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Can the inferior vena cava collapsibility index be useful in predicting hypotension during spinal anaesthesia in a spontaneously breathing patient? A mini fluid challenge

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The study was performed at the Department of Orthopaedics and Traumatology of the Kauno Klinikos Hospital of Lithuanian University of Health Sciences.

Background. Intravascular fluids are empirically administered to prevent hypotension induced by spinal anaesthesia. Ultrasound measurements of the inferior vena cava (IVC) and the IVC collapsibility index (IVC-CI) is a non-invasive method to evaluate the intravascular volume status. The aim of the study was to identify the prognostic value of the IVC collapsibility index in spontaneously breathing patients to predict severe intraoperative hypotension.

Materials and methods. Sixty patients undergoing elective knee arthroplasty under spinal anaesthesia were included in the prospective study. The diameters of IVC_{ex}, IVC_{in}, and IVC-CI were measured before and 15 min after spinal anaesthesia when administration of 500 ml of normal saline using infusion pump was finished. The haemodynamic parameters (heart rate, systolic, diastolic, and mean blood pressures, breathing rate) were collected.

Results. Severe arterial hypotension was noticed in 18.3% of the patients. No statistically significant differences were detected between changes in IVC_{ex}, IVC_{in}, and IVC-CI comparing hypotensive and non-hypotensive patients at the baseline and after the interventions ($p > 0.005$). According to receiver operating characteristic (ROC) analysis, IVC-CI is not effective in the prediction of severe hypotension during spinal anaesthesia in spontaneously breathing patients: the area under the ROC curve for IVC-CI was <0.7, $p > 0.05$.

Conclusions. IVC-CI is not an effective predictor of severe hypotension after induction of spinal anaesthesia followed by normal saline administration in spontaneously breathing patients undergoing elective knee arthroplasty. More trials, including different patient subgroups, will be needed.

Keywords: spinal anaesthesia, hypotension, fluid therapy, inferior vena cava, collapsibility index

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INTRODUCTION

One of the methods to provide safe and effective intraoperative analgesia during knee arthroplasty is spinal anaesthesia (SA). Hypotension is one of the common haemodynamic disorders (1). During the SA, sympathetic fibres are blocked and, as a result, sympathetic denervation is caused. Hypotension during SA can be caused by decreased heart preload or reduced systemic vascular resistance (relative hypovolemia) (2, 3).

Administration of intravascular fluids is one of the methods to prevent SA-induced hypotension. The risk of fluid overload during elective surgery was presented because intraoperative volume repletion is generally empirical (4, 5). Over fluid resuscitation is associated with organ dysfunction and higher mortality rate (6), thus, to avoid ineffective or even harmful intravascular volume expansion, it is important to have tools to predict hypotension and fluid responsiveness.

Ultrasound examination of the inferior vena cava (IVC) and the IVC collapsibility index (IVC-CI) is one of the useful, effective, and non-invasive methods to evaluate the intravascular volume status in mechanically ventilated patients. According to the literature, this method is inaccurate in spontaneously breathing critically ill patients (7, 8) while there is less data on non-critically ill patients (9).

The aim of this study was to identify the prognostic value of the IVC collapsibility index in spontaneously breathing patients undergoing elective knee arthroplasty to predict severe intraoperative hypotension.

METHODS

This prospective study was performed at the Department of Orthopaedics and Traumatology in the Kauno Klinikos Hospital of the Lithuanian University of Health Sciences from the 1 March to the 31 May 2016. The study was approved by Kaunas Regional Biomedical Research Ethics Committee (No. BE-2-5 issued on 18 February 2016).

Adult patients (>18 years) undergoing elective knee joint replacement surgery under spinal anaesthesia were enrolled in this study. The flow chart of patient enrolment is presented in Fig. 1. Written informed consent was obtained from all patients. Demographic data (age, sex, body mass index (BMI), body surface area (BSA), ASA status) were collected.

