

Statistical Analysis

Statistical analysis was conducted using SPSS version 28 (IBM Co., Armonk, NY, USA). For normally distributed numerical data, results were presented as mean ± standard deviation (SD) and compared using the unpaired t-test. In cases where the data did not follow a normal distribution, the median and interquartile range (25th–75th percentile) were reported and analyzed using the Mann-Whitney U test. Categorical variables were expressed as counts and percentages and assessed using either the Chi-square test or Fisher's exact test, depending on suitability. Receiver Operating Characteristic (ROC) curve analysis was used to evaluate the diagnostic accuracy of CFTc and IVCCI in predicting PSAH, assessing sensitivity and specificity at different threshold levels. The optimal cut-off point was identified using Youden's index, with calculations performed in MedCalc version 20. Pearson's correlation coefficient was applied to examine the relationship between two continuous variables. Logistic regression analysis was utilized to determine factors independently associated with the occurrence of PSAH. A P-value less than 0.05 (two-tailed) was determined statistically substantial.

Results

Patients for this study were recruited between August 2018 and February 2020. The study flowchart is presented in Figure 1. Our final analysis involved 282 individuals. PSAH occurred in 46 patients and did not occur in 236 patients. Table 1 displays the demographic and operative characteristics of the participants studied.

Table 1 show baseline demographics and operative characteristics of the studied geriatric patients with or without post-spinal anesthesia hypotension with no significant difference.

Table 2 shows hemodynamics and ultrasound measurements of the studied groups. The heart rate of patients with and without PSAH was comparable at all time points. On the other hand, the mean arterial pressure was significantly decreased in PSAH patients after 6, 9, 12, 15, 20, 30, and 40 minutes from the spinal injection (p < 0.05). Moreover, there was no statistically substantial variation between both cohorts in terms of CFTc and IVC collapsibility index.

The diagnostic performance of CFTc and the IVCCI in PSAH among the geriatric participants studied. ROC curve analysis revealed that neither CFTc nor the IVC collapsibility index were significant predictors of post-spinal anesthesia hypotension,
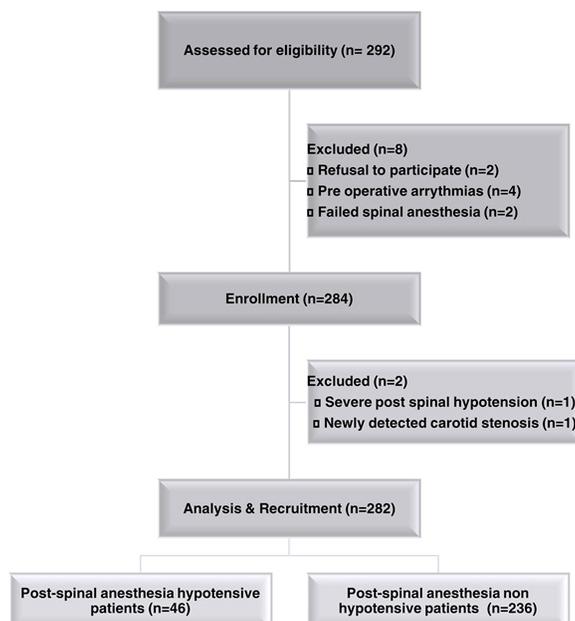
Figure 1: Study CONSORT flowchart diagram.

Table 1: Baseline demographics and operative characteristics of the studied geriatric patients with or without post-spinal anesthesia hypotension.

