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ORIGINAL ARTICLE

Comparison of 0^0, 10^0 and 25^0 Trendelenburg Tilt on Internal Jugular Vein and Optical Nerve Sheath Diameters in Healthy Adults

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Abstract

Introduction: The trendelenburg position is widely utilized to facilitate central venous cannulation. However, the optimal angle to balance efficacy and safety remains debated.

Methods: This experimental study aimed to compare the impact of 0°, 10°, and 25° trendelenburg tilt angles on internal jugular vein (IJV) and optic nerve sheath (ONS) diameters in 28 healthy adults. Measurements of maximal diameters were performed using ultrasound at each specified angle from May to June 2024.

Results: Results demonstrated that while both 10° and 25° positions significantly increased IJV and ONS diameters compared to 0° ($P<0.05$), the 25° tilt caused ONS diameters to exceed the critical safety threshold (>4.5 mm) in five subjects. In contrast, the 10° position achieved a significant increase in IJV diameter while successfully maintaining ONS measurements within safe limits.

Discussion: The findings suggest that although greater trendelenburg angles enhance IJV dilation, they may also increase ONS diameter beyond safe thresholds, raising the risk of elevated intracranial pressure. Therefore, balancing vascular access benefits with neurological safety is essential when determining the appropriate tilt angle.

Conclusion: A 10° trendelenburg tilt is recommended as the optimal angle to increase IJV diameter without elevating ONS diameter in healthy populations.

Keywords: Central venous cannulation; internal jugular vein diameter; optic nerve sheath diameter; trendelenburg

Introduction

The utilization of central venous catheters (CVC) and other implantable vascular devices has shown a rapid increase in modern medical practice across a wide range of clinical indications. In the United States alone, intensive care units (ICUs) record approximately 15 million CVC uses annually.[1] Among the various access points, the right internal jugular vein (RIJV) remains the most frequently selected cannulation site due to its favorable profile of convenience and safety.[2–4] While ultrasound-guided (USG) cannulation is established as the gold standard for increasing success rates and mitigating risks

such as hematoma and inadvertent arterial cannulation the availability of USG remains significantly limited in many clinical settings. Consequently, cannulation via anatomical landmark techniques remains a frequent and necessary alternative. [3–5]

To optimize landmark-based success, the trendelenburg position is commonly recommended as it effectively increases venous size, enhances cannulation success rates, and reduces the risk of air embolism. However, this maneuver is not without physiological consequences; a significant concern is the potential increase in intracranial pressure (ICP) resulting from the head-down tilt. In clinical practice, measurement of the optic nerve sheath diameter (ONSD) has emerged as a reliable, non-invasive method to detect such increases in ICP. [6]

Current literature indicates that a trendelenburg tilt of 10° can significantly increase internal jugular vein (IJV) diameter, with maximal distension typically occurring at a 25° tilt.[3,7] Despite these findings, there is a notable lack of comparative research evaluating the simultaneous changes in ONSD at these specific angles. Therefore, this study aims to compare the effects of 0°, 10° and 25° Trendelenburg tilt angles on both IJV diameter and ONSD in healthy adults. By defining these physiological responses, the authors seek to identify an optimal tilt angle that maximizes procedural access while maintaining intracranial safety.

Subjects and Methods

This research employed an experimental design with a single-study population receiving three sequential treatments. Using a consecutive sampling technique, 28 healthy adults aged 26–45 years with a body mass index (BMI) of 18.5–22.9 kg/m^2 were recruited. All subjects were confirmed to be normovolemic before the intervention using the ultrasound device. Exclusion criteria included a history of neck tumors, vascular malformations, or trauma; prior central venous cannulation in the target area; and systemic comorbidities such as hypertension, diabetes, or congenital heart disease. Additionally, subjects with conditions potentially altering intracranial pressure (ICP) or cerebral autoregulation, including chronic headaches, stroke, or brain tumors, were excluded.

The study protocol was reviewed and approved by the Health Research Ethics Committee (Ref. No: DP.04.03/D. XIV.6.5/61/2024). The research was conducted in accordance with the ethical principles set out in the Declaration of Helsinki. Before participation, all subjects were provided with detailed information regarding the study objectives and procedures, and written informed consent was obtained from each volunteer.

