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Effect of positive end expiratory pressures and Trendelenburg positions on cross-sectional area (CSA) of internal jugular vein assessed by ultrasound in surgical adult patients during general anaesthesia

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Abstract

Backgroundand aims*: Increasing the cross-sectional area (CSA) of the right internal jugular vein (RIJV) facilitates cannulation and decreases complications. Purpose of this study was to investigate response of PEEP and Trendelenburg position on cross-sectional area (CSA) of RIJV using ultrasound in adult subjects.*

Materials & methods*: Fifty patients of ASA grade I/II aged 18-58years of either sex undergoing elective surgeries under general anaesthesia after clearance from institutional ethical committee were enrolled for study. Transverse and AP diameter and CSA of RIJV were measured in response to supine position with no PEEP (SP0) and compared with 7 randomly ordered maneuvers: PEEP of 5 cm H2O (SP5), PEEP of 10 cm H2O (SP10), PEEP of 15 cm H2O (SP15), 10° Trendelenburg tilt position with PEEP of 0 cm H2O (TP0), 10° Trendelenburg tilt position combined with PEEP of 5 cm H2O (TP5), 10°Trendelenburg tilt position combined with PEEP of 10 cm H2O(TP10), 10° Trendelenburg tilt position combined with PEEP of 15 cm H2O (TP15).Hemodynamic changes at each maneuver were also recorded.*

Results: *Paired t-test was used for analysis using SPSS software. All maneuvers increased CSA of RIJV with respect to control condition S0. SP_5 increased the CSA on average by 11.29%, $SP_{15,}$ by 25.8%, $T_{10^\circ}P_0$ by 24.19%, $T_{10^\circ}P_{15}$ by 54.9%. No significant hemodynamic change occurred except decrease in systolic blood pressure with increasing PEEP (at SP0 127.90±13.08 mmHg at SP15 120.18±12.84 mmHg.)*

Conclusion*: The PEEP of 10cms of H_2O and 10^0 Trendelenburg position was optimum maneuver for central line cannulation of RIJV.*

Key words: *RIJV, PEEP, Trendelenburg, CSA, AP, Transverse diameter, Ultrasound*

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I. Introduction

The right internal jugular vein (RIJV) is preferred for central venous line placement , in the operative setting, because it is superficial and thus easily accessible, valveless and has a straight course into the right atrium and in majority of cases it is away from surgical site.[1]During placement of central venous cannula the incidence of mechanical complications may be high and is related to the number of needle passes.[2]Carotid artery puncture is the most common complication and infrequently results in further serious complications.[2,3]

Ultrasound guidance not only helps to localize and define the size of IJV but also decreases the incidences of complications associated with catheter placement.[4,5]This technique may be preferred in complicated cases or when access problems are anticipated.[6]A number of ultrasound studies have been conducted to determine the cross sectional area (CSA) of the right internal jugular vein in response to various maneuvres, such as the Trendelenburg and reverse Trendelenburg tilt position with different tilt degrees, Valsalva manoeuver, hepatic compression, carotid palpation, and several combinations of manoeuvers.[7-9]Most of the maneuvers (hepatic compression, humming tone, and Valsalva) are not practical under general anaesthesiaand because, in majority of cases, it is excluded from the surgical field.[1]

However two maneuverslike application of Positive end expiratory pressure and Trendelenburg position can be easily applied in patients under general anaesthesia. We tested the hypothesis that Trendelenburg position and PEEP together increases the cross-sectional area (CSA) of the RIJV in the adult population more than the each maneuver separately without any significant hemodynamic change and sought to quantify the magnitude of the resultant change with following objectives:Primary outcome: To study the CSA of RIJV at various PEEP and trendelenburg positions and find out optimum PEEP, trendelenburg position resulting into maximum CSA of RIJV.Secondary outcome:To study the hemodynamic changes corresponding to various maneuvers with trendelenburg position and various PEEP

II. Material and Methods

After approval was granted by the Ethics Committee of the University and signed informed consent was obtained from each patient, 50 ASA physical status I and II were studied. Patients were excluded from the study if they had physical status of ASA III or greater, H/o neck surgery or restriction in neck movements, Uncontrolled systemic hypertension, arrhythmias or any other cardiac disease valvular lesion affecting volume and pressures in RIJV, Hepatic disease, Renal disease, Neurological disease or Endocrinal disease, Pregnant and lactating patients, Severe respiratory disorders including COPD,Morbid obesity and if the patient was expected to be hemodynamically unstable after inducing anesthesia.

