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Study of changes in inferior vena cava diameter using ultrasonography guided technique preoperatively and intraoperatively in patients undergoing spinal anesthesia for lower limb and perianal surgeries

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Introduction

Neuraxial blockade (Spinal, Epidural and Caudal neuraxial blocks) has various routine clinical applications for surgery, obstetrics, acute postoperative pain management, and chronic pain relief.[1] Single-injection subarachnoid block or epidural anaesthesia by using local anaesthetic drug is most commonly used for the lower abdomen, pelvic organs (e.g., prostate, uterus and urinary bladder), and lower limbs surgeries, and for caesarean deliveries. Neuraxial blocks result in one or a combination of sympathetic blockade, sensory blockade, or motor blockade depending on the dose, concentration, and volume of injected local anaesthetics. Despite these similarities, there are significant technical, physiologic, and pharmacologic differences, spinal anaesthesia, requires a small mass (i.e., volume) of drug to produce rapid (<5 minutes), profound, reversible sensory analgesia in comparison with epidural and caudal anaesthesia. Therefor spinal anaesthesia almost devoid systemic pharmacologic side effects of local anaesthetic drug when compared to other neuraxial blocks like caudal and epidural analgesia. Unfortunately, these neuraxial blocks leads to blockade of the peripheral (T1-L2) and cardiac (T1-T4) sympathetic fibres in addition to sensory and motor fibres, which is responsible for reduced arterial blood pressure by decreasing cardiac output and systemic vascular resistance[1,2,3] Spinal anaesthesia is commonly used in routine clinical practice. Hypotension, bradycardia, nausea, vomiting and shivering are common side effects observed following spinal anaesthesia. Hypotension followed by spinal anaesthesia is mainly attributed to both the factors including reduced systemic vascular resistance (SVR) and reduced cardiac output. There are so many factors which can affect intraoperative blood pressure after spinal anaesthesia including preoperative volume status, comorbidities, physical status, pre-operative medications, duration of fasting and fluid resuscitation. Spinal Induced Hypotension (SIH) is a very common side effect with an incidence of 15.3–33% which may lead to organ hypo-perfusion and ischemic events if not managed timely.[4,14] Preoperative assessment of inferior vena cava (IVC) diameters by ultrasonography and calculation of IVC collapsibility index (IVC-CI) might identify patients with intravascular volume depletion. Therefore, to give clinically relevant conclusions, it has become very important for us to be more precise about the definition of hypotension under anaesthesia, best method of IVC diameter assessment by ultrasound, and also to provide the cut-offs for IVC diameter and the collapsibility index for prediction of hypotension after anaesthesia.[5] To minimize hemodynamic impairment, preventive empiric volume loading is commonly performed in anaesthesia before giving spinal anaesthesia. However, fluid preload has been proved to lower the incidence of SIH and significantly decrease vasopressor requirements. Various parameters have been studied in past few years to estimate intravascular volume status of patients before inducing spinal or general anaesthesia. Ultrasonographic determination of inferior vena cava (IVC) diameter was used in spontaneously breathing patients for assessment of intravascular volume and was reported to be reliable, noninvasive, and easy.[6] If we can find strong correlation between blood pressure variation and IVCCI, we can calculate and decide cutoff value for hypotension or low volume status of patient and thus we can manage patients prior to any end organ damage. We can also avoid unnecessary fluid preload, sometimes which may lead to fluid overload. We can also perform a bedside ultrasound to know volume status in ICU patients before and after starting fluid therapy where fluid management plays a crucial role in prognosis of patient. Now days ultrasound is not only limited to radiologist, Point of care ultrasound is being popular in the field of emergency physicians, and anaesthesiologists. It can also be used for patients in ICU setups to guide goal directed fluid therapy especially in patients with renal failure, cardiac failure and sepsis. Recently, few studies were conducted for measurement of Inferior Vena Cava Compressibility Index (IVCCI) and they have also concluded IVCCI as a reliable or good predictor of arterial hypotension after induction of general anaesthesia.[7,8,9] The aim of this study was to evaluate the ultrasound guided IVC diameter changes preoperatively and intraoperatively in patients undergoing spinal anaesthesia for lower limb and perianal surgeries.

