The transverse diameter of right common femoral vein by ultrasound in the supine position for predicting post-spinal hypotension during cesarean delivery.

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Research article

Keywords: transverse diameter, right common femoral vein, hypotension, cesarean delivery, ultrasound

Posted Date: October 14th, 2020

DOI: https://doi.org/10.21203/rs.3.rs-60513/v2

Version of Record: A version of this preprint was published on January 20th, 2021. See the published version at https://doi.org/10.1186/s12871-021-01242-8.

Abstract

Background: Post-spinal anesthesia hypotension during cesarean delivery is caused by decreased systemic vascular resistance due to the blockage of autonomic nerves, which is further worsened by inferior vena cava (IVC) compression by the gravid uterus. The aim of this study was to assess whether peak velocity and diameter of IVC below the xiphoid or the right common femoral vein (RCFV) in the inguinal region, as measured on ultrasound, could reflect the degree of IVC compression and further identify parturients at risk of post-spinal hypotension. Methods: After ultrasound measurement of peak velocities and anteroposterior diameters of the IVC and peak velocities and transverse diameters of the RCFV before anesthesia, 56 parturients undergoing elective cesarean section with spinal anesthesia were enrolled in this study. Hypotension was defined as having a drop of systolic arterial pressure >20% from the baseline. The primary outcome was ultrasound measurements of IVC and RCFV, and their association with post-spinal hypotension during cesarean delivery. Multinomial logistic regression analysis was used to identify the association between the measurements of ICV, RCFV and post-spinal hypotension during cesarean delivery. Receiver operating characteristic curves were used to test the abilities of the identified parameters to predict post-spinal hypotension, and the areas under the curve and the optimum cut-off values for the predictive parameters were calculated. Results: Longer transverse diameter of the RCFV was associated with the occurrence of post-spinal hypotension (odds ratio = 2.022, 95% confidence interval [CI] 1.261–3.243). The area under the receiver operating characteristics curve for the prediction of post-spinal hypotension was 0.759 (0.628–0.890; P = 0.001). A transverse diameter of the RCFV >12.2 mm could predict post-spinal hypotension during cesarean delivery. Conclusions: We demonstrated a longer transverse diameter of RCFV was associated with hypotension and it could predict parturients at major risk of hypotension before anesthesia.

Background

Post-spinal anesthesia hypotension, which can occur as a result of combined spinal epidural (CSE) anesthesia during cesarean delivery, can lead to adverse maternal and fetal outcomes.[1–4] Therefore, effective prediction of maternal hypotension is of great clinical importance.

Post-spinal anesthesia hypotension during cesarean delivery is caused by decreased systemic vascular resistance due to the blockage of the autonomic nerves, and it is further worsened by aortocaval compression by the gravid uterus, which eventually leads to severe hypotension.[5–8]

The aim of the study was to access whether peak velocities and anteroposterior diameters of the abdominal aorta (AA) and the inferior vena cava (IVC) below the xiphoid, or the peak velocities and transverse diameters of the right common femoral artery (RCFA) and right common femoral vein (RCFV) in the inguinal region could effectively identify parturients at risk of post-spinal hypotension during elective cesarean delivery. We hypothesized that the peak velocities and anteroposterior diameters of the AA and IVC below the xiphoid or the peak velocities and transverse diameters of RCFA and RCFV in the inguinal region could reflect the degree of aortocaval compression, and further identify parturients at risk of post-spinal hypotension.

Methods

Materials and methods

After obtaining approval from the Research Ethics Committee of the International Peace Maternity and Child Health Hospital (Ethical number: GKLW 2017-85) and registering this prospective, double-blind study at http://www.chictr.org.cn (ChiCTR1800016163), were recruited 58 parturients aged 18–40 years, with a full-term (>37-weeks' gestation) singleton pregnancy, a height of 156–170 cm, and an American Society of Anesthesiology (ASA) score of □–□ who underwent elective cesarean delivery with CSE anesthesia during January 2019 to June 2019. All parturients provided signed informed consent. The exclusion criteria for the study included ASA score of □–□, contraindications to spinal anesthesia, prolonged pregnancy (>42 weeks), preexisting or pregnancy-induced hypertension or preeclampsia, placenta previa, placental abruption, multiple pregnancy, morbid obesity (body mass index [BMI] ≥36), fetal distress or fetal abnormalities, emergent cesarean delivery, and parturient refusal.

