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Original Article

Delta Inferior Vena Cava Index Correlated with Mean Arterial Pressure (MAP) in Spinal Anesthesia

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ABSTRACT

Background: Spinal anesthesia has become an alternative to general anesthesia. However, spinal anesthesia has the most common side effects including, bradycardia and hypotension. The aim of this study was to determine the relationship between changes in the inferior vena cava index (delta inferior vena cava index) to changes in mean arterial pressure in spinal anesthesia.
Methods: This study was an observational pre-post test study in thirty-two patients who received spinal anesthesia. The inferior vena cava index (inferior vena cava collectibility index and caval-aorta index) was measured before and after spinal anesthesia (5 and 10 minutes after onset). Data were analyzed using the Kolmogorov Smirnov test, Shapiro-Wilk test, T-test, and correlation test with α=5%
Result: There was a significant difference in mean arterial pressure (MAP), delta inferior vena cava collectibility index (D-IVC-CI), and delta caval-aorta index (D-CAo-I) before and after spinal anesthesia. D-IVC-CI and D-CAo-I are significantly correlated with MAP. The correlation between D-IVC-CI and MAP had R = -0.371 (P <0.05) at 5 minutes post-anesthesia, while D-CAo-I and MAP had R = 0.472 (P <0.05) at 10 minutes post-anesthesia.
Conclusion: The delta inferior vena cava index is correlated with the mean arterial pressure (MAP) value in spinal anesthesia.

Keywords: inferior vena cava index, mean arterial pressure, spinal anesthesia

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INTRODUCTION

Since it was first discovered, spinal anesthesia has been an alternative procedure besides general anesthesia.[1] However, spinal anesthesia has side effects, including temperature regulation impairment, hypotension, and the most common, bradycardia and hypotension. Decreased cardiac output and Systemic vascular resistance (SVR) contribute significantly to anesthesia-induced hypotension.[2,3,4] In general, it depends on the elevation of the dermatome level. The vasomotor tone is determined by sympathetic nerves originating from the T5 to L1 roots, which innervate the smooth muscle of arteries and veins. This nerve block causes vasodilation of the viscera and lower extremities' veins, thereby reducing the volume of venous return to the heart.[5]

Prevention of hypotension in spinal anesthesia can be done using vasopressors, increasing intravascular volume, or both. The use of vasopressors remains controversial regarding the type of vasopressor used, its effect on increasing blood pressure through heart rate stroke (stroke volume) and cardiac output, its effect on increasing SVR without decreasing cardiac output, and its effect on increasing heart rate. Another option for treating hypotension is an intravascular fluid bolus. Increased intravascular volume has been used to treat hypotension associated with spinal anesthesia. Although large amounts of fluid sometimes cannot be used to prevent hypotension. The use of intravascular fluids sometimes is not more effective than the use of vasopressors.[6]

Sympathetic block promotes hypotension through its effects on preload, afterload, contractility, and heart rate. In other words, it determines cardiac output by reducing SVR. Preload is reduced with venodilation, resulting in peripheral blood pooling and decreased venous return. During the sympathetic block, the venous system is maximally dilated.[1]

Decreased venous return can be detected using diagnostic tools. Inferior vena cava (VCI)-ultrasound guide is one of the non-invasive diagnostic tools. Due to the decrease in the venous return from the lower extremities, blood volume through the inferior vena cava also decreases. According to the research, there is a relationship between the venous return volume and the inferior vena cava diameter measure using ultrasound guidance. The inferior vena cava diameter is in direct proportion to venous return volume. In other words, the inferior vena cava diameter is collapse when the venous return volume is decreased.[7]

Mean arterial pressure (MAP) is defined as the mean arterial pressure in one cardiac cycle, systolic, and diastolic cycle. MAP is influenced by cardiac output and systemic vascular resistance. Thus, MAP can be used as a description of the patient's arterial pressure condition.[8] The aim of the study was to analyze the correlation between the inferior vena cava index and MAP in patients before and after spinal anesthesia.

METHODS

This study is an observational study with a paired t-test (pre-test and post-test) design to analyze the correlation of inferior vena cava index and MAP. The study population was 32 patients who underwent surgery under spinal anesthesia. This research has been approved by the Health research ethics committee of Dr. Saiful Anwar general hospital (No. 400/068/K.3/302/2020). The inclusion criteria including patients undergo surgery at the central surgical installation and emergency room of Dr. Saiful Anwar general hospital under spinal anesthesia, patients with ASA I and II, aged 18-60 years, BMI 18.5 to 34.9 kg/m^2, and patients willing to participate in the study. The exclusion criteria including the patient or family refused, the patient was not cooperative, and the patient underwent an abdominal laparotomy. The drop-out criteria in this study including the patients experience high spinal, patients experience total spinal, patients experience cardiac arrest, apnea, changes in anesthetic techniques, and patients are allergic to local anesthetic drugs. Patients were given informed consent by providing an explanation the day before the day of surgery about the anesthetic action that would be undertaken. The number of samples is calculated using the following formula:

