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RESEARCH ARTICLE

"REDUCING RESPIRATORY VARIATIONS IN INTERNAL JUGULAR VEIN CROSS-SECTIONAL AREA USING PEEP AND TRENDELENBURG POSITION"

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Abstract

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Introduction: The respiratory cycle influences the size of the right internal jugular vein (RIJV). We evaluated the changes in RIJV size during the respiratory cycle in patients on positive pressure ventilation. Additionally, we investigated the impact of positive end-expiratory pressure (PEEP) and the Trendelenburg position on these respiratory fluctuations.

Methods: The study involved 24 patients who underwent general endotracheal anesthesia. Images of the right internal jugular vein (RIJV) were captured in the supine position (baseline, S0) and during three randomized maneuvers: applying a positive end-expiratory pressure (PEEP) of 10 cmH2O (S10), positioning the patient in a 10° Trendelenburg tilt (T0), and combining the Trendelenburg tilt with PEEP (T10). The aim was to measure the cross-sectional area (CSA), anteroposterior diameter, and transverse diameter of the RIJV at both its smallest and largest observed sizes during each maneuver.

Results: The study found that all maneuvers significantly reduced the fluctuation in the size of the right internal jugular vein (RIJV) ($p = 0.0004$). Specifically, compared to the supine position (S0), the maneuvers resulted in the following decreases in the cross-sectional area (CSA) from the smallest to the largest observed sizes: • S0: Decrease by 28.3% • S10: Decrease by 8.5% • T0: Decrease by 8.0% T10: Decrease by 4.4% Additionally, compared to S0, the combination of a 10° Trendelenburg tilt position with a positive end-expiratory pressure (PEEP) of 10 cmH2O significantly increased the CSA: • In the largest observed areas by 83.8% • In the smallest observed areas by 169.4% These findings suggest that the Trendelenburg tilt combined with PEEP was particularly effective in increasing the CSA of the RIJV, both at its largest and smallest observed sizes, compared to other maneuvers and the baseline supine position.

Conclusions: A 10° Trendelenburg tilt position combined with a PEEP of 10 cmH2O not only increases the size of the RIJV but also reduces fluctuation by the respiratory cycle.

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Introduction:-

Central venous catheterization through the right internal jugular vein (RIJV) using anatomical landmarks is generally successful and offers the advantage of a direct path towards the right atrium [1]. However, this common procedure is not without risks, primarily associated with needle-related trauma. Accidental puncture of the carotid artery (reported incidence, 1.9-15%) [1,2] is the most frequent complication, potentially leading to airway obstruction due to hematoma formation [3]. Other complications include thromboembolism and arteriovenous fistula formation [4,5,6], which are more likely with increased attempts at needling during catheterization [7,8].

The success of first-pass attempts can be improved with a larger internal jugular vein (IJV) [9]. Several techniques have been proposed to increase vein size. Hollenbeck et al. [10] demonstrated an increase in RIJV cross-sectional area (CSA) using 10 cmH2O positive end-expiratory pressure (PEEP) in patients under general anesthesia. Marcus et al. [11] studied the effects of 5 and 10 cmH2O PEEP, with or without Trendelenburg positioning, on RIJV CSA. However, these studies typically measure the largest CSA without accounting for respiratory cycle fluctuations, which can significantly affect IJV size, especially in patients under positive pressure ventilation during perioperative central venous catheterization [12,13].

Therefore, investigating the impact of respiratory fluctuations on IJV CSA is crucial, given its potential implications for procedural success and complication rates in clinical settings.

Objectives:-

1. The purpose of this study was to investigate changes in the size (e.g., CSA, anteroposterior [AP] diameter, and transverse diameter) of the RIJV with respect to the respiratory cycle in patients under general anesthesia and positive pressure ventilation.
2. The effects of PEEP and the Trendelenburg position on the size of the RIJV during the respiratory cycle.

Materials and Methods:-

Source Of Data –

The present study was conducted in department of anesthesiology at Basaveshwar teaching and general hospital attached to MahadevappaRampure Medical College, Kalaburagi.

Method of collection of data

Study Design –Prospective randomized control study

Place of Study- Basaweshwara Teaching and General Hospital, MahadevappaRampure Medical college Kalaburagi.

Sample Size: 24

Sampling procedure: Study subjects were selected after applying inclusion and exclusion criteria. Information was collected through prepared proforma from each case.

Inclusion Criteria:

1. Patients undergoing electivegynecologic or orthopedic surgery under general endotracheal intubation.
2. ASA (American society of anaesthesiologists) Grade I, II
3. Age 18-80 years

Exclusion Criteria :

1. History of neck surgery.
2. Previous RIJV cannulation
3. Cardiac disease, and pulmonary disease.
4. Patients were excluded after enrollment if severe hypotension after the induction of anesthesia occurred.
5. Local skin infections or disease
6. Patients with bleeding diathesis

Methodology:-

This study "reducing respiratory variations in internal jugular vein cross-sectional area using peep and trendelenburg position"was conducted on 24 patients (ASA1,2) undergoing at BasaweshwaraTeaching and General Hospital, Kalaburagi.