Item	Overall (n=282)	No PSAH (n=236)	PSAH (n=46)	p-value
Age (years)	72.12 ± 5.01	72.17 ± 4.98	71.89 ± 5.18	0.7
Sex				
Male	154 (54.6%)	130 (55.1%)	24 (52.2%)	0.7
Female	128 (45.4%)	106 (44.9%)	22 (47.8%)	
Height (m)	1.68 ± 0.1	1.68 ± 0.11	1.69 ± 0.08	0.38
Weight (kg)	79.2 ± 9.88	78.95 ± 9.53	80.46 ± 11.51	0.3
BMI (kg/m²)	28.19 ± 3.78	28.13 ± 3.76	28.48 ± 3.92	0.56
ASA physical status				
I	135 (47.9%)	114 (48.3%)	21 (45.7%)	0.7
II	147 (52.1%)	122 (51.7%)	25 (54.3%)	
Type of surgery				
Orthopedic	44 (15.6%)	37 (15.7%)	7 (15.2%)	
General surgery	70 (24.8%)	59 (25%)	11 (23.9%)	
Gynecology	64 (22.7%)	53 (22.5%)	11 (23.9%)	0.87
Urology	55 (19.5%)	44 (18.6%)	11 (23.9%)	
Vascular	49 (17.4%)	43 (18.2%)	6 (13%)	
Duration of operation (min)	79.37 ± 16.96	79.06 ± 17	80.96 ± 16.84	0.48
Comorbidities				
None	117 (41.5%)	97 (41.1%)	20 (43.5%)	
DM	94 (33.3%)	83 (35.2%)	11 (23.9%)	
HTN	63 (22.3%)	49 (20.8%)	14 (30.4%)	0.36
DM & HTN	8 (2.8%)	7 (3%)	1 (2.2%)	
Ephedrine requirement **Yes** **No**	50 (17.7%) 232 (82.3%)	4 (1.7%) 232 (98.3%)	46 (100%) 0 (0%)	**<0.001***
Dose of ephedrine (mg)	9.5 ± 2.35	6.38 ± 1.6	9.77 ± 2.21	**0.004***
Amount of fluid administered peri operative (ml)	670.25 ± 174.46	637.12 ± 150.62	840.22 ± 190.5	**<0.001***
CFTc (msec)	300.34 ± 19.65	300.43 ± 19.61	299.87 ± 20.04	0.86
IVC collapsibility index (%)	27.89 ± 5.87	28.01 ± 6.09	27.28 ± 4.61	0.44

Values are presented as mean ± SD or number (proportion). **PSAH:** Post-spinal anesthesia hypotension. **BMI:** Body mass index. **ASA:** The American Society of Anesthesiologists. **DM:** Diabetes mellitus, **HTN:** Hypertension. *: statistical significance at p-value <0.05.

Table 2: Hemodynamics and ultrasound measurements of the 282 studied geriatric patients.

Item	Overall (n=282)	No PSAH (n=236)	PSAH (n=46)	p-value
Heart rate (bpm)				
Baseline	89.44 ± 7.72	89.38 ± 7.79	89.76 ± 7.41	0.76
3 min	89.55 ± 8.10	89.36 ± 7.82	90.5 ± 9.42	0.44
6 min	90.93 ± 7.19	90.89 ± 7.07	91.13 ± 7.89	0.83
9 min	91.24 ± 7.51	91.42 ± 7.55	90.3 ± 7.34	0.35
12 min	90.85 ± 7.65	90.59 ± 7.71	92.2 ± 7.23	0.19
15 min	90.15 ± 7.56	90.23 ± 7.66	89.72 ± 7.04	0.67
20 min	89.91 ± 7.8	89.82 ± 7.17	90.37 ± 10.57	0.66
30 min	90.10 ± 7.4	89.82 ± 7.42	91.57 ± 7.19	0.14
40 min	89.09 ± 7.11	89.01 ± 7.19	89.52 ± 6.8	0.65
50 min	88.74 ± 7.42	88.62 ± 7.46	89.39 ± 7.24	0.51
60 min	88.74 ± 8.05	88.69 ± 7.93	88.96 ± 8.72	0.84
Mean arterial pressure (mmHg)				
Baseline	89.37 ± 11.63	92.08 ± 11.31	91.11 ± 9.08	0.53
3 min	90.74 ± 12	89.71 ± 11.81	87.61 ± 10.6	0.23
6 min	89.19 ± 14.53	92.28 ± 11.15	82.83 ± 13.18	**<0.001***
9 min	86.42 ± 15.28	92.54 ± 12.21	72.02 ± 13.39	**<0.001***
12 min	86.38 ± 15.2	90.95 ± 11.79	63.2 ± 8.54	**<0.001***
15 min	88.62 ± 13.48	90.84 ± 11.74	63.52 ± 9.24	**<0.001***
20 min	89.52 ± 11.76	91.8 ± 11.13	72.33 ± 12.76	**<0.001***
30 min	90.83 ± 10.49	91.15 ± 11.31	81.13 ± 10.49	**<0.001***
40 min	91.01 ± 10.72	91.6 ± 10.57	86.87 ± 9.19	**0.005***
50 min	92.23 ± 10.43	91.43 ± 11.11	88.87 ± 8.23	0.07
60 min	91.92 ± 10.97	92.5 ± 10.72	90.87 ± 8.81	0.27
CFTc (msec)	300.43±19.65	300.43 ± 19.61	299.87 ± 20.04	0.86
IVC collapsibility index (%)	27.89 ± 5.87	28.01 ± 6.09	27.28 ± 4.61	0.44