Parturients were instructed to fast for at least 6 hours before surgery. The ultrasound measurements were performed with the parturient on the transfer bed in the post-anesthesia care unit 15 minutes before anesthesia. An ultrasound device (EPIQ7; Philips, Ultrasound, Bothell, WA, USA) with a high frequency linear array probe L12-5 (5–12 MHz) was used for the measurement of transverse diameters and peak velocities of the RCFV and RCFA, and a cardiac probe SC-1 (5–1 MHz) was used for the measurement of anteroposterior diameters and peak velocities of the AA and IVC. Parturients were in a supine position when the ultrasound examination was performed. Measurement sequences for the transverse diameter of the RCFV and RCFA, peak velocity of the RCFV and RCFA, anteroposterior diameter of the IVC and AA, peak velocity of the IVC and AA were always applied to ensure all examinations finished within 15 minutes. The transverse diameter and peak velocity of the RCFV were measured 1 cm proximal to the bifurcation of the great saphenous vein flowing into the femoral vein. The transverse diameter and peak velocity of the RCFA were measured at 1 cm proximal to the distal bifurcation of the femoral artery. The cardiac probe was placed below the xiphoid. The anteroposterior diameter and peak velocity of the IVC were measured 2–3 cm below the IVC-right atrial junction during end expiration, and the anteroposterior diameter and peak velocity of the AA were measured 2 cm above the superior mesenteric artery. All peak velocities were measured using a pulsed-wave Doppler ultrasound mode. The Doppler sampling volume was placed in the center of the blood vessel, and the width of the sampling range gate was 2 mm. Doppler angle correction was performed when measuring velocity, with the calibration main line parallel to the direction of blood flow and at an angle of 50–60°. All transverse and anteroposterior diameters were measured by M-mode ultrasound. All ultrasound recordings were performed by a specified board-certified ultrasound specialist, and anesthesiologists and parturients were blinded to the examination results.

The parturient was then transferred to the operating room. After entering the room, an intravenous (IV) line was established with an 18-G IV catheter in the dorsum or wrist vein, on the right hand. Standard monitoring with electrocardiography, non-invasive blood pressure, and pulse oximetry were performed continuously. The cuff of the automated non-invasive blood pressure monitor was attached to the left arm. Systolic arterial pressure (SAP), heart rate (HR), and pulse oximetry were measured once per minute. The first two resting SAP and HR measurements with the parturient in the supine position were recorded and the average values were recorded as baseline SAP and HR measurements. If the baseline SAP was above 140 mmHg, the parturient was excluded from the study because of suspected hypertension. A CSE puncture was performed at the L3–4 level with the parturient in the right lateral decubitus position. After the cerebrospinal fluid was detected, 0.75% isobaric ropivacaine 12 mg with fentanyl 10 μg was injected intrathecally via a 27-G Whitacre needle and an epidural catheter was inserted via an 18-G Tuohy needle by advancing it 3 cm into the epidural space. The parturient was moved immediately to a supine position with left uterine displacement by placing a wedge under the right hip. Meanwhile, an open co-loaded infusion rate of 1 mL/kg/min of lactated Ringer's solution was administered until delivery. Parturients were excluded from the study if they could still feel the pinprick sensation below the T6 level at the beginning of surgery.

Hypotension was defined as having a drop of SAP >20% from the baseline value before delivery. If hypotension happened, a rescue phenylephrine bolus of 50 μg was administered by the anesthesiologist, and a phenylephrine bolus was administered every time the parturient presented with hypotension before delivery. Bradycardia was defined as a HR below 50 beats per minute (bpm). If bradycardia was identified, 0.5 mg of atropine was administered. After delivery, the Apgar scores at 1 and 5 min and neonatal body weight were recorded. 1 mL of umbilical artery (UA) blood was collected by the obstetrician immediately after delivery, and blood gas assessments were performed using a blood gas analyzer (iSTAT1 Analyzer MN:300-G; Abbott Point of Care Inc., Princeton, NJ, USA) with an iSTAT CG4+ test cartridge.

The primary outcomes were the peak velocities and anteroposterior diameter values of the AA and IVC below the xiphoid and the transverse diameter and peak velocity values of the RCFV and RCFA, as measured by ultrasound before anesthesia, and the association between these measurements and post-spinal hypotension during cesarean delivery. Patient and obstetric characteristics such as age, weight, height, BMI, gravidity, parity, gestational weeks, induction-delivery interval, upper sensory level, total intravenous fluid before delivery, neonatal body weight, 1 min and 5 min Apgar scores, and the pH of UA blood were also recorded.

Statistical analysis and sample size calculation

Based on our previous study, the odds ratio (OR) of the association between the perfusion index (PI) on the right toe and post-spinal hypotension during cesarean delivery was 0.49 (95% confidence interval [CI] 0.32 to 0.75, P = 0.0001).[8] A logistic regression OR = 2–2.5 (equal to an OR = 0.4–0.5) was assumed in this study. To measure the OR at a power of 0.9, a two-tailed α of 0.05, and a baseline prevalence of 40%, this study needed a maximal sample size of 52.[9] Considering a dropout rate of 10%, a sample size of 58 was required.

The patient and obstetric characteristics were presented as mean ± standard deviation or median (interquartile range [IQR]), as appropriate, and were analyzed by an unpaired Student's *t*-test, Fisher's exact probability test, or Pearson's Chi-Square test, as appropriate.