Patients who meet the inclusion criteria were enrolled for the study with informed consent after receiving approval from the institution's ethical committee.

Data was collected in prescribed Proforma meeting the objectives of the study.

Half an hour before the scheduled procedure, patients were transferred to the preoperative room where baseline vital signs including pulse rate, noninvasive blood pressure, oxygen saturation on room air, respiratory rate, and ECG pattern were recorded. Intravenous access was established using an 18G IV cannula.

Anesthesia was induced using propofol and fentanyl, followed by neuromuscular blockade with vecuronium (0.1mg/kg). After tracheal intubation, patients were placed on mechanical ventilation in volume-controlled mode. Ventilator settings included a tidal volume of 8 ml/kg, respiratory rate of 12 breaths per minute, inspiratory-to-expiratory time ratio of 1:2, and end-tidal carbon dioxide maintained at 30-40 mmHg. These settings remained constant throughout the study.

With the patient supine and the head in neutral position (S0), a high-frequency linear array ultrasound transducer was used to visualize the right internal jugular vein (RIJV) at the level of the cricoid cartilage in longitudinal orientation. The transducer was applied with minimal pressure to obtain optimal images. Images were captured and stored when the RIJV exhibited its maximum and minimum cross-sectional areas (CSA) during the respiratory cycle.

Following baseline imaging (S0), three maneuvers were applied in random order with a minimum 30-second interval between each:

1. Application of positive end-expiratory pressure (PEEP) at 10 cmH2O (S10),
2. Tilting the patient 10° Trendelenburg (T0),
3. Combination of PEEP 10 cmH2O and 10° Trendelenburg tilt (T10).

Ultrasound images were obtained at least 30 seconds after each maneuver to allow stabilization. During each maneuver, the RIJV circumference was electronically measured, and its CSA was calculated using the ultrasound system. The examiner was blinded to maneuver order during data collection.

Hemodynamic parameters were continuously monitored. Hypotension, defined as a 30% decrease in systolic blood pressure from baseline, was treated promptly with mephenteramine. Bradycardia (heart rate < 45 beats per minute) was managed with 0.5 mg atropine. Administration of vasoactive drugs, along with systolic blood pressure and heart rate, was documented throughout the study.

All subjects adhered to an 8-hour fasting protocol and received lactated Ringer's solution at 4 ml/kg over the first hour of the study period.

The main focus of this study was to assess changes in the cross-sectional area (CSA) of the right internal jugular vein (RIJV) under different conditions, along with secondary measures related to vein diameter variations and hemodynamic responses.

The primary outcome was the difference in RIJV CSA between its maximal and minimal measurements during four conditions: baseline (S0), positive end-expiratory pressure (PEEP) at 10 cmH2O (S10), Trendelenburg position at 10° (T0), and a combination of PEEP 10 cmH2O and Trendelenburg position (T10).

Secondary outcomes included differences in the transverse and anteroposterior (AP) diameters of the RIJV at maximal and minimal points during each of these conditions. Additionally, the study examined changes in systolic blood pressure and heart rate in response to each maneuver.

By evaluating these parameters across different respiratory and positional conditions, the study aimed to provide insights into optimizing conditions for RIJV cannulation during clinical procedures, particularly under mechanical ventilation in perioperative settings