On arrival in operation theatre routine monitoring (Mindray monitor) was commenced and baseline vital parameters of heart rate, non-invasive blood pressure including, systolic, diastolic and mean arterial pressure, peripheral oxygen saturation (SpO_2), ECG were recorded. An intravenous line with 18 G cannula was secured and ringer lactate infusion was started.Patient was pre oxygenated with 100 % oxygen for 3 minutes. All patients received premedication Inj. midazolam 0.05mg/kg, Inj. Glycopyrolate0.004mg/kg, Inj. Ondansetron 0.08mg/kg and Inj. Fentanyl 2µg/kg. After this anaesthesia was induced with Inj. Propofol 2 mg/kg body weight. Inj.Vecuronium 0.1 mg/kg body weight was administered to facilitate direct laryngoscopy and intubation. Direct laryngoscopy and intubation was performed after 3 minutes, mechanical ventilation was instituted.Ventilation was set at 6-8 ml/kg for the tidal volume, a respiratory rate of 12 breaths per minute at an inspiration-to-expiration time ratio of 1:2. $ETCO_2$ was maintained at 30-40 mmHg. The ventilator settingswere fixed while performing the study.Anaesthesia was maintained with isoflurane (1 MAC), nitrous 60% in oxygen.Patients were brought to the neutral control condition: supine position and a zero end-expiratory pressure (ZEEP) (SP0) **(Fig 1)** and the head rotated 5° to 10° to the left side without cervical extension or a neck-rest.A single operator who was experienced in use of ultrasonography then examined the cross section area of the right internal jugular vein by using a transportable ultrasound system (SonoSiteMturbo; Bothell, WA,USA) with a 38 mm 8-13 MHz linear ultrasound transducer (HFL-38) at the level of cricoidcartilage to provide a consistent anatomical landmark, one minute after each maneuvers. The transducer of 2-dimensional ultrasound was placed with the least possible pressure to avoid jugular compression. Images of the right internal jugular vein were obtained after applying 8 different maneuvers each for at least one minute in random order: : (1)Supine position with PEEP of 5 cm H2O (SP5), (2) PEEP of 10 cm H2O (SP10), (3) PEEP of 15 cm H2O (SP15), (4) a 10° Trendelenburg tilt position with a PEEP of 0 cm H2O (TP0), (5) 10° Trendelenburg tilt position combined with a PEEP of 5 cm H2O (TP5), (6) 10° Trendelenburg tilt position combined with a PEEP of 10 cm H2O (TP10),**(Fig 2)** (7) 10° Trendelenburg tilt position combined with a PEEP of 15 cm H2O (TP15). Trendelenberg position of 10º tilt was made with the help of smart phone (Iphone6) application-Angle Meter(NakhonPhagdeechat version 4.1). After each maneuver, the control condition was instituted for at least 1 min. The images of the CSA of the right internal jugular vein were obtained at least 1 min after instituting each maneuver. All images were made at end- expiration.