Values are presented as mean ± SD. **PSAH:** Post-spinal anesthesia hypotension. **CFTc:** Corrected carotid flow time. **IVC:** Inferior vena cava. *: statistical significance at p-value < 0.05.

Table 3: Correlation between corrected carotid flow time and hemodynamics for the 282 studied geriatric patients

| Item | CFTc (msec) | | | | | |
| | Overall (n=282) | | No PSAH (n=236) | | PSAH (n=46) | |
	r	P value	r	P value	r	P value
Heart rate (bpm)						
Baseline	-0.099	0.097	-0.092	0.158	-0.135	0.37
3 min	-0.059	0.327	-0.038	0.566	-0.146	0.33
6 min	0.021	0.728	0.012	0.860	0.064	0.67
9 min	0.018	0.767	0.011	0.867	0.050	0.74
12 min	-0.108	0.070	-0.105	0.108	-0.122	0.42
15 min	-0.049	0.409	-0.098	0.132	0.221	0.14
20 min	0.109	0.068	-0.018	0.782	0.556	**<0.001***
30 min	-0.026	0.659	-0.068	0.299	0.197	0.19
40 min	-0.029	0.622	-0.066	0.313	0.169	0.26
50 min	-0.072	0.226	-0.126	0.052	0.215	0.15
60 min	-0.004	0.947	-0.032	0.624	0.127	0.40
Mean arterial pressure (mmHg)						
Baseline	0.048	0.422	0.057	0.380	-0.013	0.93
3 min	0.068	0.253	0.070	0.282	0.054	0.72
6 min	0.005	0.934	0.017	0.799	-0.062	0.68
9 min	0.053	0.375	0.104	0.112	-0.168	0.26
12 min	0.049	0.417	0.068	0.297	-0.028	0.85
15 min	0.083	0.166	0.074	0.256	0.281	0.06
20 min	0.033	0.585	0.001	0.987	0.170	0.26
30 min	0.051	0.389	0.063	0.335	-0.017	0.91
40 min	0.026	0.664	0.024	0.713	0.028	0.85
50 min	0.079	0.188	0.081	0.215	0.061	0.68
60 min	-0.005	0.930	0.005	0.934	-0.077	0.61

r: Pearson's correlation coefficient. *: Statistical significance at p-value<0.05

Table 4: Correlation between inferior vena cava collapsibility index and hemodynamics for the 282 studied geriatric patients.