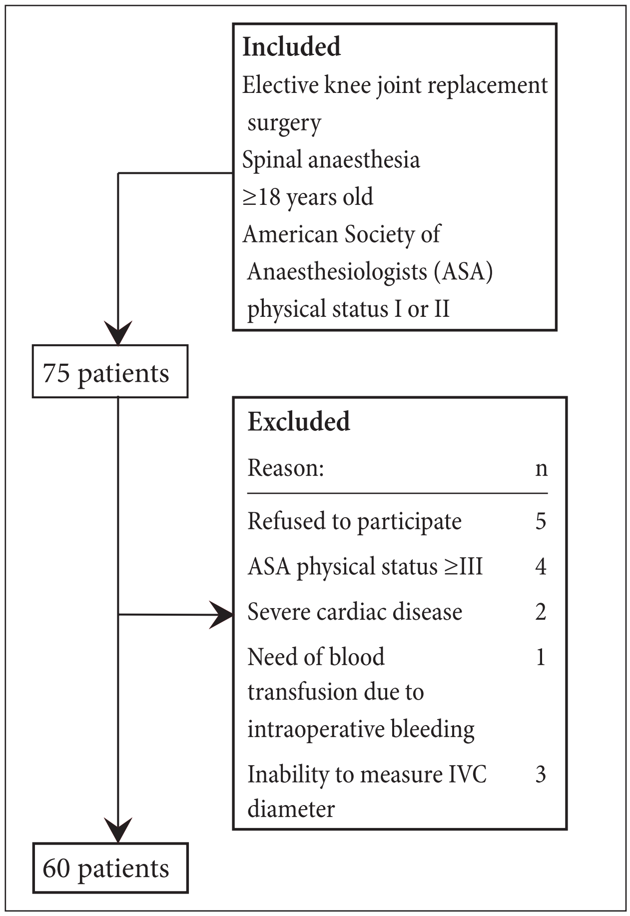

Fig. 1. Flow chart of patient enrolment

Interventions

An intravenous cannula was placed and the standard monitoring (electrocardiography, pulse oximetry, and non-invasive blood pressure) was started upon arrival to the operating room. After baseline measurements were done, administration of normal saline was started with an infusion pump and 500 ml were administered during the first 15 min after the beginning of SA. In the lateral decubitus position the subarachnoid space was identified and 15–17 mg of levobupivacaine was administered. After the SA was performed, patients were rotated in the supine position. A cold test with alcohol wipe was performed to determine the level of the sensory block.

Measurements

All measurements were noted twice: at the baseline and after the intervention. The baseline parameters were recorded before beginning of SA. The next measurements were performed 15 min after the intrathecal administration of levobupivacaine and fluid therapy of 500 ml of normal saline was finished.

The haemodynamic parameters: heart rate (HR, beats per minute, bpm), systolic (SBP) and diastolic (DBP) blood pressures, mean arterial blood pressures (MAP), breathing rate (breaths per minute, b/min) were collected. Hypotension was considered when the SBP value dropped below baseline by more than 30%.

All measurements of IVC were performed in the supine position with one leg bent as this position was needed for surgery. IVC was visualised, and IVC_{ex} and IVC_{in} were measured in the subcostal long axis view. The measurements were taken in M-mode 1–2 cm below the level of the hepatic veins (7, 9–11). IVC-CI was calculated using the following equation: IVC-CI = ((IVCex – IVCin)/IVCex) × 100% (10).

Statistical analysis

The statistical analysis was performed using IBM SPSS 22.0 software. The Kolmogorov–Smirnov test was used to determine normal distribution of the data. The choice of statistical tests depended on the sample size and data distribution. Categorical variables were compared using the Chi-square test. Not normally distributed quantitative variables were compared using the Mann-Whitney test. For normally distributed quantitative variables we applied Student *t*-test. Pearson correlation coefficient was used to detect the correlation between the variables. A receiver operating characteristic (ROC) curve was plotted to determine the threshold value of IVC-CI which provided the prediction of hypotension. We assumed IVC-CI to be clinically relevant if the area under the curve (AUC) was >0.7. The data are presented as mean with standard deviation or median with a range. Statistical significance was determined as $p < 0.05$.

RESULTS

Demographic data and clinical characteristics of the patients are presented in Table 1. There was no significant difference in demographic characteristics between hypotensive and non-hypotensive patients.