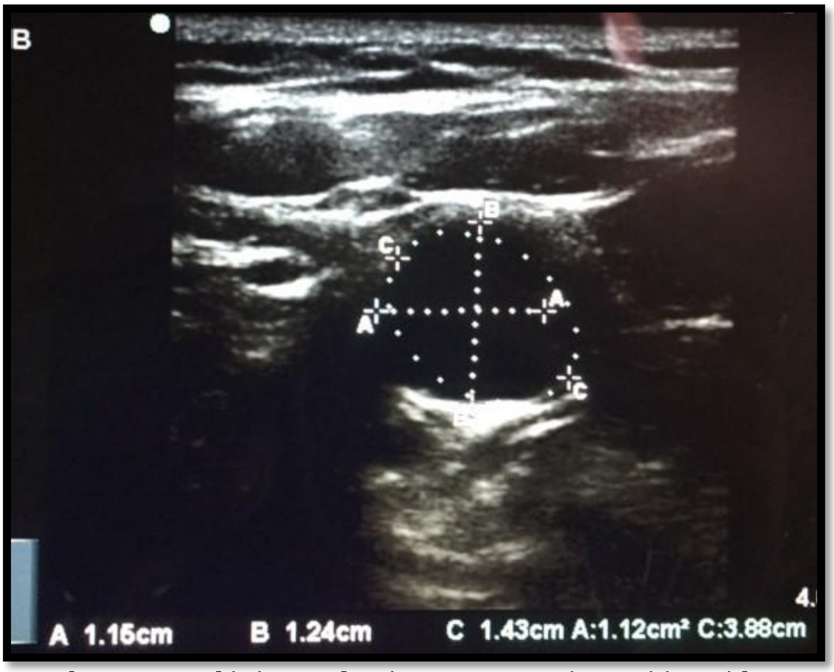

Fig1: SP_0 – Ultrasonographic image showing RIJV at supine position with no PEEP (SP_0)

Fig2: Ultrasonographic image showing RIJV at trendelenburg position with PEEP 10 (TP10)

Data that was recorded for the purpose of analysis included measurement of heart rate and non-invasive blood pressure (systolic blood pressure, diastolic blood pressure, mean arterial blood pressure) corresponding to the time of each predetermined 8 maneuvers. Transverse and anterio-posterior diameter and CSA of the right internal jugular vein were notified with help of ultrasonography at each maneuver. A 20 % decrease in mean arterial pressure below baseline or systolic pressure below 90mmHg was considered as hypotension and treated with Inj. Mephentermine IV bolus6mg IV bolus and decrease in heart rate below 50 bpm was treated with 0.2 mg to 0.5mg atropine sulphate. And PEEP applied was immediately removed. The use of vasoactive drugs was recorded along with the patients' systolic blood pressure and heart rate. Monitoring of airway pressures was done but were not recorded for analysis in this study.

The preliminary sample size was decided in consultation with a statistician. The average difference in the CSA of the right IJV before and after applying a 10 cm H2O PEEP in 10^0 Trendelenburg was $0.30cm^2$. A sample size of 45 patients was calculated in order to obtain 80% statistical power at a significance level of 0.05. Assuming 10% dropout rate final sample size was 50 patients for the present study.

Data was analyzed using SPSS software version 20. Data was presented as the Mean ± SD for continuous data. For comparison between two readings at various maneuvers, Wilcoxon signed rank test and paired t-test was used. P value (significance value) < 0.05 was considered as significant and <0.001 was considered highly significant

III. Results

The patient characteristics are summarized in Table 1.

Characteristic	**Mean±SD**
ASAI/II	38/12
Age(years)	38.1±7.91
Gender(M:F)	22:28
Weight(inKg)	62±13
Height(incm)	160±8.7
TypeOfSurgery OpenCholecystectomy Lapratomy MRM Colostomy Hernioplasty Excision(lump)	 31 4 3 4 3 5

*Data is presented as Mean±SD

No Vasoactive medication was given to treat arterial blood pressure fluctuations after applying a PEEP.All maneuver increased the CSA, AP diameter and transverse diameter, of the RIJV with respect to the control condition

The Cross sectional area of internal jugular vein at baseline was found to be 1.24±0.655 cm^2, (Fig 1)and the percentage increase in area at SP_0SP_5,SP_0SP_{10} ,SP_0SP_{15} ,$SP_0T_{10^\circ}P_0$, $SP_0T_{10^\circ}P_5$, $SP_0T_{10^\circ}P_{10}$,(Fig2) $SP_0T_{10^\circ}P_{15}$ was 11.29%, 25.8%, 25.8%, 24.19%, 37.91%, 54.8%, 54.9% respectively.(Table 2)