IVC, AA, RCFV, and RCFA measured in the supine position, were analyzed by multinomial logistic regression analysis to determine if they were independently associated with the incidence of post-spinal hypotension. Then, area under the receiver operating characteristic (ROC) curves were used to test the ability of the identified parameters to predict post-spinal hypotension, and the area under the curve (AUC) was calculated. The AUC is a measure of the accuracy of a parameter (AUC $\leq$ 0.5 indicates no predictive ability and AUC = 1.0 indicates the best possible prediction). The maximal value of Youden's index was used as the criterion for selecting the optimum cut-off values of the predictive parameters, and the Youden's index = sensitivity + specificity – 1.

All statistical analyses were performed using SPSS for Windows version 24.0 (SPSS Inc., Chicago, IL, USA). Statistical significance was set at $P < 0.05$.

Results

A total of 122 parturients were recruited, and 64 parturients were excluded from the study because they did not meet the inclusion criteria, they declined to participate, or because an ultrasound operator was not available. Ultrasound measurements were completed successfully in the remaining 58 parturients. Two parturients showed a sensory level below T6 at the beginning of surgery without hypotension. Finally, 56 parturients were followed up and analyzed (Fig. 2).

Hypotension occurred in 24 (43%) parturients. Patient characteristics in the hypotension and no hypotension groups are presented in Table 1, and the obstetric characteristics of the two groups are presented in Table 2. Maternal BMI was greater in the hypotension group ($P = 0.04$). The mean neonatal weight was significantly heavier in the hypotension group than in the no hypotension group ($P = 0.015$). There was no significant differences with respect to age, weight, height, gravity, parity, gestational age, baseline SAP, HR, induction to delivery interval, upper sensory level, total fluid before delivery, surgery time, 1 min and 5 min Apgar scores, and pH of UA blood between the two groups (Tables 1 and 2).

Table 1
Patient Characteristics

	Hypotension (n = 24)	No hypotension (n = 32)	P value
Age (year)	32.5 ± 4.5	32.6 ± 4.1	0.986
Weight (kg)	74.2 ± 9.7	69.5 ± 7.3	0.050
Height (cm)	163.2 ± 3.9	163.4 ± 4.7	0.860
BMI	27.9 ± 3.5	26.1 ± 2.8	0.040
Gravity (n)	[a]2(1-2.75)	[a]1(1–2)	0.155
Parity (n)	[a]0(0–0)	[a]0(0–0)	0.571
Gestational age (weeks)	39.1 ± 1.1	38.7 ± 0.8	0.120
Baseline SAP (mmHg)	123 ± 12	121 ± 9	0.530
Baseline HR (bpm)	84 ± 12	83 ± 11	0.891

Values are mean ± SD or [a]median (IQR). BMI, body mass index; SAP, systolic arterial pressure; bmp, beats per minute; SD, standard deviations; IQR, interquartile range.

Table 2
Obstetric characteristics

	Hypotension (n = 24)	No hypotension (n = 32)	P value
Induction-delivery interval (min)	11.8 ± 3.1	11.3 ± 3.7	0.635
Upper sensory level	[a]T5 (T4-T6)	[a]T5 (T4-T6)	0.530
Total intravenous fluid before delivery (mL)	374 ± 81	354 ± 90	0.403
Surgery time (min)	46.2 ± 16.6	43.8 ± 14.8	0.579
Neonatal body weight (g)	3712 ± 414	3416 ± 463	0.015
1 min Apgar	[a]10 (10–10)	[a]10 (10–10)	0.571
5 min Apgar	[a]10 (10–10)	[a]10 (10–10)	1.000
Umbilical artery pH	7.30 ± 0.04	7.31 ± 0.03	0.551

Values are mean ± SD or [a]median (IQR). min, minute; SD, standard deviations; IQR, interquartile range.

Table 3 shows the AP diameters and peak velocities of the IVC and AA, and the transverse diameters and peak velocities of the RCFA and RCFV in the hypotension group and no hypertension group. The transverse diameter of the RCFV in the hypotension group was significantly longer than that of the RCFV in the no hypotension group (P = 0.000).

Table 3
The parameters of vessels probed by ultrasound between two groups.

	Hypotension (n = 24)	**No hypotension (n = 32)**	**P value**
AP diameter of IVC (mm)	12.0 ± 2.2	11.5 ± 1.6	0.227
Peak velocity of IVC (cm/s)	33.6 ± 15.7	39.1 ± 16.3	0.094
AP diameter of AA (mm)	15.5 ± 1.2	15.4 ± 1.2	0.423
Peak velocity of AA (cm/s)	61.9 ± 17.4	64.5 ± 17.8	0.475
Transverse diameter of RCFA (mm)	6.7 ± 0.6	6.4 ± 0.6	0.139
Peak velocity of RCFA (cm/s)	72.5 ± 18.8	80.3 ± 25.6	0.208
Transverse diameter of RCFV (mm)	12.8 ± 1.7	11.2 ± 1.4	0.000
Peak velocity of RCFV (cm/s)	8.2 ± 3.5	8.5 ± 4.9	0.810

Values are mean ± SD. AP, anteroposterior; IVC, inferior vena cava; AA, abdominal aorta; RCFA, right common femoral artery; RCFV, right common femoral vein; SD, standard deviations.