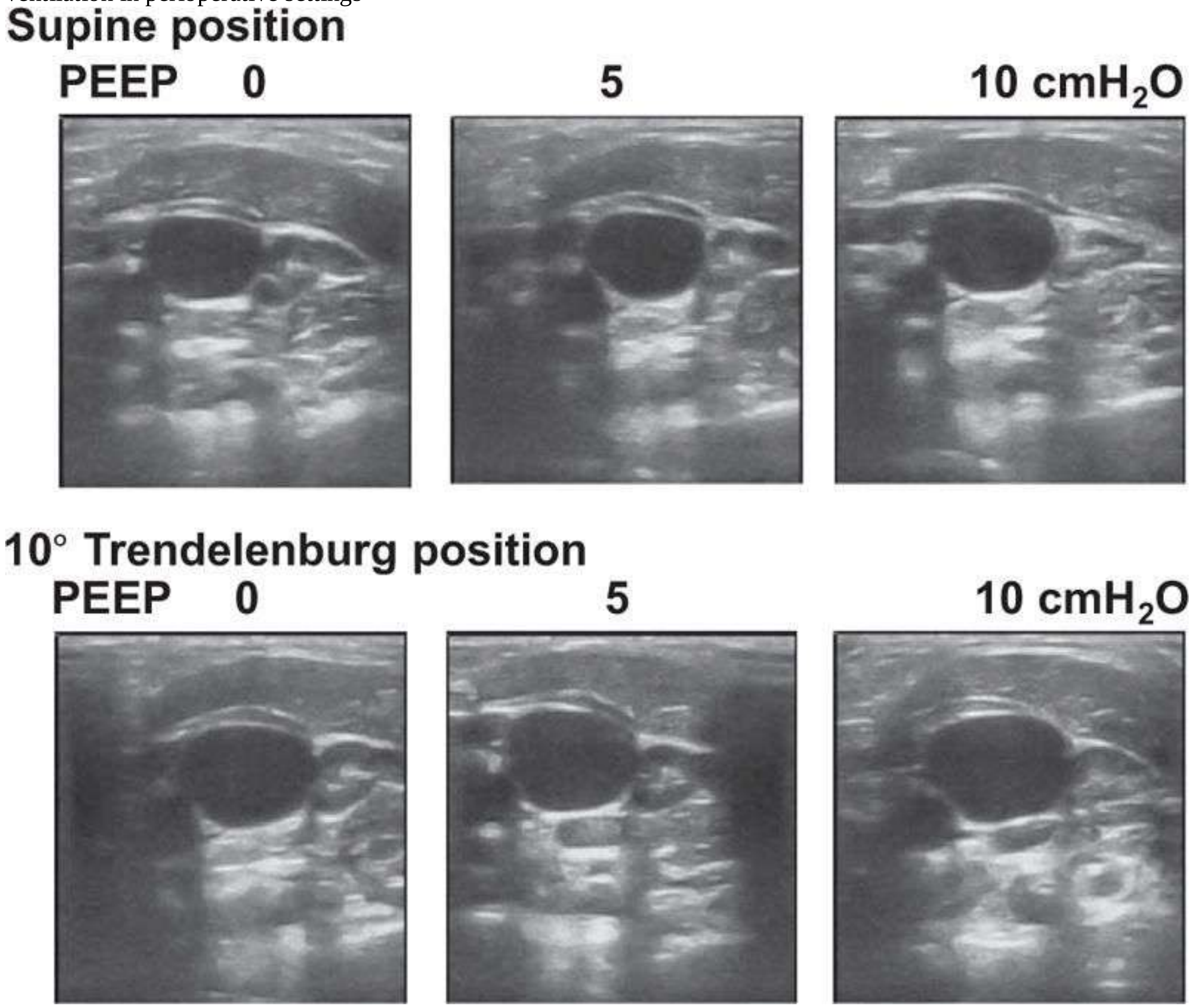


Fig.:- USG images of Right internal jugular vein.