The study was conducted from May 27, 2024, to June 11, 2024. Initially, subjects were placed in a supine position on a specialized bed equipped with a built-in, calibrated clinometer to ensure precise elevation and lowering of the trendelenburg angles. To verify normovolemia, hemodynamic status was assessed using an abdominal ultrasound probe to measure the inferior vena cava (IVC) index.

Once hemodynamic adequacy was confirmed, the cricoid cartilage was marked as a reference point on the neck. The internal jugular vein (IJV) cross-sectional area (CSA) was measured using conventional ultrasound at this level. Simultaneously, the optic nerve sheath diameter (ONSD) was measured using a lateral axial trans-bulbar ultrasound approach. Measurements for both the maximal IJV and ONS diameters were recorded sequentially for each subject at three specific trendelenburg tilt angles respectively: 0°, 10° and 25°. The same investigator performed all ultrasound examinations to maintain measurement consistency.

Result

Subject characteristics, including age, gender, weight, height, and hemodynamic status, were recorded. Numerical variables are presented as mean, standard deviation, median, and range. Categorical data are presented as frequency

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distributions and percentages in Table 1.

Based on the data in Table 1, this study involved 28 subjects with a mean age of 30 years and a standard deviation of 2 years, ranging from 26 to 34 years. The majority of subjects were male (18 individuals, 64.3%), while the remaining 10 (35.7%) were female.

Subject weight ranged from 44.0 kg to 78.0 kg, with a mean of 59.6 kg (SD 8.5 kg). Mean height was 1.67 meters (SD 0.08 meters), ranging from 1.54 to 1.85 meters. The mean BMI was 21.3 (SD 1.7), with a range of 18.6 to 22.9. Furthermore, the mean Inferior Vena Cava Collapsibility Index (IVC CI) was 16.0% (SD 1.13%), with values ranging from 14.2% to 17.5%, indicating that all subjects were in a normovolemic state.

This study compared internal jugular vein (IJV) diameters across three degrees of trendelenburg tilt: 0°, 10°, and 25°. Data analysis revealed significant differences in IJV diameter among these three tilt angles. Based on the data presented in Table 2, it can be concluded that at a 0° tilt, the mean IJV diameter was 13.0 mm with a standard deviation (SD) of 2.0 mm, indicating that the vein size remains relatively constant in the supine position. The median diameter was also 13.0 mm, with a range of 10.2 mm to 17.2 mm.

When the tilt was increased to 10°, the mean IJV diameter increased to 15.6 mm (SD 2.7 mm). The median IJV diameter at this tilt was 15.3 mm, with a range of 12.2 mm to 21.6 mm. This increase demonstrates venous dilation with increasing tilt. At a 25° tilt, the mean IJV diameter reached 17.0 mm (SD 2.5 mm). The median IJV diameter was 16.8 mm, with a range of 13.6 mm to 23.0 mm. This suggests that a steeper tilt angle is associated with a more significant increase in venous diameter.

The comparison of IJV diameters at various trendelenburg tilt degrees is shown in Table

Table 1 Subject Characteristics

Variable	n=28
Age (year)	
Mean±Std	30±2
Range (min-max)	26–34
Gender, n (%)	
Male	18(64.3)
Female	10(35.7)
Weight (kg)	
Mean±Std	59.6±8.5
Range (min-max)	44.0–78.0
Height (m)	
Mean±Std	1.67±0.08
Range (min-max)	1.54–1.85
Body Mass Index (BMI)	
Mean±Std	21.3±1.7
Range (min-max)	18.6–22.9
IVC CI (%)	
Mean±Std	16.0±1.13
Range (min-max)	14.2–17.5

Table 2 Comparison of Trendelenburg Tilt and Internal Jugular Vein (IJV) Diameter

Variable	Trendelenburg Tilt			p-value
	0^0	10^0	25^0	
IJV diameter (mm)				
Mean±Std	13.0±2.0	15.6±2.7	17.0±2.5	<0.001*
Median	13.0	15.3	16.8	
Range (min-max)	10.2–17.2	12.2–21.6	13.6–23.0	