Table 4 shows that the transverse diameter of the RCFV, as measured by ultrasound with the parturient in the supine position, was a risk factor for post-spinal hypotension during cesarean delivery (OR = 2.022, 95% CI 1.261–3.243, P = 0.003). Other parameters measured by ultrasound were not risk factors for post-spinal hypotension.

Table 4. Results of multinomial logistic regression analysis to predict

the incidence of post-spinal hypotension during elective cesarean delivery

	OR	95% CI		P value
		lower limit	upper limit	
AP diameter of IVC	0.824	0.642	1.056	0.125
Peak velocity of IVC	1.029	0.997	1.062	0.079
AP diameter of AA	0.963	0.665	1.396	0.844
Peak velocity of AA	1.000	0.972	1.028	0.988
Transverse diameter of RCFA	1.722	0.545	5.446	0.355
Peak velocity of RCFA	0.978	0.945	1.012	0.199
Transverse diameter of RCFV	2.022	1.261	3.243	0.003
Peak velocity of RCFV	1.063	0.903	1.250	0.465

AP, anteroposterior; IVC, inferior vena cava; AA, abdominal aorta;

RCFA, right common femoral artery; RCFV, right common femoral vein.

OR, odds ratio; 95% CI, 95% confidential interval.

The ROC analysis revealed that the transverse diameter of the RCFV with the parturient in the supine position was suitable for prediction of parturients at risk of hypotension (AUC = 0.759, 95% CI 0.628–0.890, P = 0.001) (Fig. 3). The optimum cut-off point on maximum Youden index was 12.2 mm with a sensitivity of 62.5%, specificity of 78.1%, positive predictive value of 68.2%, and negative predictive value of 73.5%.

Discussion

In this study, anteroposterior diameters and peak velocities of the IVC and AA below the xiphoid, as well as the transverse diameter and peak velocities of the RCFA and RCFV, were measured by ultrasound before anesthesia. We hypothesized that the diameters and peak velocities before anesthesia could reflect the degree of aortocaval compression, and further predict parturients at risk of hypotension. As a result, the transverse diameter of the RCFV was found to be a risk factor for hypotension after spinal anesthesia during cesarean delivery, and a cut-off value of > 12.2 mm could be used to predict subsequent hypotension.

Many studies have demonstrated that velocities or diameters of the compressed IVC and AA could indicate the degree of aortocaval compression by the gravid uterus, and could change dramatically in the supine position during late pregnancy using magnetic resonance imaging (MRI).[10,11,12,13] Lee et al. also demonstrated a dramatic change in cardiac output on suprasternal Doppler with patients in the supine position in late pregnancy.[14] However, none of these studies further clarified the relationship between the degree of aortocaval compression and the incidence of hypotension after spinal anesthesia during cesarean delivery. In this study, anteroposterior diameters and velocities of the IVC and AA below the xiphoid at the proximal end of the compressed IVC and AA, measured by cardiac probe, were chosen as the indirect parameters of the compression degree of the IVC and AA. This was because the compressed IVC, AA, and their main branches were under the gravid uterus or located in the pelvic cavity, which made them difficult to probe on ultrasound. However, these indirect parameters of the IVC and AA could not reflect the real compression degree of the IVC or AA by the uterus. Thus, none of the IVC or AA parameters were risk factors for hypotension after spinal anesthesia during cesarean delivery.

The RCFA and RCFV, as the main extensions of the right extra-iliac artery and vein, respectively, are the sub-branches of the AA and IVC. As they are close to the body surface, they can be easily detected by a high frequency probe. More importantly, the RCFA and RCFV are located at the distal part of the aortocaval compressed point, so we hypothesized that the peak velocities and diameters of the RCFA and RCFV would have more significance than the indirect parameters of the AA and IVC below the xiphoid in women at high risk of hypotension after spinal anesthesia during cesarean delivery. As a result, the transverse diameter of the RCFV was found to be a risk factor for hypotension after spinal anesthesia, which further proved our hypothesis. However, the transverse diameter and velocity of the RCFA could not identify the women at risk of hypotension after spinal anesthesia, and the arterial vessels did not change shape dramatically, even under compression by the uterus.