The Antero-posterior diameter of internal jugular vein at baseline was found to be 1.095±0.044 cm and the percentage increase in area at SP_0SP_5,SP_0SP_{10} ,SP_0SP_{15} ,$SP_0T_{10^\circ}P_0$, $SP_0T_{10^\circ}P_5$, $SP_0T_{10^\circ}P_{10}$, $SP_0T_{10^\circ}P_{15}$ was 9.1%,15.5%, 15.5%, 21.1%, 28.4%, 35.7%, 35.8% respectively.(Table 2)

The Transverse diameter of Internal jugular vein at baseline was found to be 1.348±0.031 cm and the percentage increase in area at SP_0SP_5,SP_0SP_{10} ,SP_0SP_{15} ,$SP_0T_{10^\circ}P_0$, $SP_0T_{10^\circ}P_5$, $SP_0T_{10^\circ}P_{10}$,(Fig 2) $SP_0T_{10^\circ}P_{15}$ was 6.8%, 11.1%, 11.9%, 12.6%, 17%, 22.3%, 23.1%. (Table 2)

Table 2: Mean changes in CSA, A-P Diameter and Transverse Diameter of RIJV

	CSA	**A-PDiameter**	**TransverseDiameter**
SP_0	1.2417±0.6500	1.0959±0.044	1.3482±0.031
SP_5	1.3875±0.6473 (11.29%)	1.1934±0.028 (9.1%)	1.4332±0.030 (6.8%)
SP_{10}	1.5646±0.6437 (25.8%)	1.2634±0.035 (15.5%)	1.4960±0.0311 (11.1%)
SP_{15}	1.5648±0.6439 (25.8%)	1.2636±0.035 (15.5%)	1.5004±0.037 (11.9%)
$T_{10^\circ}P_0$	1.5408±0.6260	1.3210±0.024	1.5176±0.034

	(24.19%)	(21.1%)	(12.6%)
T10ºP5	1.7106±0.6207 (37.91%)	1.4024±0.027 (28.4%)	1.5708±0.034 (17%)
T10ºP10	1.9204±0.6092 (54.8%)	1.4842±0.038 (35.7%)	1.6498±0.025 (22.3%)
T10ºP15	1.9234±0.6095 (54.9%)	1.4872±0.042 (35.8%)	1.6500±0.026 (23.1%)

*Data is presented as Mean±SD. ** Data represented in brackets shows percentage change in area and diameter

There were significant increases in the CSA of the RIJV with increases in PEEP up to 10 cm H2O and a nonsignificant trend toward further increases with greater PEEP above 10 cm H2O. The cross sectional area in a population of 50 patients consisting of 28 females and 22 male in supine and trendelenburg position of 10º with PEEP values of 0, 5, 10 and 15 cms of H2O was also studied. In present study there was no statistically significant difference in the cross sectional area amongst male and female population (p value ≥ 0.05).(Table 3)

TABLE 3: CHANGES IN CSA IN MALE AND FEMALE AT VARIOUS MANEUVERS

	GENDER	N	Mean	SD	tvalue	pvalue
SP0	MALE	22	1.133	0.414	-1.045	0.301
	FEMALE	28	1.327	0.785		
SP5	MALE	22	1.270	0.444	-1.137	0.261
	FEMALE	28	1.480	0.766		
SP10	MALE	22	1.462	0.472	-0.997	0.324
	FEMALE	28	1.645	0.751		
SP15	MALE	22	1.462	0.472	-0.997	0.323
	FEMALE	28	1.645	0.751		
T10ºP0	MALE	22	1.423	0.403	-1.184	0.242
	FEMALE	28	1.633	0.752		
T10ºP5	MALE	22	1.596	0.432	-1.158	0.252
	FEMALE	28	1.800	0.732		
T10ºP10	MALE	22	1.811	0.453	-1.125	0.266
	FEMALE	28	2.006	0.705		
T10ºP15	MALE	22	1.818	0.456	-1.084	0.284
	FEMALE	28	2.006	0.705		