Item	IVC collapsibility index (%)					
	All cases		No PSAH (n=236)		PSAH (n=46)	
	r	P value	r	P value	r	P value
Heart rate (bpm)						
Baseline	0.009	0.87	0.022	0.74	-0.073	0.63
3 min	0.052	0.38	0.078	0.23	-0.076	0.61
6 min	-0.098	0.10	-0.117	0.07	0.017	0.91
9 min	-0.017	0.78	0.005	0.94	-0.188	0.21
12 min	-0.021	0.73	-0.023	0.72	0.028	0.85
15 min	-0.006	0.91	0.008	0.90	-0.125	0.41
20 min	0.050	0.41	0.044	0.50	0.094	0.53
30 min	0.053	0.37	0.037	0.57	0.205	0.17
40 min	-0.039	0.51	-0.059	0.37	0.113	0.45
50 min	-0.037	0.53	-0.042	0.51	0.016	0.92
60 min	-0.068	0.25	-0.068	0.29	-0.070	0.64
Mean arterial pressure (mmHg)						
Baseline	-0.091	0.12	-0.080	0.22	-0.205	0.17
3 min	0.0	0.99	0.010	0.88	-0.099	0.51
6 min	-0.078	0.19	-0.098	0.13	-0.089	0.55
9 min	-0.084	0.15	-0.150	0.02	0.011	0.94
12 min	-0.055	0.35	-0.113	0.08	-0.155	0.30
15 min	-0.054	0.36	-0.123	0.06	-0.033	0.83
20 min	-0.087	0.14	-0.147	**0.024***	-0.054	0.72
30 min	-0.067	0.26	-0.072	0.27	-0.196	0.19
40 min	-0.107	0.07	-0.103	0.11	-0.221	0.14
50 min	-0.006	0.92	0.009	0.88	-0.187	0.21
60 min	-0.072	0.23	-0.059	0.37	-0.210	0.16

r: Pearson's correlation coefficient. *: Statistical significance at p-value<0.05
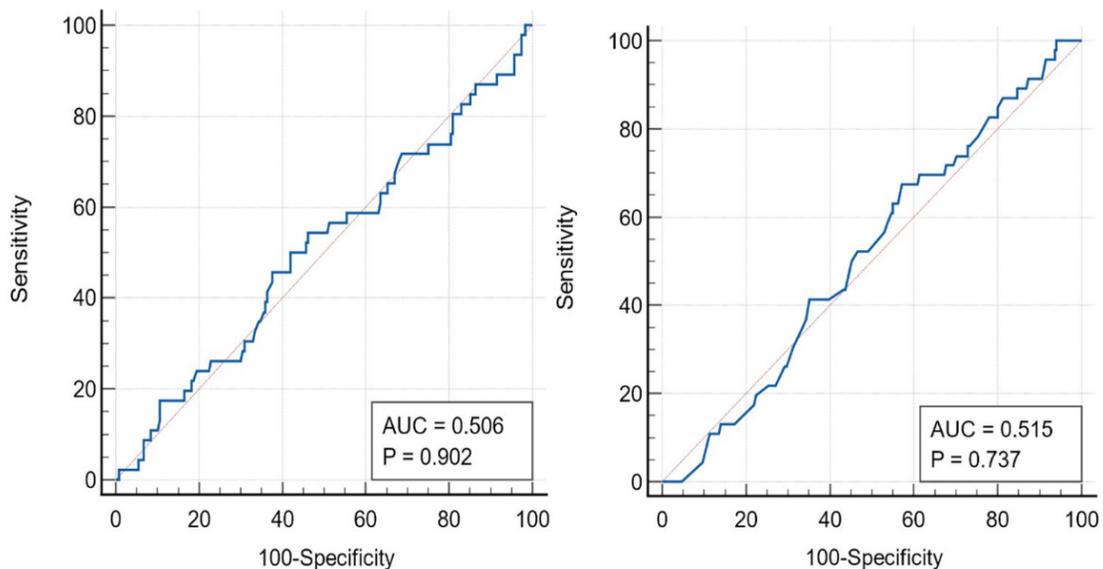
Figure 2: Receiver operating characteristic (ROC) curves of corrected carotid flow time (CFTc) (left graph) and inferior vena cava collapsibility index (IVCCI) (right graph) for the prediction of post-spinal anesthesia hypotension for the 282 studied geriatric patients.

with AUCs of 0.5 (95% CI: 0.446–0.566) and 0.5 (95% CI: 0.455–0.574), respectively. No statistically significant difference was found between the two methods in predicting post-spinal anesthesia hypotension in this population.

Figure 2 shows receiver-operating characteristic curves of CFTc (left curve) and IVCCI (right curve) values for the prediction of PSAH for the 282 studied geriatric patients. Both variables have curves closely following the diagonal reference line, indicating AUC values near 0.5 and poor predictive performance.