Many studies have suggested that preoperative baseline vascular tone and central blood volume are related to the incidence of hypotension after spinal anesthesia during cesarean delivery. Thus, PI, pleth variability index (PVI), HR, or heart rate variability (HRV) were used to predict the hypotension. Both Toyama[5] and Duggappa[15] demonstrated that a baseline PI of the index finger of > 3.5 could predict the incidence of spinal anesthesia-induced hypotension during cesarean delivery. Sun found greater baseline PVI was associated with hypotension after spinal anesthesia for cesarean delivery, but that it may not be a clinically useful predictor.[16] Meanwhile, Kuwata et al. demonstrated PVI immediately after anesthesia was a good predictor of hypotension.[17] Frölich demonstrated that a baseline HR over 90 bpm may be useful to predict post-spinal hypotension.[18] Yokose et al. also demonstrated that a HR of < 71 bpm and > 89 bpm are prognostic values that are useful for predicting hypotension, but other parameters such as PVI, PI, and HRV are not useful.[19] Hanss et al. found that changes in HRV may reflect sympatholysis during spinal anesthesia, and preoperative HRV could be a predictor of patients at risk of hypotension after spinal anesthesia.[20,21] Although some of the above parameters could effectively predict hypotension after spinal anesthesia, in most cases, additional medical appliances are required for detection. While ultrasound becomes an essential means, just like anesthesia machine to anesthesiologists, and can easily be accessed by most anesthesiologists. Moreover, in recent years, imaging examinations such as ultrasound and MRI have also been used to identify aortocaval compression by a gravid uterus. Humphries et al. found that the IVC velocities at the level of origin and at the level of the renal veins was significantly reduced, while that of the azygos vein increased significantly on MRI. [22,23] This observation was made with the parturient in the supine position compared to the left lateral position in pregnancies between 34–38 weeks' gestation without anesthesia. Fields et al. found that on ultrasound, 76% of pregnant patients had a maximum IVC diameter in the left lateral tilt position at the level of 2 cm distal to the branching of the hepatic vein.[24] Zieleskeiwicz et al. found the changes in velocity-time integral of subaortic flow, as measured by ultrasound with a cardiac probe, when the parturient was changed from a supine position to a position with their legs elevated could predict hypotension after spinal anesthesia.[25]

However, the point of the probe in all above-mentioned studies was above the proximal part of the aortocaval compression point, and all these parameters reflected the degree of aortocaval compression indirectly. Xu et al. demonstrated that the right and left toe perfusion index value could effectively predict the incidence of post-spinal hypotension during cesarean delivery.[8] Similar to our study, their observed parameters were also located at the distal part of the aortocaval compression point, which could effectively indicate the degree of aortocaval compression and predict the incidence of post-spinal hypotension.

A height of within 155–170 cm was chosen as a criterion of enrollment so as to eliminate the height bias that exists with post-spinal hypotension; however, this must be noted as a limitation of the study. Therefore, the RCFV transverse diameter cut-off value for parturients with a height outside this range needs be researched further.

Conclusions

We demonstrated that the transverse diameter of the RCFV, as measured on ultrasound, was a predictor of post-spinal hypotension during elective cesarean delivery and a transverse RCFV diameter beyond 12.2 mm could effectively predict parturients at risk of hypotension before anesthesia. The transverse diameter of the RCFV by ultrasound may be a useful method to predict hypotension after CSE anesthesia during elective cesarean delivery in everyday practice.

List Of Abbreviations

AA = abdominal aorta; IVC = inferior vena cava; RCFA = right common femoral artery; RCFV = right common femoral vein; OR = odds ratio; CI = confidence interval; CSE = combined spinal epidural; ASA = American Society of Anesthesiology; BMI = body mass index; IV = intravenous; SAP = systolic arterial pressure; HR = heart rate; UA = umbilical artery; PI = perfusion index; IQR = interquartile range; ROC = receiver operating characteristic; AUC = area under the curve; AP = anteroposterior; MRI = magnetic resonance imaging; PVI = pleth variability index; HRV = heart rate variability

Declarations

Ethics approval and consent to participate: This study was approved by the Research Ethics Committee of the International Peace Maternity and Child Health Hospital (Ethical number: GKLW 2017-85). All participants provided informed consent to participate.

Availability of data and materials: The datasets generated and analyzed during the current study are available in the ultrasound.xlsx.

Consent for publication: Yes.

Competing interests: The authors declare that they have no competing interests.

Funding: Clinical Science and Technology Innovation Program from Shanghai Shen Kang Hospital Development Center (SHDC12016225 to Z.X.) .

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Critical revision and final approval of the manuscript: [Tao Xu, Zifeng Xu]

All authors have approved the submitted version and have agreed both to be personally accountable for their own contributions and ensure that questions related to the accuracy or integrity of any part of the work, even ones in which he/she was not personally involved, are appropriately investigated, resolved, and the resolution documented in the literature.

Acknowledgments:

The work was supported by Clinical Science and Technology Innovation Program from Shanghai Shen Kang Hospital Development Center (SHDC12016225 to Z.X.); Chinese Academy of Medical Sciences Research Unit (No. 2019RU056), Shanghai Jiao Tong University; CAMS Innovation Fund for Medical Sciences (CIFMS) (No. 2019-I2M-5-064) and Shanghai Municipal Key Clinical Specialty, Shanghai, China.