Methods

It was a prospective observational study done on total 160 patients with age group 18 to 60 years (ASA grade 1 or 2 only) undergoing elective surgeries in both

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lithotomy and supine position after giving spinal anaesthesia. The written, verbal and informed consents were taken prior to surgery in which expected duration was less than 2 hours. The patients were not willing to give consent for participation into the study, ASA grade 3 or 4, undergoing pelvic and abdominal surgeries, BMI >30 kg/m^2, Patients with hypertension, ischemic heart disease, major renal, hepatic and endocrine dysfunction, cardio-pulmonary compromised patients, emergency surgeries (full stomach), allergy to anesthetic drug, patients with history previous vascular surgery and IVC filters in situ, blood loss >500 ml, and patients with anatomical variation in IVC or non-visualisation of IVC were excluded from the study. The patients were divided into four groups named L2, L3, P2 and P3 according to volume of drug used to give spinal anaesthesia(indicated by 2 and 3 in mililitre) and type of surgery either lower limb surgeries done in supine position(L) or perianal surgeries done in lithotomy position(P). All the parameters will be recorded at six time points throughout the surgery including at pre-induction, 5 min, 10 min, 20 min, 30 min and at the end of the surgery after induction. All the hemodynamic parameters will be recorded in supine position for all patients in group L-2 and L-3. Meanwhile recording position may vary in patients of group P-2 and P-3, where preinduction and at the end of surgery parameters will be recorded in supine position but at all other time points, parameters will be recorded in lithotomy position in this two groups. Spinal anaesthesia will be given to all patients under all aseptic precautions, in a sitting position, at L3-L4 interspace only, using 25 G quincke's needle with bevel of needle facing cranially, after observing a free flowing clear cerebrospinal fluid. As soon as possible after giving spinal anaesthesia, supine or lithotomy position will be given to all patients after confirmation of successful subarachnoid block. Successful subarachnoid block will be assessed by sensory analgesia upto T-10 level by spirit swab test. Hemodynaemic changes will be assessed by USG guided IVC diameter changes and IVC collapsibility index preoperatively, intraoperatively and at the end of surgery. 1st hour fluid replacement will remain fixed at 15 ml/kg body weight for each patient recruited in study. And it will be started soon after shifting patient into operation theatre securing two 18 G intravenous catheters. Mephentermine Sulphate 6mg was given intravenously in case of intraoperative hypotension occurs. IVC diameter will be measured by using curvilinear, 2-5 Hz frequency probe with B-Mode ultrasound, after tracing IVC opening into right atrium, at level 3 cm below its opening into right atrium, in a subxyphoid longitudinal axis view. during spontaneous breathing at height of inspiration(IVCmin) and expiration(IVCmax). IVCCI was calculated using the formula $\text{IVCCI} = \frac{\text{IVCmax -IVCmin}}{\text{IVCmax}}$ x 100 %.

Results

Comparison of difference in means of different variables of all patients at different time points

Table 1: Difference in means of different variables of all groups at different time points for all patients.

Mean Of Variables	Pre-Induction	5 Min	10 Min	20 Min	30 Min	At the end of surgery	P-Value
IVC Dm During Inspiration (IVCmin) in mm	6.97	7.68	7.99	7.71	8.75	8.27	<0.001