Table 3 and Table 4 illustrate the correlation between CFTc, IVCCI, and the hemodynamic parameters of the studied geriatric patients. An intermediate positive correlation was observed between CFTc and the 20-minute heart rate in PSAH patients (r = 0.556, P < 0.001). In contrast, a substantial weak negative correlation was noted between IVCCI and the 20-minute mean arterial pressure in non-PSAH patients (r = -0.147, P = 0.02).

Discussion

The study compared the efficacy of ultrasonographic assessment of CFTc and IVCCI in predicting PSAH in geriatric patients. The results showed that ROC analysis indicated the non-statistical significance of the area under the curve for CFTc and IVCCI, which is reflected in the fact that neither CFTc nor IVCCI can be considered significant predictors in predicting PSAH in geriatric patients. Also, a weak negative correlation was noted between IVCCI and 20-minute MAP in non-PSAH patients. While ephedrine requirement and fluid administration were significantly higher in patients with PSAH, heart rate remained comparable between groups.

Older adults exhibit distinct hemodynamic characteristics, such as reduced cardiovascular reserve and altered autonomic regulation. These factors could diminish the sensitivity and specificity of ultrasonographic indices like CFTc and IVCCI. In our study, despite comparable heart rates, subsequent MAP reductions in the PSAH group underscore the complex interplay of age-related cardiovascular changes. This complexity, influenced by multifactorial age-related changes may not be adequately captured by static or dynamic ultrasonographic measures alone [27].

A study conducted at Kauno Klinikos Hospital evaluated the prognostic value of IVCCI in predicting severe intraoperative hypotension in spontaneously breathing individuals undergoing elective knee arthroplasty. Despite empirical administration of intravascular fluids to prevent spinal anesthesia-induced hypotension. Measurements of IVC diameters and IVCCI before and after spinal anesthesia, along with hemodynamic parameters, revealed no significant differences between hypotensive and non-hypotensive patients. ROC analysis further confirmed that IVCCI was not a reliable predictor, with an area under the ROC curve of less than 0.7 and a p-value greater than 0.05. The findings suggest that IVCCI is not an effective tool for predicting severe hypotension in this patient population [24]. These results are consistent with our recent result on IVCCI. Like our study, they

focused on geriatric patients. The mean age of the included cases was 72.12 years, and in Jaremko et al. it was 70.4 years [24].

Another study focused on the same age group with a mean age of 71 years. This study investigated predictors of PSAH in elderly individuals undergoing elective oeration under spinal anesthesia, focusing on ultrasonographic carotid artery flow evaluation during the passive leg raise (PLR) test and preoperative transthoracic echocardiography (TTE) parameters. While carotid blood flow in the semirecumbent position showed some predictive capability with an area under the ROC curve of 0.754 (95% CI, 0.612–0.865), it did not maintain significance in multivariate analysis. These findings suggest that ultrasonographic carotid artery flow measurements during PLR testing may not reliably predict PSAH in elderly patients, which is in concordance with our results about CFTc [28].

Also, our results matched with a study done by Wang et al. that performed a prospective, observational study aimed to assess the predictive capability of CFTc and carotid peak velocity variation (ΔVpeakCCA) measured via carotid Doppler ultrasound for PSAH in 42 patients undergoing elective surgery. Despite evaluating these parameters both preoperatively and intraoperatively, 43% of patients experienced PSAH, with no significant differences observed in CFTc or ΔVpeakCCA between normotensive and hypotensive groups (p = 0.91 and p = 0.34, respectively). The area under the receiver-operating curve for CFTc and ΔVpeakCCA was 0.52 and 0.59, respectively, indicating poor predictive performance. Furthermore, there was no correlation found between these ultrasound parameters and the percentage change in blood pressure post-spinal anesthesia, and they concluded that highlighting the limitations of carotid Doppler ultrasound in preoperatively identifying those at risk of hypotension following spinal anesthesia [29].