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Figures

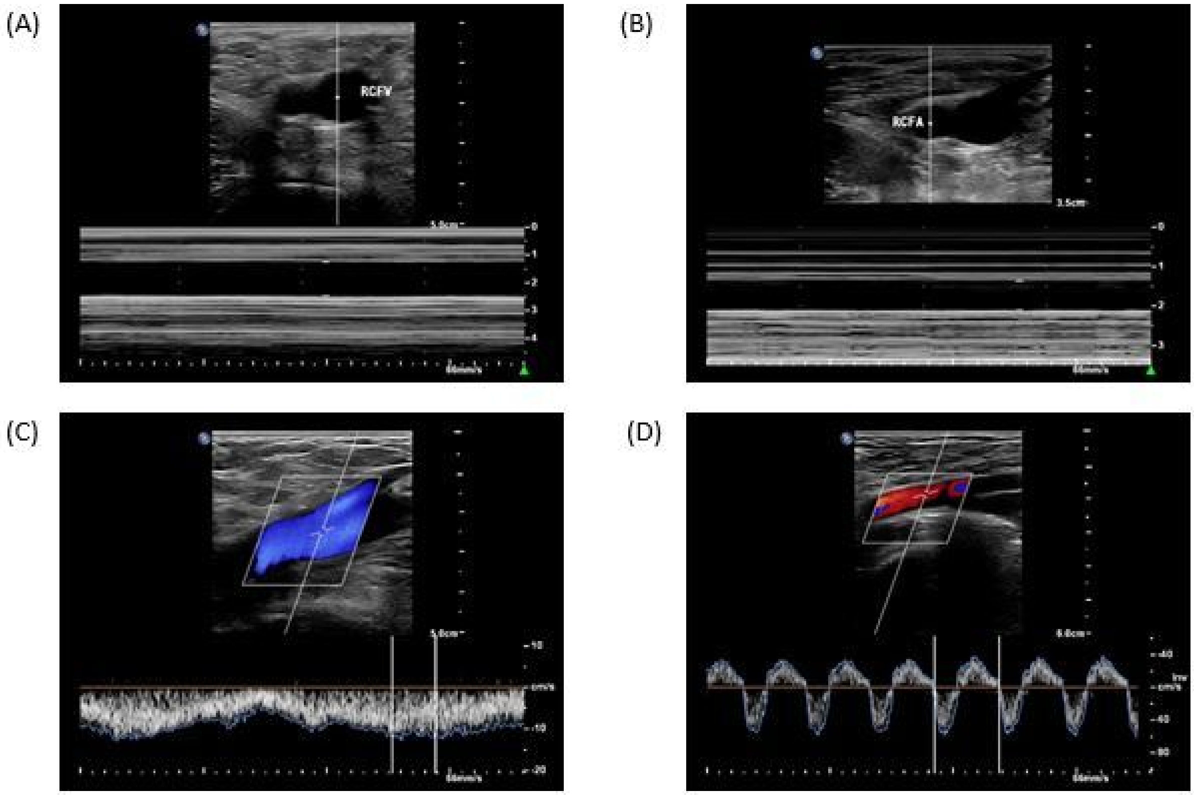

Figure 1

(A) M-mode image showing the transverse diameter of RCFV; (B) M-mode image showing the transverse diameter of RCFA; (C) Pulsed-wave Doppler-mode image showing the peak velocity of RCFV; (D) Pulsed-wave Doppler-mode image showing the peak velocity of RCFV. RCFV, right common femoral vein; RCFA, right common femoral artery.