*Data is presented as Mean±SD

Heart of patients did not vary significantly with application PEEP but there was significant decrease in heart rate (SP0-77.26/min, TP0-70.98/min) on application of 10^0trendelenburgposition.The Systolic blood pressure decreased with increasing PEEP value in supine position. Baseline systolic blood pressure (SP0) was 127.90mmhg, whereas at SP15 it was 120.18mmhg. This decrease in systolic blood pressure values was statistically highly significant (p value-0.00). When patients were placed in Trendelenburg position SBP increased but was still less than baseline supine position (T10ºP0) was 125.82mmHg (p value- 0.690). The Diastolic blood pressure did not vary significantly with increasing PEEP value in supine as well as in Trendelenburg position.(Table 4)

Table 4: Table showing baseline comparison of Heart Rate Systolic BP Diastolic BP value with other maneuvers

	H.R MEAN	p-VALUE	SBP	p-VALUE	DBP	p-VALUE
SP_0	77.26		127.90		78.96	
SP_5	75.10	0.844	125.30	0.255	77.86	0.232
SP_{10}	77.40	0.720	123.72	0.624	76.46	0.240
SP_{15}	77.10	0.970	120.18	0.000	75.86	0.144
$T10^oP_0$	70.98	0.002	125.82	0.690	76.70	0.065
$T10^oP_5$	72.56	0.282	124.34	0.408	76.04	0.108
$T10^oP_{10}$	75.84	0.114	123.84	0.062	75.80	0.063
$T10^oP_{15}$	76.28	0.909	124.20	0.291	76.10	0.074

*(p-value < 0.05 statistically significant), ** (p-value <0.001 highly significant) ***Data is presented as Mean±SD.

Application of PEEP does not affect heart rate and diastolic blood pressure significantly but there is significant fall in systolic blood pressure with application of PEEP of 15cm of H_2O. Application of trendelenburg position caused decrease in heart rate significantly. But there was no requirement of mephentermine or atropine due to hypotension or bradycardia during the study period.

IV. Discussion

In the present study, we found, an increase in anteroposterior diameter, transverse diameter and CSA of the right internal jugular vein (RIJV) after application of PEEP 5-15 cmH2O compared to the baseline value of these parameters in supine position. On addition of 10^0Trendelenberg position there was further increase these parameters with PEEP of 5-10 cm of H2O in anaesthetizedparalyzed patients. At PEEP of 15 cm of H_2O there was no further increase in any diameter or area in both supine and trendelenburg position but there was significant fall in systolic blood pressure at this PEEP.

Higher values of PEEP beyond 15 cms of H2O and more than 10^0 Trendelenburg tilt position, compromised the hemodynamics of the patients in the few studies done earlier.[10,11] Hence maneuvers with these values were not part of the study. Clenaghan et al. studied the change in RIJV diameter in healthy subjects in different Trendelenburg positions (10, 15, 20, 25, and 30°). The authors reported that even a 10^0 tilt is effective while a 25° Trendelenburg tilt achieved the optimum distension butimpractical in unstable patients. The authors recommended using a 10° tilt.[12]

In present study out of 50 patients, 28 were males and 22 were females. We found that CSA of RIJV with application of PEEP and Trendelenburg position in both males and females, were comparable. However, Mareata et al conducted a study on 26 females and 31 males and they found significant increase in CSA of male patients while, changes were variable and largely unpredictable, in female patients, which are contrary to our results.[13] Their results are different probably because of study on small sample of cardiac patients (coronary artery bypass or valve surgery). A larger size study is required to authentically conclude about the significant difference in changes in CSA of RIJV in male and female.