$$n = \frac{\left\{ z_{1-\alpha/2}\sqrt{P_o(1-P_o)} + z_{1-\beta}\sqrt{P_a(1-P_a)} \right\}^2}{\left(P_a - P_o\right)^2}$$

n = minimum sample size; Z_α = standard normal distribution value (table Z) at certain α; Z_β = standard normal distribution value (table Z) at certainβ; Po = proportion in the population; Pa = estimated proportion in the population; Pa-Po = estimated difference in the proportions studied with proportion in the population.

The parameters measured in this study included the inferior vena cava collectibility index (IVC-CI), caval-aorta index (CAo-I), and mean arterial pressure (MAP). Patients have fasted for 6 to 8 hours of pre-anesthetic. The patients were given crystalloid infusion according to the perioperative protocol. The patients were in supine position, oximetry and electrocardiographic monitor installed, and non-invasive blood pressure is measured. The parameters before induction was record. The patient was then given spinal anesthesia according to standard procedures. The patient was positioned supine as in pre-induction. Venous diameter, inferior vena cava collectibility index, aortic index, blood pressure, and pulse at the 5 and 10 minutes after the onset of anesthesia was achieved. The measurement of the diameter is carried out using ultrasound. The patient underwent surgery.

The data obtained were analyzed using the data normality test with the Kolmogorov Smirnov test, the Shapiro-Wilk test, and the correlation test in the SPSS version 18 program (IBM Statistic, USA) with α=5%. The research hypothesis is the changes in the inferior vena cava index correlated to the mean arterial pressure in spinal anesthesia.

RESULT

In this study, a sample of 32 patients was obtained. The characteristics of the research subjects included gender, age, BMI, ASA, and type of surgery. The demographic characteristics of the subjects can be seen in table 1. The mean age of the study subjects were 44.84 ± 11.92 years old. Based on the age group, the majority of study subject was early middle-age adult (46-55 years old) (37.50%). A total of 18.80% of subjects were male patients, and 81.2% were female patients. Based on the BMI classification, it shows that of the 32 samples, the majority of the subject (46.90%) were classified as normal. The majority of patients (81.3%) were ASA II. Half of the study subjects mostly underwent radiotherapy surgery.

The mean MAP of subjects pre-spinal anesthesia (103.70 ± 11.85) was higher than post-spinal anesthesia. The MAP parameter significantly decreased to 91.57 ± 12.5 (5 minutes post-spinal) (P= 0.000) and continued to decrease to 87.53 ± 14.06 10 minutes post-spinal anesthesia (P= 0.000). The CA-I also decrease the spinal anesthesia procedure from 83.86 ± 25.18 to 79.25 ± 27.95 (5 minutes after spinal) and 70.45 ± 26.71 (10 minutes after spinal anesthesia). The IVC-CI increased after spinal anesthesia from 31.83 ± 8.72 to 42.51 ± 11.10 (5 minutes) and decreased to 38.83 ± 11.96 after 10 minutes after spinal anesthesia. However, the IVC-CI 10 minutes post-spinal anesthesia significantly higher than pre-anesthesia. Based on the T-test, all parameters had a significant difference pre and post-spinal anesthesia (P< 0.05) (Table 2).

Mean change in each parameter pre-post spinal anesthesia (called delta (D)) can be seen in table 3. The mean D-MAP was 12.13 ± 10.05 at 5 minutes post-spinal anesthesia and 16.17 ± 0.138 at 10 minutes post-spinal anesthesia. The mean D-IVC-CI parameter changed by 0.14 ± 0.23 at 5 minutes after spinal anesthesia and 0.24 ± 0.30 at 10 minutes after spinal anesthesia. The mean D-IVC-CI was -11% ± 0.11 at 5 minutes post-spinal anesthesia and -7 ± 0.11% at 10 minutes post-spinal anesthesia. The mean D-CA-I was 5 ± 0.16% at 5 minutes post-spinal anesthesia and 13 ± 0.15% at 10 minutes post-spinal anesthesia.

The correlation between venous and aorta index with MAP can be determined using the correlation test. Based on the correlation test, D-IVCCI has a significant correlation with D-MAP (R= -0.371) at the 5-minute post-spinal anesthesia. The negative correlation is indicated as an inverse proportional. D-CA-I has a significant correlation with D-MAP (R= 0.472) with a positive correlation (P<0.05) (Table 4).