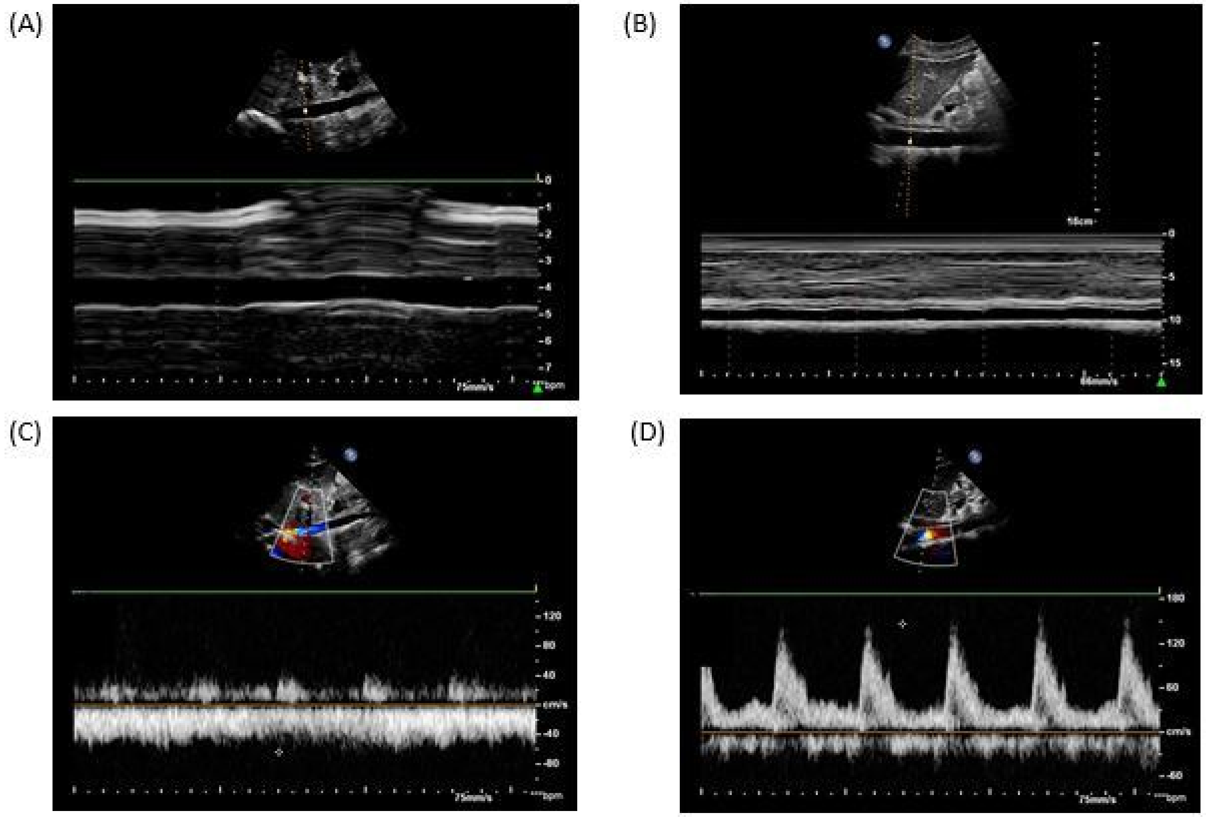

Figure 2

(A) M-mode image showing the anteroposterior diameter of IVC; (B) M-mode image showing the anteroposterior diameter of AA; (C) Pulsed-wave Doppler-mode image showing the peak velocity of IVC; (D) Pulsed-wave Doppler-mode image showing the peak velocity of AA. IVC, inferior vena cava; AA, abdominal aorta.