Although hypotension during SA was common in almost all patients, severe hypotension (drop of arterial blood pressure >30% from the baseline) was registered in 18.3% ($n = 11$) of the patients. No statistically significant differences were detected between changes in IVC_{ex}, IVC_{in}, and IVC-CI comparing hypotensive and non-hypotensive patients at the baseline and after the interventions (15 min after the beginning of SA). The variations of haemodynamic parameters and ultrasonography indices are shown

Table 1. Demographic data and clinical characteristics of the patients

	Total	Hypotensive 11 (18.3%)	Non-hypotensive 49 (81.7%)	*p* value
Age, mean (SD), years	69.35 (9.14)	70.45 (7.37)	69.1 (9.54)	**0.3**
Sex, *n* (%)				
Male	14 (23.3)	4 (28.6)	10 (71.4)	**0.258**
Female	46 (76.7)	7 (15.2)	39 (84.8)	
ASA class, *n* (%)				
I	8 (13.3)	1 (12.5)	7 (87.5)	**0.647**
II	52 (86.7)	10 (19.2)	42 (80.8)	
BMI, mean (SD), kg/cm^2	30.97 (4.77)	32.93 (4.5)	30.53 (4.76)	**0.919**
BSA, mean (SD), m^2	2.04 (0.18)	2.11 (0.17)	2.03 (0.18)	**0.542**
Breathing rate, mean (SD), b/min	16 (2)	15 (1.8)	16 (2.3)	**0.32**
Sensory block, *n* (%)				
Th 10	42 (70)	7 (16.7)	35 (83.3)	**0.764**
Th 11	18 (30)	4 (22.2)	14 (77.8)	

in Table 2. Also, we found no statistically significant correlation between MAP and IVC-CI ($r = -0.012$, $p = 0.927$) after the interventions.

IVC-CI does not predict severe hypotension during SA; the receiver operating characteristic (ROC) curve is presented in Fig. 2. The AUC of the ROC curve for prediction of severe hypotension was less than 0.7 and p value more than 0.05 (baseline: AUC 0.5 (95% CI 0.28, 0.72, $p = 0.975$); after interventions: AUC 0.44 (95% CI 0.24, 0.63, $p = 0.535$)).

Table 2. Comparison of haemodynamic parameters and ultrasonography indices between the groups

	Baseline			After interventions		
	Hypotensive	Non-hypotensive	*p* value	Hypotensive	Non-hypotensive	*p* value
MAP, mean (SD), mmHg	104 (12.76)	91 (12.1)	**0.675**	64 (9.8)	79 (10.5)	**0.001**
HR, mean (SD), bpm	71.56 (13.06)	74.22 (13.06)	**0.37**	62 (9.39)	64 (11.47)	**0.461**
IVC_{ex}, median (range), mm	11.8 (7.8–21.7)	12.6 (5.67–32.2)	**0.612**	12.5 (9.59–15.4)	13.5 (6.88–24.8)	**0.660**
IVC_{in}, median (range), mm	7.58 (2.29–14.5)	8.2 (2.67–22.9)	**0.828**	8.28 (4.34–12.6)	8.72 (2.67–17.4)	**0.593**
IVC-CI, median (range), %	33 (14–71)	35 (3–78)	**0.975**	24 (9–61)	30 (3–80)	**0.789**