Note: *Repeated Measures ANOVA; significant at p<0.05

3. Further comparative analysis showed that the difference in IJV diameter between 0° and 10° tilt was 2.6 mm, with a 95% confidence interval (CI) of 2.1 mm to 3.1 mm. A very low p-value (p<0.001) indicates that this difference is statistically significant. When comparing 0° and 25° tilt, the mean difference in IJV diameter was 4.0 mm, with a confidence interval of 3.5–4.4 mm. The p-value remained very low (p<0.001), indicating strong statistical significance for this difference. Furthermore, the comparison between 10° and 25° tilt showed a mean difference in diameter of 1.4 mm, with a confidence interval of 1.1–1.6 mm. The p-value was also very low (p<0.001), indicating that this difference is statistically significant.

The IJV diameter increased significantly with increasing trendelenburg tilt degrees. The increase from 13.0 mm at 0° tilt to 17.0 mm at 25° tilt demonstrates that a higher degree of tilt is closely associated with greater venous dilation. Significant differences between each tilt level (0° vs. 10°, 0° vs. 25°, and 10° vs. 25°) support this conclusion with p<0.001, confirming that changes in IJV diameter are closely related to the degree of trendelenburg tilt.

The comparison of Optic Nerve Sheath Diameter (ONSD) across different trendelenburg tilt degrees is presented in Table 4. A comparative analysis of ONSD changes across various tilt degrees, using the Bonferroni post hoc test, is shown in Table 5.

This study evaluated ONSD at three trendelenburg tilt degrees: 0°, 10°, and 25°. Analysis revealed significant differences in ONSD across all three degrees. Data in Table 4 indicate that in the neutral position (0°), the mean ONSD was 3.69 mm (SD 0.20 mm). The median ONSD was 3.70 mm, with a range of 3.40 mm to 4.10 mm, suggesting that ONSD tends to be small and relatively consistent in the supine position.

When the tilt was increased to 10°, the mean ONSD rose to 3.96 mm (SD 0.19 mm). The median ONSD at this degree was 3.90 mm, with a range of 3.60 mm to 4.30 mm. This increase indicates significant optic nerve sheath dilation with increasing tilt. At a 25° tilt, the mean ONSD reached 4.24 mm (SD 0.19 mm), with a median of 4.20 mm and a range of

Table 3 Post Hoc Analysis of the Comparison Between Trendelenburg Tilt and Internal Jugular Vein (IJV) Diameter

Variable	Comparison	Mean Difference (95% CI)	p-value
IJV diameter (mm)	0^0 vs 10^0	2.6(2.1–3.1)	<0.001*
	0^0 vs 25^0	4.0(3.5–4.4)	<0.001*
	10^0 vs 25^0	1.4(1.1–1.6)	<0.001*

Note: *Bonferroni test; significant at p<0.05

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Tabel 4 Comparison of Trendelenburg Tilt and Optic Nerve Sheath (ONS) Diameter

Variable	Trendelenburg Tilt			p-value
	0^0	10^0	25^0	
ONS Diameter (mm)				
Mean±Std	3.69±0.20	3.96±0.19	4.24±0.19	<0.001*
Median	3.70	3.90	4.20	
Range (min-max)	3.40–4.10	3.60–4.30	3.80–4.60	

Note: *Repeated Measures ANOVA; significant at p<0.05

Tabel 5 Post Hoc Analysis of the Comparison between Trendelenburg Tilt and Optic Nerve Sheath (ONS) Diameter

Variable	Comparison	Mean Difference (95% CI)	p-value
ONS Diameter (mm)	0º vs 10º	0.28 (0.24–0.31)	<0.001*
	0º vs 25º	0.55 (0.50–0.60)	<0.001*
	10º vs 25º	0.28 (0.23–0.32)	<0.001*

Note: *Bonferroni test; significant at p<0.05

3.80 mm to 4.60 mm. This demonstrates that a steeper tilt is associated with a more significant increase in optic nerve sheath diameter.