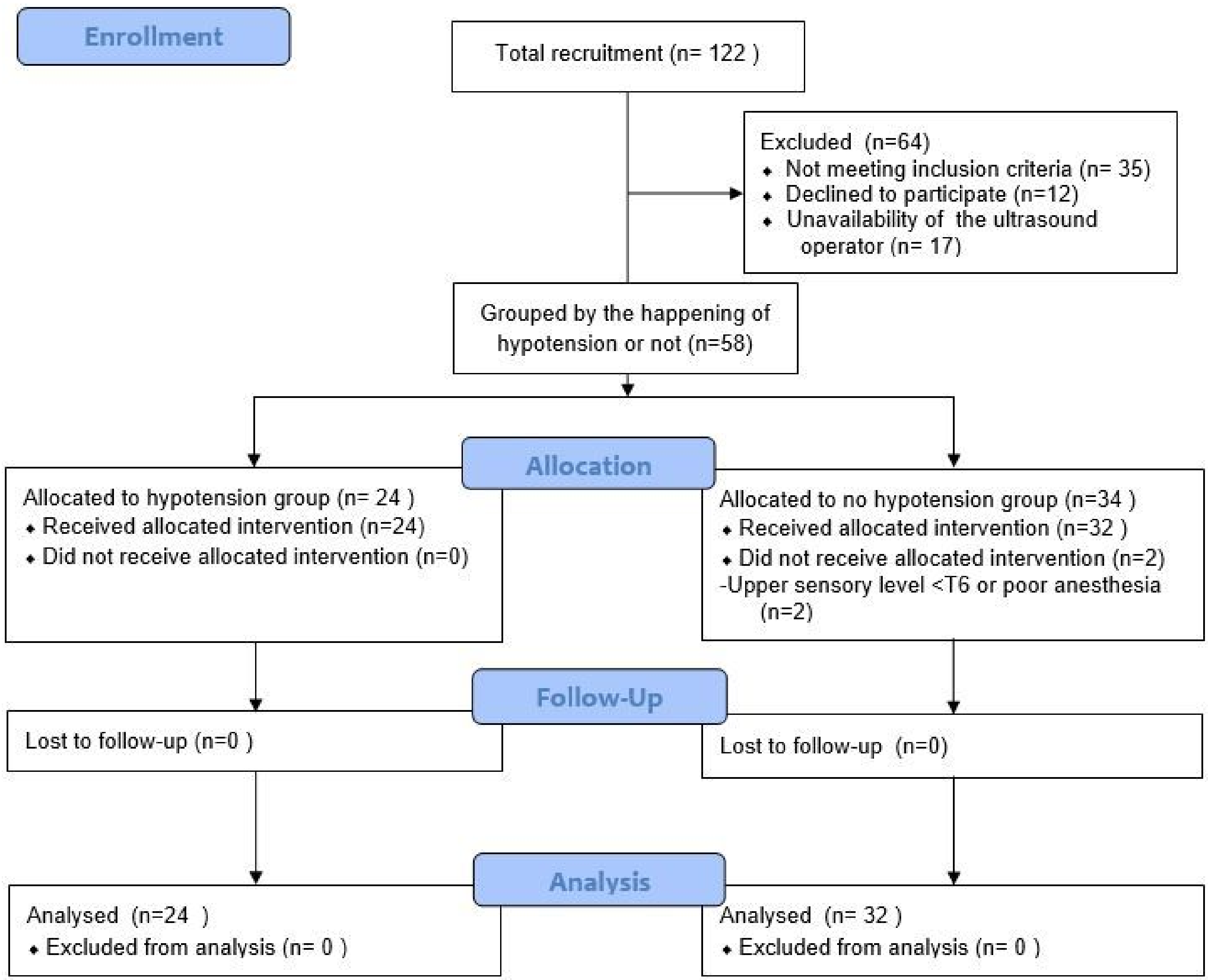

Figure 3

CONSORT flow diagram

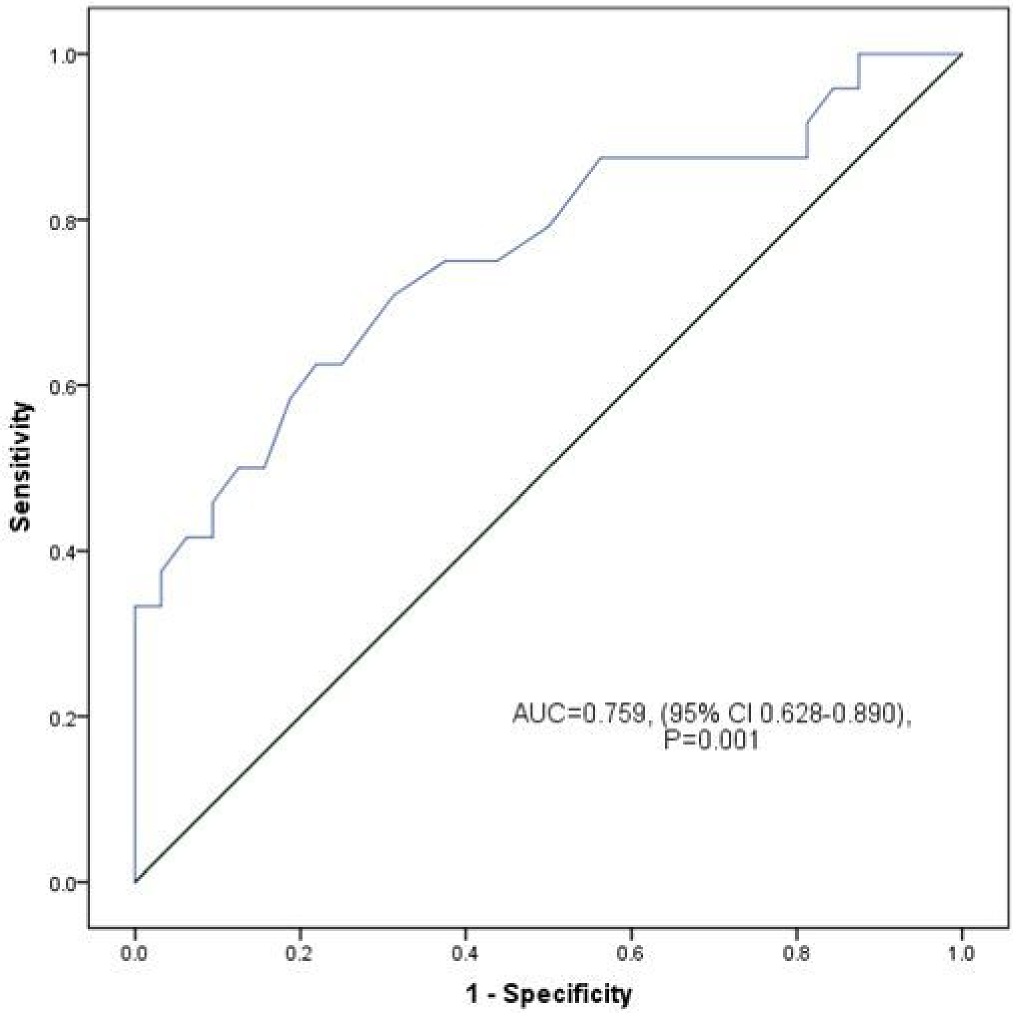

Figure 4

Receiver operating characteristics (ROC) curve of transverse diameter of RCFV for prediction of post-spinal hypotension. RCFV, right common femoral vein.

Supplementary Files

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- ultrasound.xlsx