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The effect of passive leg raising on the cross-sectional area of the right internal jugular vein in obese patients undergoing surgery: a prospective observational study

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ABSTRACT

Objectives To observe the association between passive leg raising (PLR) and the cross-sectional area (CSA) of the right internal jugular vein (IJV) in obese patients undergoing elective surgery.

Design Prospective observational study with randomised position sequence.

Setting Single-centre, tertiary care hospital in Shanghai, China.

Participants Forty obese patients (body mass index (BMI) >30 kg/m²) scheduled for elective surgery were enrolled. Inclusion criteria were American Society of Anesthesiologists Physical Status Classification (ASA) physical status II–III and age ≥18 years. Exclusion criteria included history of neck surgery, severe cardiovascular disease, end-stage renal disease, severe infection or sepsis and significant coagulopathy.

Observations Patients underwent ultrasound measurements of the right IJV in two positions: supine (S0) and passive leg raise at 40° (PLR40). Each position was maintained for at least 1 min prior to measurement.

Primary outcome The primary outcome was to observe whether the CSA of the right IJV differed between the S0 position and passive leg elevation. In post hoc analyses, we examined factors affecting the relative CSA change (CSAγ), including neck circumference, BMI, age, sex, ASA physical status and heart rate as predictors.

Results The CSA of the right IJV was significantly larger in the PLR40 position (2.05 cm²) compared to the S0 position (1.67 cm², p=0.003). Linear regression analysis showed a slight positive correlation between neck circumference and the percentage change in CSA (correlation coefficient: 0.066, p<0.05).

Conclusion The CSA of the right IJV was significantly larger in the PLR40 position in obese patients undergoing surgery.

Trial registration number Chinese Clinical Trial Registry ChiCTR2400080513.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ Within-subject comparison: Observing each patient in two positions allowed for paired comparisons within the same individual, reducing intersubject variability and enhancing the ability to detect differences in the cross-sectional area (CSA) with a smaller sample size.
⇒ *Use of ultrasound*: The use of ultrasound for measurements provides real-time, non-invasive and accurate data on the CSA of the internal jugular vein.
⇒ *Specific focus on obese patients*: This study addresses a specific clinical challenge in a population where vascular access is particularly difficult.
⇒ *Single-centre study*: The results may not be generalisable to different patient populations or clinical settings due to the study being conducted in a single centre.
⇒ *Possible unmeasured confounders*: There might be unmeasured or unaccounted confounders that could influence the results, such as patient hydration status or underlying vascular conditions.

INTRODUCTION

Establishing venous access plays a crucial role in the fields of emergency care, intensive care and anaesthesia.[1 2] However, establishing venous access in obese patients presents significant challenges.[3 4] Obese patients often have a thicker and shorter neck, which increases the depth of puncture and obscures anatomical landmarks, making venous access more difficult. Additionally, a high body mass index (BMI) is an important risk factor for complications during venous access.[5]

Research has shown that the success rate of central venous catheterisation is closely related to the cross-sectional area (CSA) of the vein.[6 7] The right internal jugular vein (IJV) is the most commonly used vessel for deep venous catheterisation, and various techniques have been employed to increase the CSA of the IJV, including positive end-expiratory pressure, the Trendelenburg position, passive leg raising (PLR) and the Valsalva manoeuvre.[8 9] However, most studies have focused on non-obese populations,[10 11] and the unique physiological characteristics of obese patients make it difficult to directly apply these conclusions.[12] For example, a study by Ozkan *et al* found that the Trendelenburg position did not significantly increase the CSA of the IJV in obese patients.[13] On the other hand, PLR, a simple and commonly used positional adjustment, can enhance the CSA of the IJV while exerting less pressure on the chest and abdominal cavity,[14 15] but its effectiveness in obese patients has not been thoroughly studied.

This study aims to observe the association between PLR and the CSA of the right IJV, with the goal of providing more evidence for clinical practice in central venous catheterisation for obese patients.

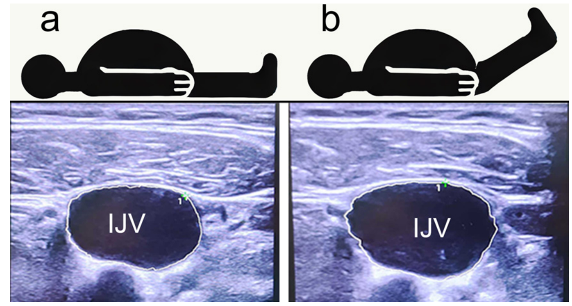

Figure 1 Diagrams of different body positions and ultrasound images of IJV. (a) Supine position. (b) PLR40 position. IJV, internal jugular vein.