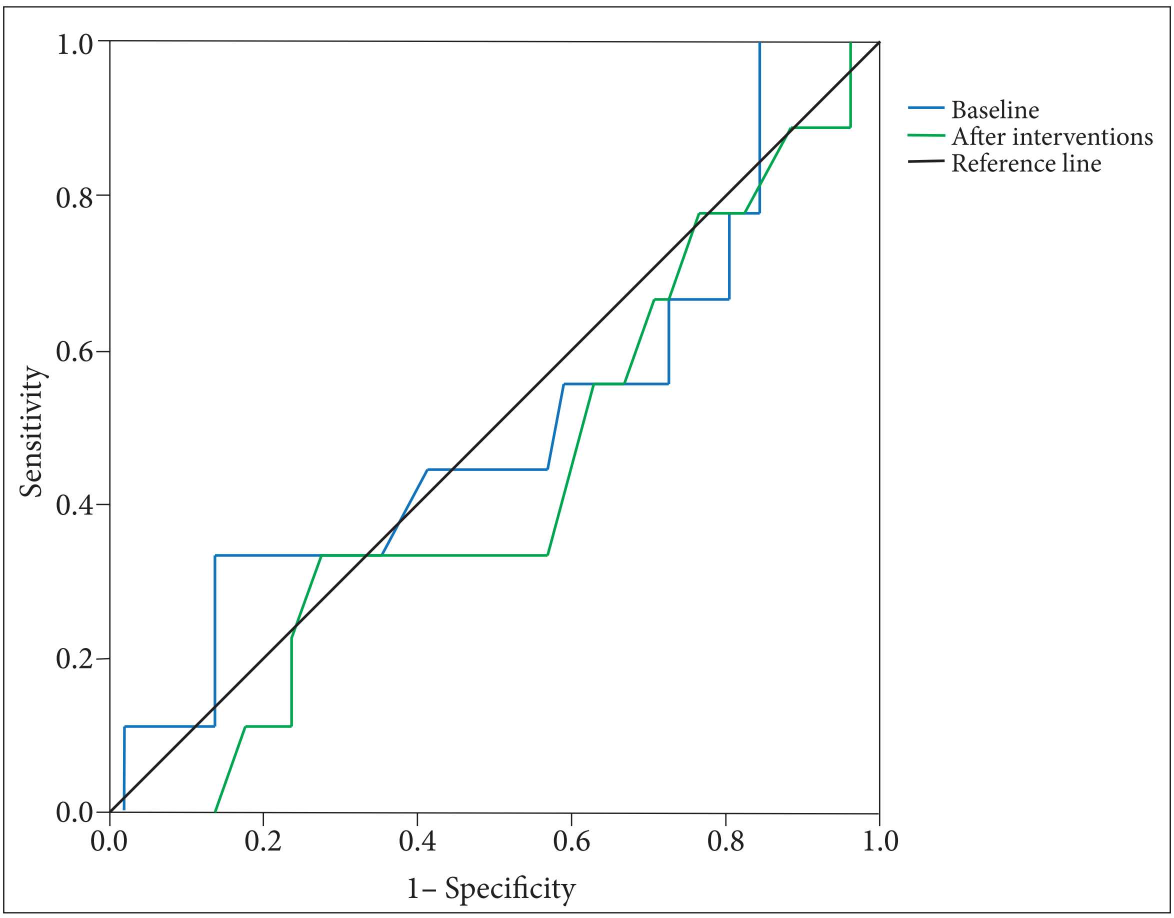

Fig. 2. The ROC curve analysis of the IVC-CI during SA after mini fluid therapy in elective knee arthroplasty as predictor of severe hypotension. The relationship between true-positive (sensitivity) and false-positive (1 – specificity). AUC baseline is 0.5 ($p > 0.05$), AUC after interventions – 0.44 ($p > 0.05$)

DISCUSSION

An adequate tissue perfusion during surgery is crucial to prevent the adverse outcomes (12). SA is one of the common methods of intraoperative analgesia during knee replacement surgery. SA-induced sympathetic denervation causes a dilatation of peripheral blood vessels. The haemodynamic changes depend on the relationship between dilation of venous and arterials (13). This may lead to reduced heart preload and hypotension, which can be associated with hypoperfusion (14). Therefore, it is important to evaluate intravascular volume status during the surgery. We hypothesized that reduction of heart preload and development of hypotension during SA can be associated with the increased collapsibility index of IVC.

The rate of severe hypotension in our population was 18.3%. The incidence of hypotension in our study was lower compared to the literature (1, 14, 15) during SA followed by mini fluid therapy. There are three general determinants of blood pressure: intravascular volume status, cardiac output, and systemic vascular resistance (SVR) (generally determined by sympathetic activity) (6). SA-induced sympathetic denervation causes the reduction of SVR, which leads to relative hypovolemia (2, 3). We failed to find statistically significant differences in changes of IVC_{in}, IVC_{ex}, and IVC-CI between the hypotensive and non-hypotensive patients after the intervention. The intravascular volume status did not significantly change after SA was performed as it was followed by mini fluid therapy. We suggest that if heart preload does not change, the main reason of SA-induced hypotension followed by mini fluid therapy is the reduction in SVR. It is logical that in this state the main treatment of SA-induced hypotension should be vasopressors (16).