The Cross sectional area of RIJV increased with increasing PEEP and trendelenburg position. A possible explanation of increase in CSA with all the maneuver is that PEEP increases intrathoracic pressure thereby compressing the superior vena cava which in turn decreases return to superior vena cava, leading to increased IJV pressure and reducing collapsibility of IJV.[14,15,16]No further increase in CSA of RIJV beyond PEEP 10 occurred as compliance of vessel is limited therefore pressures of RIJV could not be increased further.[2]Trendelenburg maneuver increases height between the right atrium and right internal jugular vein and decreased return to the superior vena cava and by making the vein less collapsible due to increase intravascular pressure.[17,18,19,20] Machanalli G et al conducted a sono-anatomical analysis of right internal jugular vein and carotid artery at different levels of positive end-expiratory pressure in anaesthetised paralysed patients and concluded conclude that application of PEEP 10–15 cmH2 O in 20°Trendelenburg position increases CSA and AP diameter of IJV and simultaneously decreases CA overlap of IJV in anaesthetised paralysed patients.[21]

Marcus et al evaluated the impact of different PEEP 5, 10 cms of H2O in both supine and 20° Trendelenburg position on the CSA of RIJV in 50 patients undergoing major cardiothoracic surgery and found that, all maneuvers increased the CSA of the right internal jugular vein with respect to the control condition S0. They conclude that 10° Trendelenburg position with PEEP of 10 cms of H2O to be most effective in increasing the CSA of RIJV. Results of present study were similar to their study. However, the little difference in percentage increase of CSA of RIJV can be attributed to difference in methodology. In present study application time of PEEP and noting the parameters is 1min whereas Marcus et al. allowed only 30s. Better equilibration of pressure transmitted to the venous system occurreddue to more time in our study.[11] Several other authors have reported similar increase in area with increasing PEEP but there were no further increases in CSA with greater PEEP >12 cm H2O.[2,17,20]

In present study, there was one patients who showed no change in cross sectional area on applying PEEP and trendelenburg position, that suggest that each and every patient was not a responder to change in PEEP and trendelenburg position because of lower compliance of the vessels.[13]Marcus et al in their study found considerable number of non- responder veins in response to all maneuvers and they attributed this to lower compliance of the vessels due to higher body mass index[11].

There is significant fall in systolic blood pressure at PEEP of 15cm of H2O,in present study. This can be explained by the fact that on application of PEEP, intrathoracic pressure increases which in turn decreases venous return (preload) resulting into reduction in cardiac output and thus reducing systolic blood pressure. The Diastolic blood pressure did not vary significantly with increasing PEEP value in supine as well as in Trendelenburg position,it can be explained by the fact that application of PEEP does not have any effect on afterload so diastolic blood pressure did not change much.

Sibbald W J et al in their study evaluated the effect of the Trendelenburg position on systemic and pulmonary hemodynamics in critically ill patients. They concuded that in normotensive patients, the head-down tilt enhanced the preload of both the ventricles, leading to slight improvement in cardiac output, it decreased systemic vascular resistance, and had no effect on mean arterial pressure. This effect was probably mediated by baroreceptor stimulation. In hypotensive patients, the Trendelenburg position did not increase preload, slightly increased afterload, and decreased cardiac output.[22]

Han et alstudied that systolic blood pressure decreased significantly by 7.0 mmHg following the application of 10 cms H20 PEEP but no patients required vasoactive medications.[17]Other researchers also found similar hemodynamic changes.[1,20]

Limitations of the present study were firstly this study is done on ASAI and II patients, so these results maynot be applied on sick patients and patients with co morbidities, with high PEEP and trendelenburg position. Secondly, we cannot assess the success rate and the extent to which cannulation will be facilitated by these maneuvers.Thus further research should focus on the clinical usefulness of Trendelenburg and PEEP with respect to the success rate of central venous catheterization and patient outcomes.

V. Conclusion

Both a 10 cm of H_2O PEEP and 10^0 Trendelenburg position are effective in increasing area of RIJV without compromising hemodynamics of the patient. Increasing PEEP further to 15cm does not increase area further but decrease systolic blood pressure. Hence we concluded that application of 10cm of H2O PEEP along with 10^0 Trendelenburg position produces optimal distension of RIJV without compromising hemodynamic status of anaesthetized patient.

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