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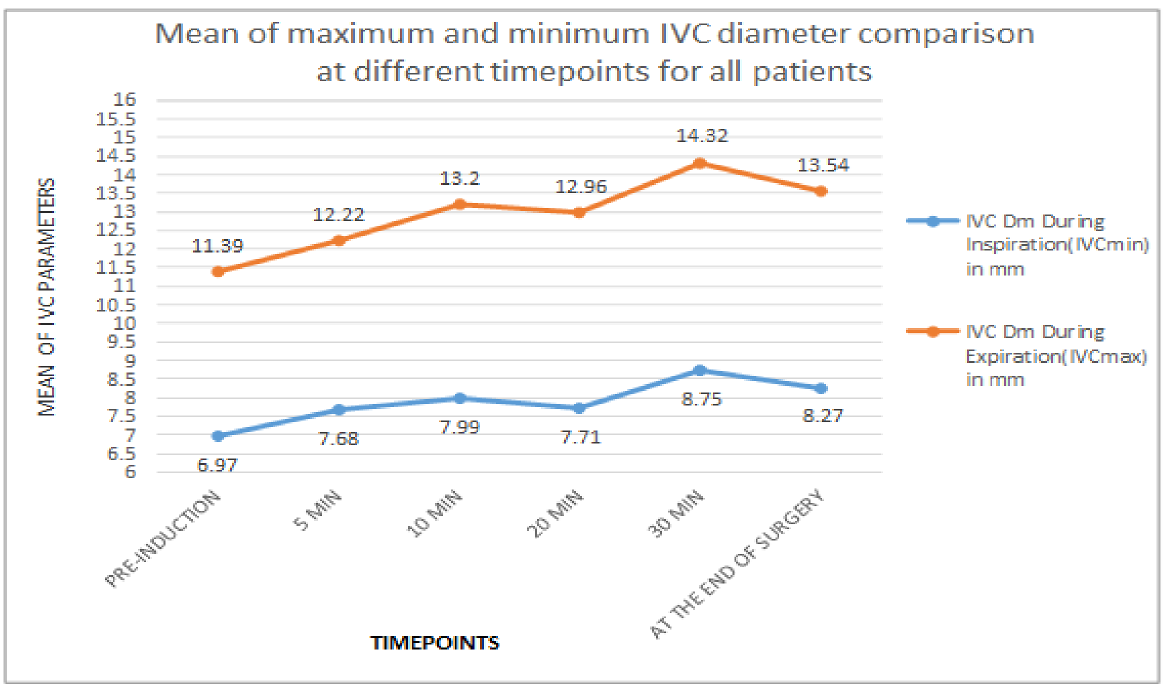
IVC Dm During Expiration (IVCmax) in mm	11.39	12.22	13.2	12.96	14.32	13.54	<0.001
IVCCI (%)	38.2	36.6	38.9	39.7	38.3	38.5	0.188
DBP (mmHg)	80.6	74.7	72.7	69	69.7	67.1	<0.001
SBP (mmHg)	126.3	114.2	108	114	116	114.5	<0.001
MAP (mmHg)	95.4	85.7	83	83.8	84.9	81.4	<0.001
HR (bpm)	82.8	83.5	82.4	79.3	76.4	76.8	<0.001
RR (breaths/min)	14.9	14.9	14.9	14.9	14.9	14.9	0.005
SpO2(%)	98.7	98.7	98.7	98.7	98.7	98.7	0.536

Here, we have applied repeated measures of ANOVA (RMANOVA) test using SPSS to compare mean of different variables at different time points with baseline or pre-induction mean of that particular variable. We have got all p-values significant (<0.05) for all the variables provided in table above, except for IVCCI (%), SpO2 and RR which are >0.05 being statistically insignificant. so, we can comment that we found significant difference at different time points as above-mentioned table at 5 min, 10 min, 20 min, 30min and at the end of surgery when compared with baseline or pre-induction recordings for all the recorded variables except for IVCCI (%), SpO2 and RR. We found no statistically significant difference for IVCCI (%), SpO2 and RR at any time points when compared with baseline or pre-induction recordings.

Graph 1: Profile plot for mean IVC min and IVC max at different time points for all patients



Here, we have plotted means of minimum diameter – IVCmin (at height of inspiration - IVCinsp) and maximum diameter – IVCmax (at height of expiration - IVCexp) predecided different timepoints (data is taken from table no.-1). We found increasing pattern in both the diameters with time when compared to pre-induction

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measured diameter value. Moreover, we noticed maximum increase in mean of maximum and minimum diameter at 30 minute timepoint and minimum values of mean diameters for the same were at pre-induction timepoint. Group wise comparison of mean IVC min diameters at different time points

Table 2: Group wise mean IVC min at different time points.