DISCUSSION

This study was conducted to analyze the correlation between the inferior vena cava index and caval-aorta index with MAP. In theory, spinal anesthesia promotes vasodilation of the arteries and peripheral veins, reducing blood flow to the heart. As a result, the volume of blood that fills the vena cava, especially the inferior vena cava, decreases, and the size of the inferior vena cava becomes smaller. The inferior vena cava's

Tabel 1. Characteristic of the study subject

Demography characteristic	(n)	Percentage (%)	Mean ± SD
Age			
• Teenager (17-25 year old)	4	12.5	44.84 ±11.92
• Young adult (26-35-year-old)	2	6.3	
• Adult (36-45 year old)	8	25.0	
• Middle-age adult (46-55 year old)	12	37.5	
• Old adult (56-65-year-old)	6	18.8	
Gender			
• Male	6	18.8	
• Female	26	81.2	
BMI			
• Underweight	1	3.1	24.1 ±3.33
• Normal	15	46.9	
• Overweight	6	18.8	
• Obesitas Kelas 1	7	21.9	
• Obesitas Kelas 2	3	9.4	
ASA			
• ASA I	6	18.8	
• ASA II	26	81.3	
Types of surgery			
• Obstetrics and gynecology	4	13	
• Orthopedic	10	31	
• Radio-therapy	16	50	
• Urology	2	6	
Preoperative fluid (ml)			265.63 ±161.86

BMI: Body Mass Index; ASA: American Society of Anesthesiology

Table 2. The mean MAP, IVC-CI, and CAo-I pre-post-spinal anesthesia

Parameters	Pre spinal (Mean ± SD)	5' Post spinal (Mean ± SD)	10' Post spinal (Mean ± SD)	P-Value	
				pre-spinal and 5' post-spinal	pre-spinal and10' post-spinal
MAP	103,70 ± 11,85	91,57 ± 12,5	87,53 ± 14,06	0,000*	0,000*
IVC-CI (%)	31,83 ± 8,72	42,51 ± 11,10	38,83 ± 11,96	0,000*	0,001*
CAo-I (%)	83,86 ± 25,18	79,25 ± 27,95	70,45 ± 26,71	0,006*	0,000*

MAP = Mean Arterial Pressure; IVC-CI = Inferior Vena Cava Collapsibility Index; CAo-I = Caval-Aorta Index; p-value T-test (significant if P< 0.05)*

Tabel 3. The mean delta IVC-CI and CAo-I

Parameters	Post-Spinal 5'	Post-Spinal 10'
D-MAP	12,13 ±10,05	16,17 ±0,138
D-IVC-CI (%)	-11 ±0,11	-7 ± 0,11
D-CA-I (%)	5 ±0,16	13 ±0,15

MAP:Mean Arterial Pressure; IVC-CI: Inferior Vena Cava Collapsibility Index; CAo-I: Caval-Aorta Index

Tabel 4. Correlation coefficient (R) between D-IVC-CI and D-CAo-I with D-MAP

	D-MAP	
	R= 5' post-anesthesia	R= 10' post-anesthesia
D-IVC-CI (%)	-0.371 (P< 0.05)*	-0.253 (P > 0.05)
D-CA-I (%)	-0.050 (P > 0.05)	0.472 (P < 0.05) *

D-MAP: Delta Mean Arterial Pressure; D-IVC-CI: Delta Inferior Vena Cava Collapsibility Index; D-CAo-I: Delta Caval-Aorta Index; *: Significant in the correlation test diameter can be identified by ultrasound examination. Reduced venous return can lead to a complication of spinal anesthesia, such as hypotension or defined as a decrease in MAP by 15 mmHg.[1,7,9]

There were significant changes in the IVC-CI and CAo-I pre and post-spinal anesthesia (5 minutes and 10 minutes post-spinal anesthesia). The study subject experiences a decrease in the CAo-I and an increase in IVC-CI. According to the theory, spinal anesthesia causes the preganglionic sympathetic block. Sympathetic block produces hypotension through its effects on preload, afterload, contractility, and heart rate. In other words, through a change in cardiac output and a decrease in SVR. Preload is reduced by venodilation mediated by sympathetic block, resulting in peripheral blood collection and decreased venous return, and decreased SVR. The decrease in SVR due to peripheral vasodilation, especially in the extremities, intestinal organs, and all venous systems that to the inferior vena cava. The inferior vena cava receives the drainage of blood from the venous system of the pelvic area, inferior extremities, abdominal venous system (including the viscera), portal hepatic vein system, and urogenital. All these venous systems make up the largest part of the component of venous return to the heart, i.e. the maximum volume of blood is in the veins as much as 65% of the total volume of blood in the body. There will also be less blood returning to the right atrium through the vena cava. In spontaneously breathing subjects, this is what causes the VCI diameter to become smaller and the IVC-CI to be higher.[1,10,11,12]