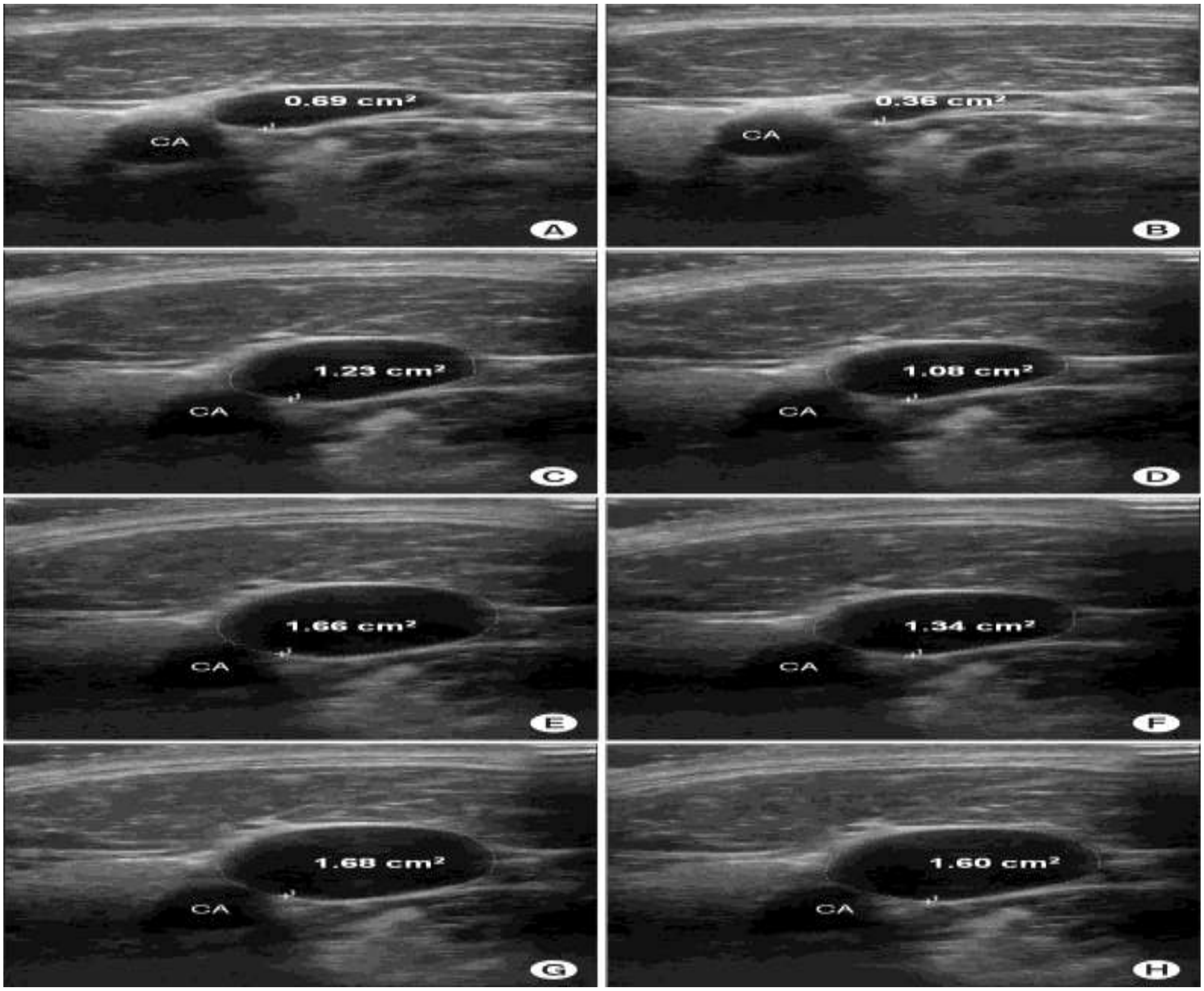


Fig.:- Ultrasound images of the right internal jugular vein from one patient in four different maneuver combinations for the largest and smallest sizes recorded.

Largest cross-sectional area measured during S0 (A), S10 (C), T0 (E) and T10 (G), respectively.

Smallest cross-sectional area measured during S0 (B), S10 (D), T0 (F) and T10 (H).

CA: carotid artery,
Max: largest values during a respiratory cycle,
Min: smallest values during a respiratory cycle,
S0: supine baseline,
S10: a positive-end expiratory pressure (PEEP) of 10 cmH_2O,
T0: a 10° Trendelenburg tilt position,
T10: a 10° Trendelenburg tilt position combined with a PEEP of 10 cmH_2O.

Statistics

At the outset of the study protocol, both positive end-expiratory pressure (PEEP) and the Trendelenburg position were applied in a randomly assigned sequence. All statistical analyses were conducted using SAS version 9.1 (SAS Institute, Cary, NC, USA). The significance of respiratory-induced changes in the cross-sectional area (CSA) of the right internal jugular vein (RIJV), as well as the transverse and anteroposterior (AP) diameters, was evaluated using Generalized Estimating Equation (GEE) analysis. Statistical significance was determined with a threshold of $P < 0.05$.

To assess the impact of the different maneuvers on RIJV characteristics, changes in the largest and smallest CSAs, transverse, and AP diameters were analyzed using a mixed model. A P value less than 0.05 was considered statistically significant.

For the study, data on the largest and smallest CSAs at baseline (S0) and under PEEP 10 cmH2O (S10) were collected from ten patients. The sample size calculation was based on a pilot study involving ten subjects, where the average changes in CSAs were found to be 0.34 ± 0.18 (mean ± SD) for S0 and 0.16 ± 0.11 for S10. With an alpha level of 0.05, a power of 90%, and accounting for a 20% dropout rate, a minimum sample size of 22 was determined.

This approach ensured that the study had adequate statistical power to detect meaningful differences in RIJV measurements under the specified conditions, thereby contributing robust findings to guide clinical practice.

Results:-

Patient Characteristics:

- **Gender Distribution:**
  - Males: 10
  - Females: 14

Data and Outcomes:

- Complete datasets and analyzable images were collected for all patients.
- There were no reported complications.