Group Name	Mean IVC diameter during inspiration (IVC $_{min}$)						P-Value
	Pre-Induction	5 MIN	10 MIN	20 MIN	30 MIN	At the end of surgery	
L2	7.84	8.91	9.80	8.08	8.44	8.31	<0.001
L3	6.98	7.45	7.61	7.89	7.77	8.15	
P2	6.50	6.98	7.18	7.31	8.98	8.72	
P3	6.55	7.39	7.36	7.54	9.83	7.91	

We found significant difference (p-value <0.05) between groups when mean IVC diameters during inspiration (IVC min) of each group are compared using repeated measures of ANOVA test.

Graph 2: Profile plot for Group wise mean IVC min at different time points.

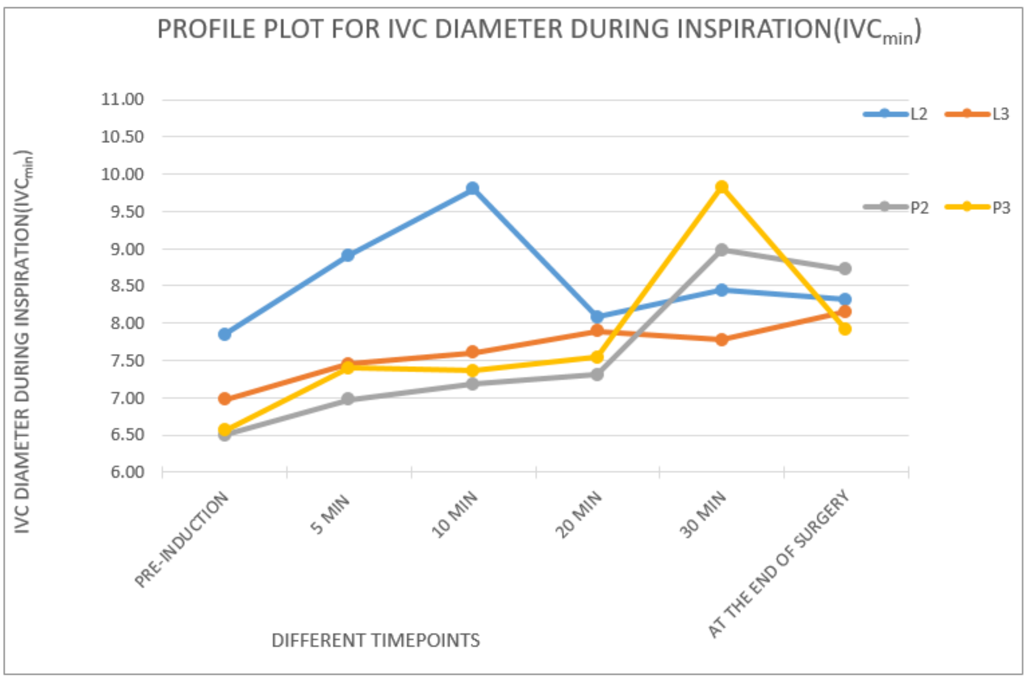

Table 3: Group wise mean IVC max at different time points

Group name	Mean IVC diameter during expiration(IVC $_{max}$)						p-Value
	Pre-Induction	5 Min	10 Min	20 Min	30 Min	At the end of surgery	
L2	11.71	12.94	14.91	13.04	13.42	13.04	<0.001
L3	11.93	12.90	13.57	13.57	13.61	13.51	
P2	11.07	11.18	11.99	12.69	15.10	13.69	
P3	10.84	11.87	12.32	12.53	15.15	13.93	

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We found significant difference (p-value <0.05) between groups when mean IVC diameters during expiration (IVCmax) of each group are compared using RMANOVA test.

Graph 3: Profile plot for group wise mean IVC max at different time points.