Complementary findings from other clinical contexts, such as pregnant women undergoing elective cesarean section, were consistent with our results. The hypothesis that IVCCI could identify hypovolemic parturients at risk of PSH was tested in a prospective observational study involving 45 women. Despite measuring IVCCI in both supine positions (without wedge) and left lateral tilt (with wedge) before spinal anesthesia and noting changes in blood pressure post-anesthesia, their findings indicated that IVCCI was not a reliable predictor of PSAH. Specifically, the area under the ROC curve for IVCCI with wedge was 0.46 (95% CI 0.27, 0.64), and for IVCCI without wedge was 0.38 (95% CI 0.19, 0.56), with sensitivity and specificity values suggesting limited discriminatory power. These results align with our study's findings that neither IVCCI nor corrected carotid flow time effectively predicted PSH in geriatric patients, underscoring the need for caution in extrapolating predictive abilities of these indices across different patient populations and clinical settings [30].

Chowdhury et al. performed a study on adult patients with a wider age group between 18-60 years who underwent elective lower abdominal operations under spinal anesthesia and investigated

the utility of the IVCCI and carotid artery peak systolic velocity variations (CAPVV) as predictors of PSAH. Despite their established use in assessing volume status in critically ill patients, their findings indicate limited diagnostic accuracy of both IVCCI and CAPVV in predicting PSH. They demonstrate that IVCCI > 21.15 ml demonstrated 69.7% specificity and 58.8% sensitivity, while CAPVV > 18.33 showed 54.6% specificity and 70.6% sensitivity for predicting PSAH. A composite model incorporating IVC max, CAPVV, and baseline mean blood pressure marginally improved prediction, but overall, neither IVCCI nor CAPVV, independently or in combination, proved robust in predicting PSH in this surgical cohort. These results parallel our study's findings regarding the ineffectiveness of IVCCI and corrected carotid flow time in predicting PSH in geriatric patients, highlighting the challenges in extrapolating these indices' predictive value across different patient populations and clinical settings [31].

On the other hand, a recent meta-analysis investigated the utility of IVCCI in predicting PSAH across 12 studies involving 1076 patients undergoing non- cesarean section (CS) surgeries or CS. The analysis revealed that patients experiencing PSAH exhibited significantly higher IVCCI values compared to those without PSAH, with a mean difference of 11.12%. The pooled incidence rate of PSAH was found to be 40.5%, underscoring its clinical relevance. IVCCI demonstrated robust diagnostic reliability with a sensitivity of 77% and specificity of 82%, supported by a high pooled area under the curve (AUC) of 0.85, indicating its effectiveness in identifying patients at risk of PSAH. Despite these strengths, the study suggests the need for future research to evaluate its applicability in high-risk patient groups and explore strategies to integrate IVCCI into clinical practice to enhance patient safety. Their results may be due to physiological changes in pregnant women & their different ages [32].

Another study focused on evaluating IVCCI as a predictor of hypotension in patients undergoing central neuraxial block (CNB) for elective surgery, a context with limited prior research on IVCCI's perioperative utility. A total of 100 ASA grade I/ II patients aged 18–60 years were included, with an ultrasound examination of the IVC conducted preoperatively. Patients were categorized into a group with IVCCI ≥50% and a group with IVCCI <50%. Following CNB administration, the former group exhibited a significantly higher incidence of hypotension (56.60%) compared to the latter group (4.87%), demonstrating IVCCI's predictive value (P < .001). Moreover, the ones with IVCCI ≥50% required more vasopressors and fluid boluses, indicating greater hemodynamic instability. These findings underscore the potential of preoperative IVCCI assessment to guide proactive management strategies aimed at reducing the incidence and severity of hypotension following CNB in elective surgical settings [33].

Study Limitations
This study has some limitations. The single-center design may limit the generalizability of the findings. Future studies should consider multicenter designs to validate our findings. Additionally, the geriatric population's heterogeneity in terms of comorbidities

and physiological reserve could introduce variability that may not be fully accounted for in these results. Future papers should focus on integrating multiple parameters and employing advanced predictive models to enhance the assessment and management of PSAH risk in geriatric patients. This approach could ultimately enhance patient safety and outcomes in this vulnerable population.

Conclusion
This study concludes that neither CFTc nor IVCCI can be used independently as reliable predictors of PSAH in geriatric patients. Their role in predicting PSAH in the elderly appears limited and further research is needed to explore more comprehensive predictive tools for PSAH in this age group.

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