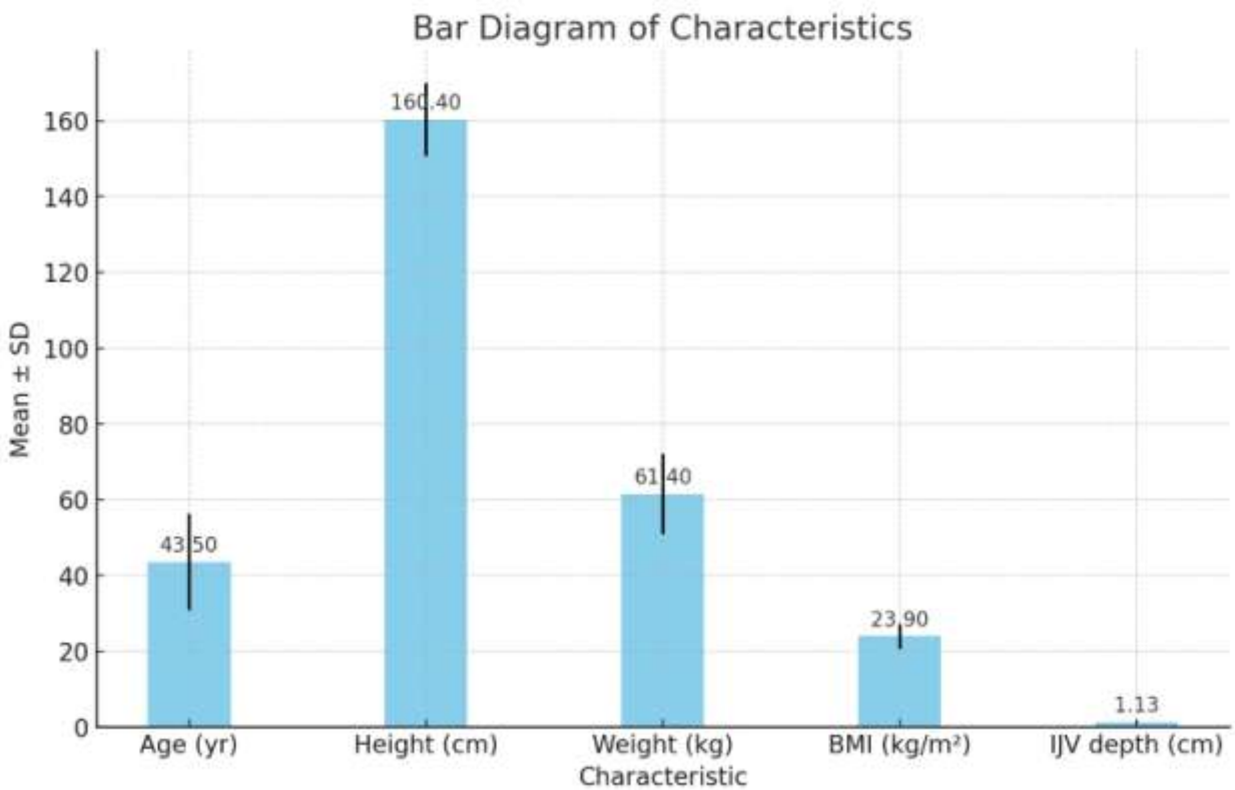
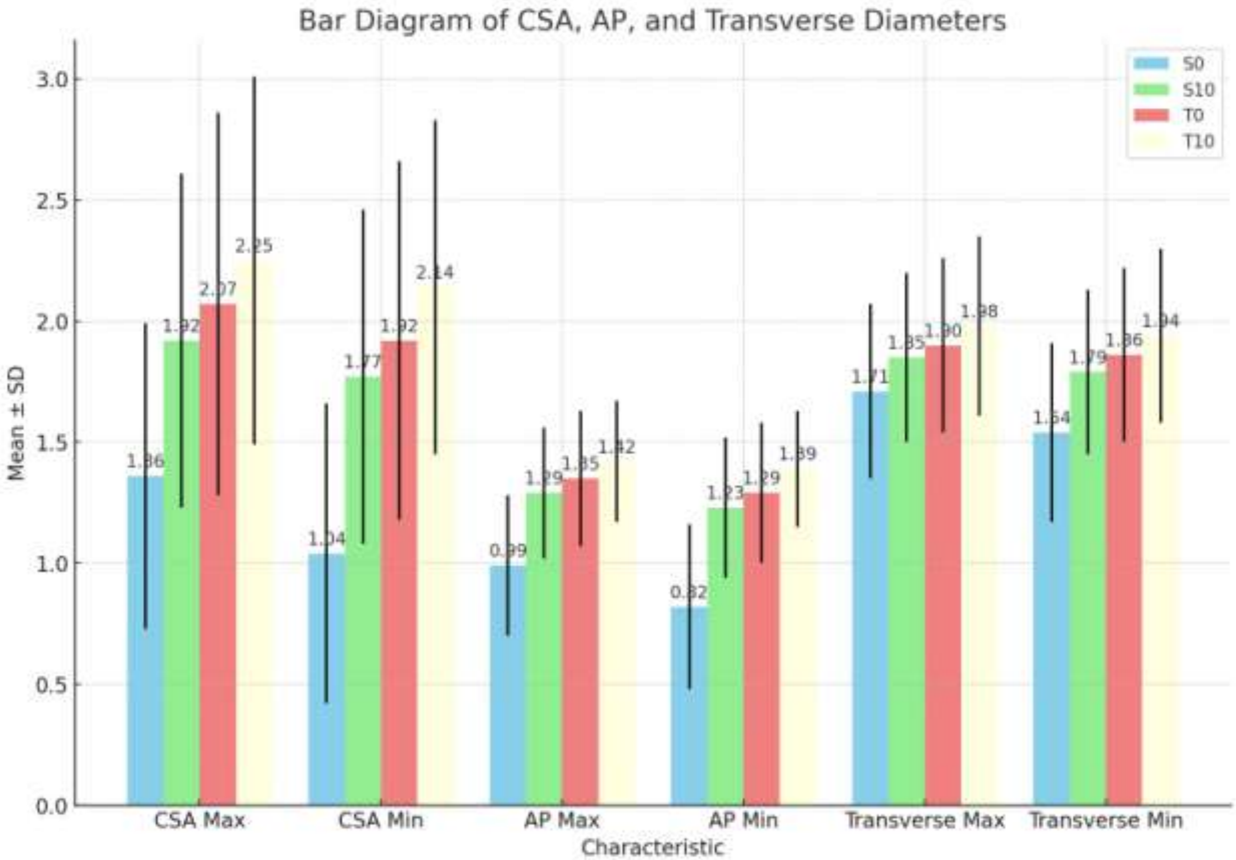