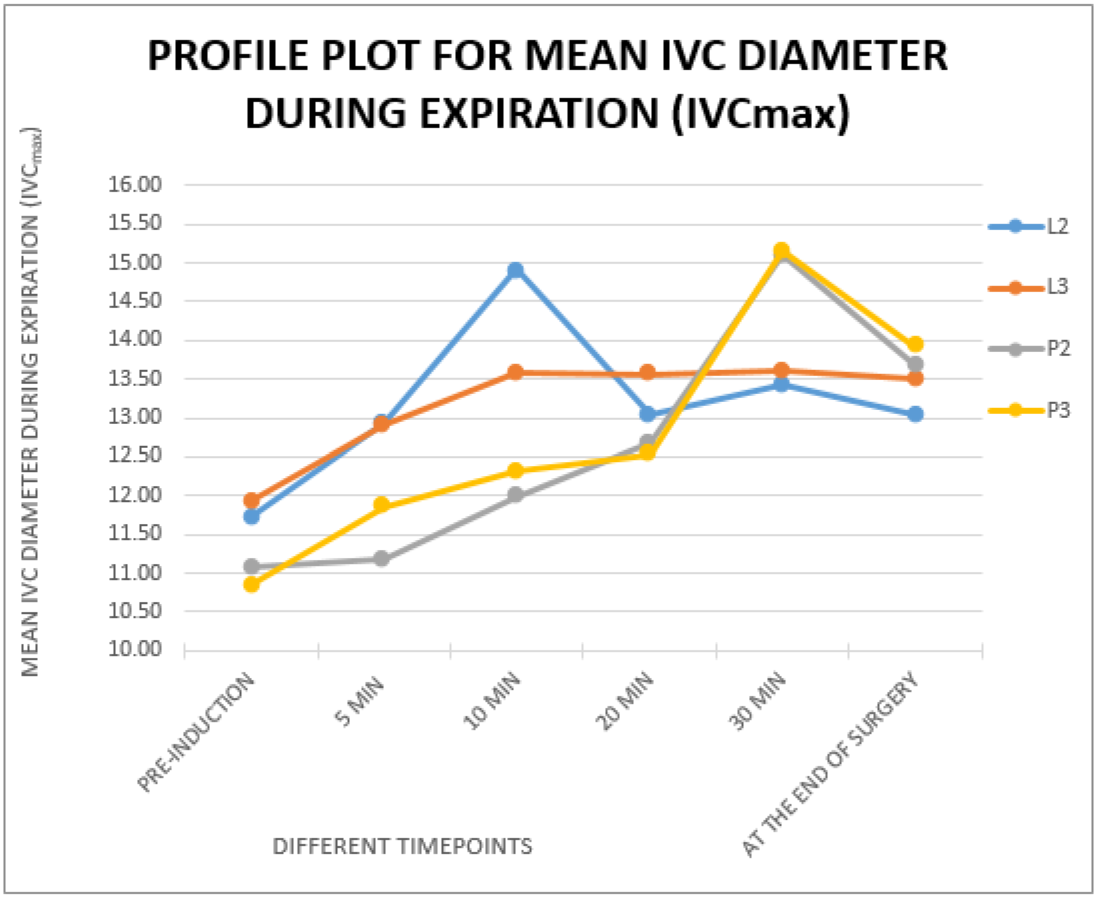

Table 4: Group wise mean IVCCI (%) at different time points.

Group Name	IVCCI%						p-Value
	Pre-induction	5 Min	10 Min	20 Min	30 Min	At the end of surgery	
L2	32.2	30.8	33.1	36.5	36.4	35.7	0.017
L3	41.0	41.2	42.8	40.7	41.8	39.0	
P2	40.7	37.1	39.8	42.5	40.6	36.3	
P3	38.8	37.4	39.9	39.3	34.6	42.9	

We found significant difference (p-value <0.05) between groups when mean IVCCI (%) of each group are compared using RMANOVA test.