In this study, where the researchers compared the ratio between the inferior vena cava and the aorta, there was a decrease in CAo-I. The decrease is due to the aorta diameter was less affected when the inferior vena cava diameter becomes smaller. This is due to the difference in the anatomical structure of the arteries. Arteries walls were thicker, has more connective, elastic, and smooth muscle tissue. Therefore, arterial walls are much stronger than veins and, on average, eight times more rigid than veins. It means an increase in the blood pressure can increase blood in the vein about eight times higher than in the same size artery. Therefore, the diameter of the aorta is relatively unaffected when the inferior vena cava becomes smaller.[1,10,11,12]

The relationship between changes in each parameter (delta) to changes in MAP can be determined using the correlation test. Based on the correlation test, D-IVC-CI has a significant correlation with D-MAP (R= -0.371) at the 5 minute after spinal anesthesia. The relationship that occurs is negative so that the D- IVC-CI value is inversely proportional to the MAP. D-CA-I significantly has a strong enough correlation with D-MAP (R = 0.472) with a positive relationship, meaning that the increase in D-CA-I is linear with an increase in D-MAP.

According to the theory, it is known that spinal anesthesia can cause hypotension. Intra-operative hypotension defined when MAP <65 mmHg or MAP decrease ≥20% from baseline.[13] Many mechanisms are thought to cause hypotension induced by spinal anesthesia, including the direct circulatory effect of local anesthetics, relative adrenal insufficiency, skeletal muscle palsy, increased vasomotor block, and respiratory insufficiency. However, the most acceptable is the preganglionic sympathetic block produced by spinal anesthesia. Sympathetic block produces hypotension through its effects on preload, afterload, contractility, and heart rate. Preload is one of the most important factors related to hypotension. Preload is reduced by venodilation mediated by sympathetic block. Also, the inferior vena cava is one of the anatomical components of preload. This factor contributes to the decrease of IVC diameter and an increase in the IVC-CI, and the decrease of CAo-I, which is associated with a decrease in MAP.[1,9,14]

In this study, the D-CAo-I has the strongest correlation with the D-MAP. According to previous studies, it was stated that the IVC diameter, IVC-CI, and CA-I were good predictors for the occurrence of hypotension after anesthesia. However, the CAo-I is a stronger predictor than the IVC diameter and IVC-CI. The CAo-I is more precise in predicting intravascular volume than both IVC diameter and IVC-CI. Whereas in spinal anesthesia, preload fluid is almost always given during spinal anesthesia. A preferable CAo-I is also recommended for spontaneous breathing patients such as in spinal anesthesia. IVC diameter and IVC-CI alone, without involving aortic component, are mainly affected by intra-abdominal and intrathoracic pressure especially in patient with respiratory desease such as asthma and respiratory tract infections. The inferior vena cava has an elastic wall so that it has a larger capacitance than the aorta. So, if the examination of the inferior vena cava alone, without involving the aorta, will produce a various result, especially in patients with different age, body mass index, and body surface area.[11,15,16]

At the beginning of the acute phase, the IVC-CI was correlated with a decrease in MAP 5 minutes after anesthesia. In previous studies, sudden loss in venous return caused a reduction in the collapsibility of the inferior vena cava, where there was no significant change in the caval-aorta index. Because of the high capacitance and compliance, which is about 30 times that of the arteries and aorta, the inferior vena cava has a shape that remains elliptical; even the volume of blood reaches 200% of the total intravascular volume. As a result, there will be a change in shape in the inferior vena cava without changing its maximum diameter. Spinal anesthesia causes relative hypovolemia. Vasodilation causes the inferior vena cava to collapse in the early minutes of onset, where the minimum diameter significantly decreases, and the maximum diameter slightly decreases. Furthermore, during spinal anesthesia, the minimum diameter will increase, and the maximum diameter will slightly decrease adapt to the condition of the intravascular volume. In addition, sympathetic block stimulation also leads to the increase of the inferior vena cava collapsibility.[17,18,19]

The lack of this study includes using a variety of preoperative fluids in every ward. In addition, this study included patients with comorbidity (hypertension), although the inclusion criteria were ASA I-II. The ultrasound examination was carried out by the investigators themselves because of the limitation of the operator.

CONCLUSION

There were significant changes in the IVC-CI and CA-I pre and post-spinal anesthesia. The delta of the inferior vena cava index, both IVC-CI and CA-I, correlated with mean arterial pressure (MAP).

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CONFLICT OF INTEREST

None

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