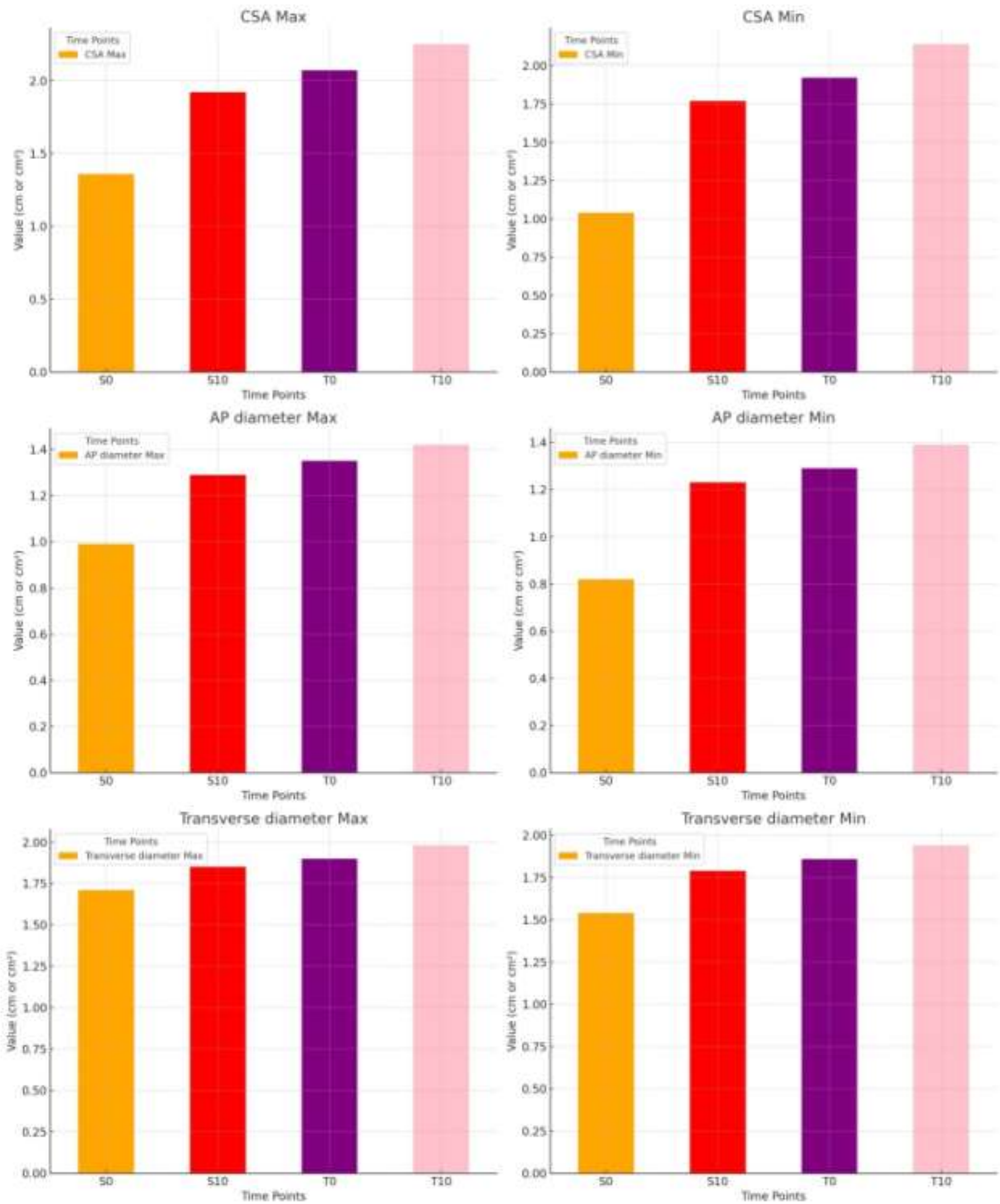