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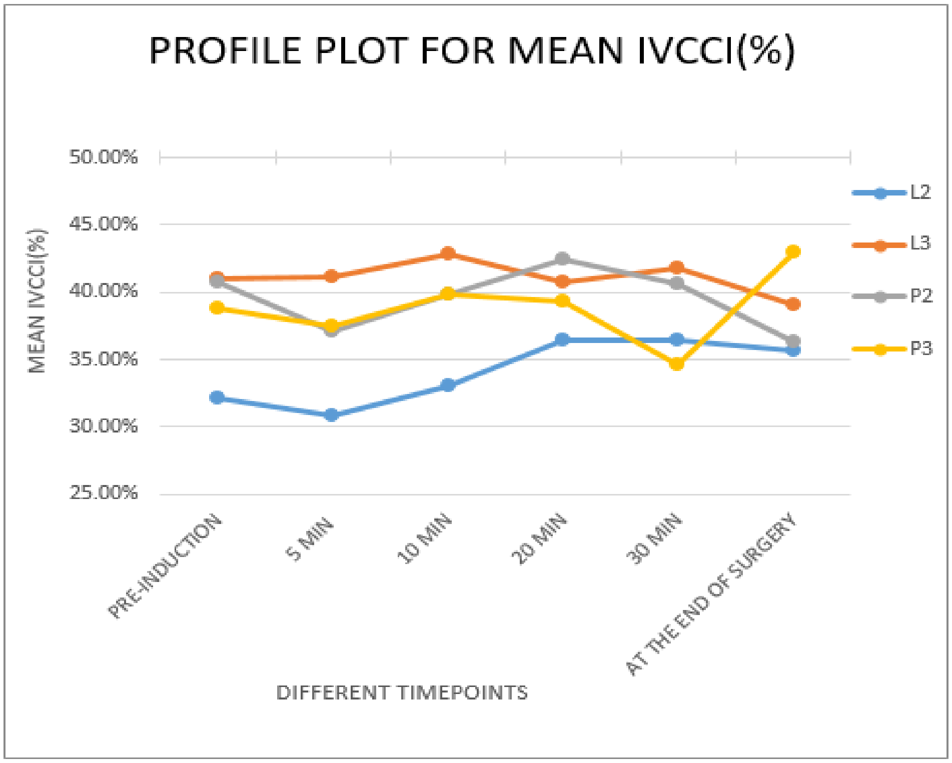
Graph 4: Profile plot for group wise mean IVCCI (%) at different time points.



We divided 160 patients into two group by occurrence of hypotension (with consideration of hypotension when SBP<100) named as hypotensive group vs non-hypotensive group and IVCCI (%) for all patients were plottedto prepare ROC curve to decide cut-off to diagnose hypotension at each time points. ROC curve showed AUC >0.5 at all-time points suggesting a good classification and SPSS software image and cutoff points are as mentioned below.

Graph 5: ROC curve for IVCCI (%) at different time points derived by SPSS software

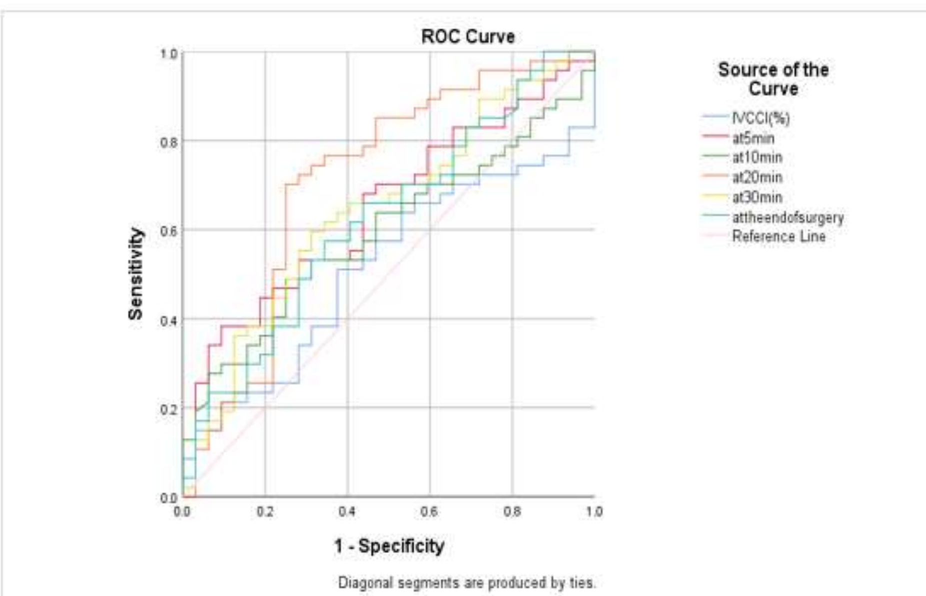


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Table 6: Area Under the Curve (AUC) for IVCCI (%) At differenttime points