Our study showed that the IVC collapsibility index is not a useful tool to predict severe hypotension during SA followed by fluid therapy in spontaneously breathing patients undergoing elective knee arthroplasty, as the AUC of the ROC curve for IVC-CI was <0.7 ($p > 0.05$). Some studies find opposite results. For example, Zhang et al. (17) found that IVC-CI helped to predict hypotension during general anaesthesia after induction. The main reasons of different results are: the type of anaesthesia (general vs. spinal), a different population, and the type of surgery.

Furthermore, it is important to note that the inferior vena cava is a large vessel, the diameter of which depends on changes in extrinsic and intrinsic factors. It is known that changes in the intrathoracic pressure and in the breathing manner significantly affect the IVC diameter in a spontaneously breathing patient (18, 19). We asked patients to breathe normally while the measurements of IVC were taken. Moreover, individual properties of the IVC wall, elasticity in particular, may affect the measurement results (20).

CONCLUSIONS

An increase in IVC-CI does not help to identify severe hypotension during SA after normal saline administration in spontaneously breathing patients undergoing elective knee arthroplasty. The circulating blood volume and heart preload did not change after intravascular administration of crystalloids during SA. More trials, including different patient subgroups, will be needed.

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SPONTANIŠKAI KVĖPUOJANČIŲ PACIENTŲ APATINĖS TUŠČIOSIOS VENOS VARIABILUMO INDEKSO VERTĖ PROGNOZUOJANT HIPOTENZIJĄ SPINALINĖS ANESTEZIJOS METU. INFUZINĖS TERAPIJOS ĮTAKA

Santrauka

Tikslas. Siekiant išvengti hipotenzijos per spinalinę anesteziją infuzinė terapija dažniausiai skiriama empiriškai. Ultragarsu išmatuojamas apatinės tuščiosios venos (ATV) diametras bei ATV kintamumo indeksas (ATV-VI) yra neinvazinis metodas, leidžiantis įvertinti cirkuliuojantį kraujo tūrį. Tyrimo tikslas – įvertinti ATV-VI prognostinę reikšmę, atsižvelgiant į sunkią hipotenziją operuojant spontaniškai kvėpuojančius pacientus.

Medžiaga ir metodai. Prospektyviniame tyrime dalyvavo 60 pacientų, kuriems buvo atliekama kelio sąnario endoprotezavimo operacija taikant spinalinę anesteziją. ATV iškvėpimo ir įkvėpimo diametrai bei ATV-VI buvo matuojami prieš ir 15 min. po spinalinės anestezijos, naudojant automatinę švirkštinę pompą buvo skirta 500 ml fiziologinio tirpalo į veną. Registruoti hemodinamikos parametrai (širdies dažnis, sistolinis, diastolinis bei vidurinis kraujo spaudimai, kvėpavimo dažnis).

Rezultatai. Sunki hipotenzija buvo nustatyta 18,3 % pacientų. Vertinant ATV iškvėpimo ir įkvėpimo diametrus bei ATV-VI prieš ir po intervencijos tarp pacientų su hipotenzija ir be, statistiškai reikšmingo skirtumo nenustatyta. Atsižvelgiant į ROC kreivės analizę darytina išvada, kad ATV-VI nėra efektyvus metodas prognozuoti sunkią hipotenziją spinalinės anestezijos metu spontaniškai kvėpuojantiems pacientams: plotas po ROC kreive $<0,7$, $p > 0,05$.

Išvados. ATV-VI nėra efektyvus būdas prognozuoti sunkią hipotenziją po spinalinės anestezijos ir infuzinės terapijos spontaniškai kvėpuojantiems pacientams, kuriems atliekama kelio sąnario endoprotezavimo operacija. Reikėtų atlikti daugiau tyrimų įtraukiant kitus pacientų pogrupius.

Raktažodžiai: spinalinė anestezija, hipotenzija, infuzinė terapija, apatinė tuščioji vena, variabilumo indeksas