Fig. 1:- demographic and baseline information.

Fig 2 presents the variations in CSA, transverse diameter, and AP diameter for the largest and smallest RIJV based on position changes or PEEP application, as well as the differences between inspiration and expiration. When both maneuvers (T10) were combined, there was a 4.4% decrease in the CSA respiratory change in the RIJV compared to a 28.3% decrease at baseline (S0) (P = 0.0004; GEE analysis). The individual effects of PEEP and the Trendelenburg position on the respiratory change-induced decrease in CSA of the RIJV were 8.5% and 8.0%, respectively (both P = 0.0004; GEE analysis). Across all patients, the CSA, transverse diameter, and AP diameter of the largest and smallest RIJV increased with the application of PEEP, the Trendelenburg position, and their combination



Here are the bar charts illustrating the cross-sectional area (CSA), anteroposterior (AP) diameter, and transverse diameter under different conditions (S0, S10, T0, T10). The yellow bars represent the maximum values, and the orange bars represent the minimum values, with error bars indicating the standard deviation for each measurement.

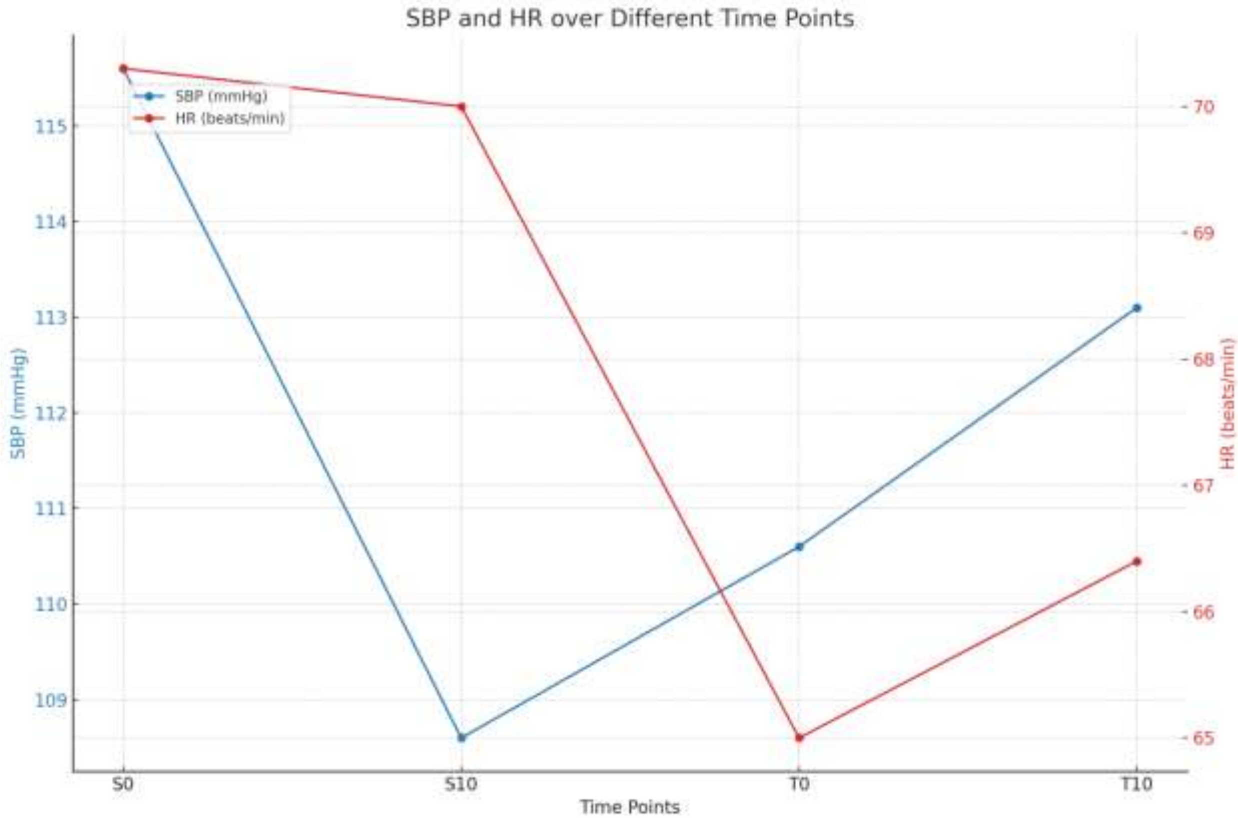


Each subplot shows how these measurements vary across the conditions:

1. **CSA under Different Conditions**
2. **AP Diameter under Different Conditions**
3. **Transverse Diameter under Different Conditions**

These visualizations help compare the changes in these parameters across different conditions.