Area Under the Curve					
Test Result Variable(s)	Area	Std. Error[a]	Asymptotic Sig.[b]	Asymptotic 95% Confidence Interval	
				Lower Bound	Upper Bound
IVCCI(%)	.515	.065	.818	.387	.643
at 5min	.648	.062	.027	.526	.769
at 10min	.595	.063	.155	.470	.719
at 20min	.713	.063	.001	.589	.836
at 30min	.644	.063	.030	.521	.768
At the end of surgery	.624	.064	.063	.499	.749

The test result variable(s): at10min, at the end of surgery has at least one tie between the positive actual state group and the negative actual state group. Statistics may be biased. where,

- Under the nonparametric assumption
- Null hypothesis: true area = 0.5
- Threshold values for IVCCI (%) decided at each time points to diagnose hypotension.

Table 7: Threshold values for IVCCI (%) with sensitivity and specificity to diagnose hypotension.

	Sensitivity	1-Specificity	IVCCI (%)
at pre induction	0.766	0.938	21.42%
at 5 min	0	0.031	59.2%
at 10 min	0.894	0.969	22%
at 20 min	0	0.031	63.26%
At 30 min	0.021	0.031	61.35%
at the end of surgery	1	1	11.16%

Discussion

Spinal anaesthesia causes various hemodynamic changes which are combined result of various factors like dose of local anaesthetic, volume status, physical status (ASA Grade), built of the patient, duration of fasting before surgery and position or table tilt after block.[14]

In our study we found fall in hemodynamic parameters like Systolic Blood Pressure, Diastolic Blood Pressure, Mean Arterial Pressure and Heart rate at different time points when it was compared with baseline which is not a new concept observed after giving spinal anesthesia. Many clinical textbooks of anaesthesiology and articles have mentioned these changes.[1,2,12]

Various studies have been conducted regarding IVC diameter measurement during perioperative period but they have different methodology and outcomes. Many studies are comparing IVCCI% with intraoperative hypotension and as a result giving cut-off value of IVCCI to diagnose hypotension. Few studies are based on randomized control trials like studies done by Ayyanagouda B. et al and Ceruti S. et al gives conclusion that IVCCI guided fluid optimization reduces incidence of intraoperative arterial hypotension.[10,11]

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Although it is quite challenging to standardize all the factors responsible for hemodynamic instability after spinal anaesthesia and to focus on a single parameter, we decided to study the changes in inferior vena cava diameter during peri-operative period after giving spinal anaesthesia for surgeries done in supine as well as in lithotomy position. In our study, we found increase in both maximum and minimum mean IVC diameters at different time points after giving spinal anaesthesia in all group when it was compared with baseline or pre-induction maximum and minimum mean IVC diameters.

We found AUC >0.5 in ROC curve for IVCCI with significant p-values at 5-minute, 20minute and 30-minute time point after spinal anaesthesia, while at all other time points, they were insignificant. We have reported lack of sensitivity and specificity at all-time points after spinal anaesthesia. We can say that our study is comparable with Mohammed S et al who has reported about poor diagnostic accuracy for prediction of hypotension in his study. He also found area under the curve for collapsibility index 0.51.[13]

In contrast to our study, meta-analysis done by Zhang et al shows good diagnostic accuracy of IVCCI as the area under the curve was 0.9(95% confidence interval, 0.82-0.95). he included only 8 studies for meta-analysis out of 235 studies named as Barbier et al.2004, Brun et al.2013, Byon et al.2013, Corl et al.2012, Feissel et al.2004, Machare-Delgado et al.2011, Moretti and Pizzi 2010, and Muller et al.2012, all are showing area under the curve between 0.56 – 0.91 at 95% confidence interval.[15] In our study we are getting values of AUC at all the time points within this range.

Conclusion

Maximum IVC diameter (IVCmax) and minimum IVC diameters (IVCmin) increases after giving spinal anesthesia during spontaneous respiration. There is no significant change in mean of IVCCI occurs after giving spinal anaesthesia for surgery with minimal blood loss in supine and lithotomy position when means of IVCCI are compared within group.

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