Further comparative analysis in Table 5 shows that the difference in ONSD between the 0° and 10° tilt was 0.28 mm (95% CI: 0.24–0.31 mm). A very low p-value (p<0.001) indicates that this difference is statistically significant. When comparing the 0° and 25° tilts, the mean difference in ONSD was 0.55 mm (95% CI: 0.50–0.60 mm), with the p-value (p<0.001) confirming strong statistical significance. Additionally, the comparison between the 10° and 25° tilts showed a mean difference of 0.28 mm (95% CI: 0.23–0.32 mm; p<0.001), which is also statistically significant.

In summary, ONSD increases significantly with higher degrees of trendelenburg tilt. The progression from 3.69 mm at 0° to 3.96 mm at 10° and 4.24 mm at 25° demonstrates that a steeper tilt angle correlates with greater optic nerve sheath dilation. Significant differences between all tilt levels (0° vs. 10°, 0° vs. 25°, and 10° vs. 25°) confirm that changes in ONSD are closely linked to the degree of trendelenburg tilt.

Discussion

At a 0° tilt, the mean IJV diameter was 13.0 mm with a standard deviation of 2.0 mm, indicating that the vessel size is relatively constant in the supine position. The median diameter was also 13.0 mm, with a range of 10.2 mm to 17.2 mm. These results are consistent with a previous study examining IJV morphology in the supine position, which reported a mean IJV diameter of 14.1 mm.[8]

At a 10° tilt, the mean IJV diameter increased to 15.6 mm with a standard deviation of 2.7 mm. The median IJV diameter at this inclination was 15.3 mm, with a range of 12.2 mm to 21.6 mm. This increase demonstrates venous dilation that correlates with the degree of tilt. At a 10° tilt, there was an increase in IJV diameter of 2.6 mm (20%) compared to the 0° position. The head-down position causes an increase in venous pressure in that region, subsequently resulting in the dilation of the internal jugular vein.[3]

At a 25° tilt, the mean IJV diameter reached 17.0 mm, representing an increase of 4.0 mm (30.8%) compared to the 0° position.

This indicates that a steeper tilt is associated with a more significant increase in venous diameter. These findings are consistent with a systematic review and meta-analysis, which reported an IJV diameter of 15.5 mm at a 10° angle and 16.7 mm at a 25° tilt.[3]

The increase in venous diameter occurs due to the influence of gravitational force, which facilitates the filling and distention of the upper central veins, thereby expanding the IJV diameter.[5] The trendelenburg position also induces an autotransfusion effect within the first ten minutes in normovolemic patients. This phenomenon occurs due to systemic venous distensibility, which allows the IJV to dilate.[3]

There was an increase in IJV diameter of 2.6 mm between the supine position and a 10° trendelenburg tilt. This increase in IJV diameter was more significant than the increase observed at a 25° trendelenburg tilt. Nevertheless, based on the results of the comparative analysis using the Bonferroni test, there was a mean difference in diameter of 1.4 mm (8.9%) between the 10° and 25° tilts, with a confidence interval of 1.1 mm to 1.6 mm. A very low p-value ($p<0.001$) indicates that this difference is statistically significant. Several studies have demonstrated that a 10° trendelenburg tilt can significantly increase IJV diameter, and at a 25° tilt, venous diameter distension reaches maximal dilation.[3,7]

A larger IJV diameter facilitates easier identification of the vessel. In adult patients, the diameter and cross-sectional area of the right IJV are significantly larger than those of the left IJV. These findings provide the rationale for the right IJV as the preferred access point for cannulation procedures.[8]

Optic nerve sheath diameter (ONSD) measurements were recorded by collecting ultrasound data from the right eye using a lateral transbulbar axial approach. The recorded diameter represented the maximum ONSD observed over 30 seconds at each tilt angle. Based on the data, the highest mean, standard deviation, median, and range were obtained at a 25° trendelenburg tilt. The results of this study showed that in the supine position, the mean ONSD was 3.69 mm, with a median of 3.7 mm and a range of 3.4 mm to 4.1 mm. These findings indicate that in the supine position, the ONSD tends to be small and relatively consistent.