The systolic blood pressure showed a significant reduction of 7.0 mmHg after the application of 10 cmH2O PEEP (P = 0.024) (FIG 3). In the 10° Trendelenburg position (T0) and with a combination of 10 cmH2O PEEP and 10° Trendelenburg position (T10), the heart rate also decreased significantly (P = 0.0005 and P = 0.004, respectively) (fig 3). Moreover, there was no need for mephenteramine or atropine due to hypotension or bradycardia during the study period



Discussion:-

This study aimed to assess the impact of the respiratory cycle on the size of the right internal jugular vein (RIJV) and to determine the effects of PEEP and the Trendelenburg position on anesthetized adult patients under positive pressure ventilation. The cross-sectional area (CSA) of the RIJV was largest during inspiration and smallest during expiration, with a mean reduction from largest to smallest of 28.3 ± 14.7%. The application of either the Trendelenburg position or PEEP reduced this difference, and when combined, the difference decreased further, with the largest and smallest CSAs being 2.25 ± 0.76 and 2.14 ± 0.69 cm², respectively.

Using ultrasound-guided RIJV puncture resulted in fewer puncture attempts, a higher success rate, and a greater likelihood of successful puncture on the first attempt, thereby reducing complications. However, ultrasound-guided IJV cannulation still caused complications, the most common being carotid artery puncture at a rate of 1.4%. To mitigate complications, various studies have aimed to increase vein size through methods such as Trendelenburg positions, the Valsalvamaneuver, inspiratory hold, and PEEP. Previous studies focused primarily on maximizing vein size without considering size changes according to the respiratory cycle.

To reduce complications like carotid artery puncture, it is advisable to maximize the IJV diameter through controlled ventilation at end-inspiration. This approach minimizes vein collapsibility during puncture and reduces unnecessary needle advancement, thereby decreasing the risk of artery puncture. Inserting the needle after induction and timing puncture at end-inspiration during intermittent positive ventilation is recommended. This study demonstrated that both the Trendelenburg position and PEEP application not only increased vessel size but also reduced size fluctuations caused by the respiratory cycle. Combining the two interventions was more effective in reducing fluctuations, making synchronized puncture timing unnecessary.

Several parameters were used to determine IJV size in this study: CSA, anterior-posterior (AP) diameter, and transverse diameter. Previous studies reported increases in diameter, but the vein was more ovoid than round, making the term diameter vague. This study found that using the Trendelenburg position or PEEP alone minimally changed the transverse diameter while increasing the AP diameter, thus increasing the CSA and reducing the possibility of transfixation and posterior wall puncture. If previous studies had used the transverse diameter, results could have been underestimated. Therefore, the primary outcome was set to the change in CSA, and secondary outcomes included changes in the transverse and AP diameters. The results indicated that the Trendelenburg position and/or PEEP application increased the CSA mainly by increasing the AP diameter.

Clenaghan et al. investigated changes in RIJV diameter in healthy subjects at various Trendelenburg positions and found that even a 10° tilt was effective, with a 25° tilt achieving optimal distension. They recommended a 10° tilt. Lobato et al. observed that a 10° Trendelenburg position increased RIJV CSA by 25%, with further increases when combined with hepatic compression or inspiratory hold, while a 20° Trendelenburg position provided no additional benefit. This study's PEEP application was based on previous research showing that a PEEP of 10 cmH2O increased RIJV CSA by 22.3 and 41.0%, respectively. Therefore, a 10° Trendelenburg tilt and a PEEP of 10 cmH2O were chosen.

Two major limitations were noted: First, changes in IJV CSA are directly related to successful cannulation, but this study did not conclusively prove that a larger vessel size increased the success rate. Second, the observers were not blinded to the maneuvers, although the order of maneuvers was randomized and a blinded examiner measured the CSA and diameters using stored images.

Combining a 10° Trendelenburg tilt with a PEEP of 10 cmH2O reduced respiratory fluctuations in the RIJV, specifically decreasing the mean difference in CSA, AP diameter, and transverse diameter during the respiratory cycle by 4.4, 2.4, and 1.9%, respectively, compared to baseline (28.3, 20.8, and 10.3%). Additionally, this combination did not decrease systolic blood pressure from baseline. To minimize RIJV size fluctuations according to the respiratory cycle and maximize its size, a 10° Trendelenburg tilt combined with a PEEP of 10 cmH2O is recommended during needle insertion for cannulation of the RIJV under positive pressure ventilation.

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