These results are consistent with previous studies conducted on healthy individuals in other countries. Research involving healthy Canadians showed a mean ONSD of 3.68 mm. Another study reported a median ONSD of 3.6±0.6 mm, whereas research in the United Kingdom on healthy subjects reported a mean ONSD of 3.4–3.6 mm.[9]

At a 10° trendelenburg tilt, the mean ONSD increased to 3.96 mm. This represents a 0.28 mm (7.5%) increase in diameter compared to the 0° position. This increase demonstrates significant optic nerve sheath dilation with an increasing degree of inclination. The trendelenburg position enhances blood translocation to the central compartment and reduces cerebral venous drainage, thereby increasing intracranial pressure.[10]

At a 25° tilt, the mean ONSD reached 4.24 mm. The median ONSD was 4.20 mm, with a range of 3.80 mm to 4.60 mm. This indicates that a steeper tilt angle is associated with a more significant increase in optic nerve sheath diameter. These findings are consistent with research conducted on anesthetized patients undergoing laparoscopic procedures in the trendelenburg position. In that study, the mean ONSD in the supine position was 4.8 mm; upon placing the patient in a 30° trendelenburg tilt, the ONSD increased by 0.4 mm (8.3%).[11] This contrasts with the results of the current study, which showed a mean ONSD difference of 0.55 mm (12.9%) between the 25° trendelenburg tilt and the 0° position. This discrepancy is highly likely due to significant differences in the study populations and methodologies.

There was a change in ONSD of 0.28 mm (7.1%) at a 25° tilt compared to a 10° tilt. This increase is slightly smaller than the 7.5% increase observed when comparing the 10° and 0° positions. These findings are consistent with other studies demonstrating that the increase in optic nerve sheath diameter is directly proportional to the degree of

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trendelenburg inclination.[10]

An increase in ONSD was observed at a 25° trendelenburg tilt, with a mean diameter of 4.24 mm. The range of mean diameters at the 25° inclination was 3.8 mm to 4.6 mm. Notably, five subjects exhibited an optic nerve sheath diameter exceeding 4.5 mm. This indicates a potential elevation in intracranial pressure (ICP), as previous research has demonstrated that ONSD measurements within the estimated range of 4.5 to 5.5 mm in healthy adult volunteers are associated with an ICP increase of >20 mmHg.[12]

This study's methodological strengths were through standardized protocols, utilizing a tilt table with an integrated clinometer and real-time ultrasonography to ensure objective accuracy and precision in measurements. Furthermore, rigorous variable control was maintained by evaluating the IJV diameter across three respiratory cycles to minimize potential bias resulting from respiratory variability. The validity of these findings is further supported by robust statistical analysis, ensuring that the results demonstrate high reliability in describing vascular morphological changes in response to body positioning.

Despite these strengths, several limitations must be acknowledged. First, the study subjects consisted of healthy individuals, which limits the generalizability of the results to patients with pathological conditions or hemodynamic instability. Second, this study focused on the morphometric parameter of IJV diameter and did not evaluate clinical outcomes, such as success rate or cannulation duration. Finally, subject comfort became a constraint at tilt angles exceeding 10°, potentially limiting the practical applicability of these steeper positions in conscious patients or certain clinical field conditions.

Conclusion

Based on the study findings, the 25° trendelenburg tilt provides the greatest increase in internal jugular vein (IJV) diameter compared to the 0° and 10° positions, which theoretically facilitates easier vein identification and higher cannulation success rates. However, this steeper angle poses a potential clinical risk of elevated intracranial pressure (ICP), as evidenced by optic nerve sheath diameter (ONSD) measurements exceeding the 4.5 mm safety threshold in several subjects.

In contrast, a 10° trendelenburg tilt achieves a clinically significant increase in IJV diameter while successfully maintaining ONSD within normal limits, thereby minimizing the risk of adverse neurological effects. Therefore, the 10° trendelenburg position is highly recommended for medical procedures requiring central venous access, as it provides an optimal balance between procedural efficacy and patient safety.

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