METHODS

Study design and participants

This prospective observational study investigated the association between body position and the CSA of the right IJV in obese patients. The study was conducted at Tongren Hospital, Shanghai Jiao Tong University School of Medicine, between March and June 2024. The study was approved by the Ethics Committee of Tongren Hospital, Shanghai Jiao Tong University School of Medicine (approval number: 2023-083-02), and registered at the Chinese Clinical Trial Registry (registration number: ChiCTR2400080513). The protocol of this study has been published.[16] This study is reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology guidelines.

All participants provided written informed consent before any study procedures were performed. The consent process was conducted in accordance with the ethical guidelines of the Ethics Committee, ensuring that patients were fully informed about the study, its procedures, potential risks, benefits and their right to withdraw from the study at any time without affecting their medical care.

We recruited adult patients scheduled for elective surgery. Inclusion criteria were ASA (American Society of Anesthesiologists Physical Status Classification) II–III, age ≥18 years, BMI >30 kg/m². The ASA classification evaluates preoperative health status: ASA II indicates a patient with mild to moderate systemic disease (eg, controlled hypertension or diabetes), while ASA III describes severe systemic disease that limits activity but is not incapacitating (eg, poorly controlled diabetes or stable heart disease).

Exclusion criteria included:

History of neck surgery (to avoid altered neck anatomy and IJV physiology)

Severe cardiovascular disease (due to potential haemodynamic instability and confounding effects on IJV)

End-stage renal disease (because of fluid imbalance and altered vascular tone)

Severe infection or sepsis (to prevent unreliable IJV measurements due to systemic inflammation)

Significant coagulopathy (primarily for patient safety and homogeneity of the study population)

Position sequence and measurement bias control

To minimise order bias, the sequence of positions (S0 followed by PLR40 or vice versa) was randomised for each patient using a computer-generated sequence, with allocation concealment ensured by sequentially numbered, opaque, sealed envelopes. Ultrasound imaging was performed by an experienced senior anaesthesiologist. To prevent measurement bias, images were saved, and a second anaesthesiologist, unaware of the patient's position, measured the IJV-CSA from the stored images using the ultrasound machine's software.

Procedures

On arrival in the operating room and prior to the induction of anaesthesia, the study procedures were initiated. First, baseline measurements of systolic blood pressure, heart rate and neck circumference were obtained. Subsequently, patients were observed in two positions in a randomised order, see figure 1.

1. **Supine (S0):** Horizontal supine position
2. **Passive Leg Raising 40° (PLR40):** PLR position with legs elevated to 40° ± 2° (angle between legs and horizontal plane) using a special pillow. This angle was selected based on the systematic review by Pickett *et al*.[17]

Each position was maintained for at least 1 min. A minimum 1-min interval in the baseline S0 position was maintained between the two positions to minimise potential carryover effects from the prior position. The rationale for choosing a 1-min position duration is based on the following considerations: common practice in previous studies,[18 19] the rapid onset of haemodynamic effects following postural changes[20] and the need to avoid patient discomfort associated with prolonged passive positioning. During this time, ultrasound imaging of the right IJV was performed using a linear (7.5 MHz) probe (Mindray M8) at the level of the cricoid cartilage. Images were obtained at end-expiration with minimal probe pressure. Between positions, patients were repositioned to a baseline horizontal S0 position (no pillow). For IJV

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imaging in both positions, the head was rotated 20° to the left. Images were stored, and after all positioning and imaging for each patient were finished and the probe removed, a blinded anaesthesiologist performed offline CSA measurements of the right IJV from the stored images, using the ultrasound machine's built-in software to manually trace the IJV circumference and automatically calculate the area. The CSA was recorded in square centimetres (cm^2).

Baseline characteristics were collected through multiple parameters. Anthropometric measurements included neck circumference, which was measured with a flexible tape at the level of the cricoid cartilage with the patient in neutral head position (recorded to the nearest 0.1 cm), and BMI, which was calculated as weight (kilogrammes) divided by height squared (metres) using calibrated scales and stadiometer measurements. Vital signs, specifically blood pressure and pulse rate, were measured non-invasively using a Mindray BeneVision N22 monitor in the S0 position on operating room arrival (measured in mm Hg and beats per minute, respectively). Laboratory parameters comprised haemoglobin, which was obtained from preoperative blood tests (measured in mmol/L). Clinical parameters included fasting time (hours) and preoperative infusion volume (millilitres), both extracted from anaesthesia records, along with ASA physical status as determined by the attending anaesthesiologist. All continuous variables were analysed in their original units without transformation, while categorical variables (sex, ASA class) were coded as binary/nominal variables prior to analysis.

Outcomes

The primary outcome was to observe whether the CSA of the right IJV differed between the S0 position and passive leg elevation. The original protocol[16] included success rates of right IJV cannulation as a secondary outcome, with successful cannulation defined as a successful puncture on the first attempt and failure defined as more than two attempts or puncture of the internal carotid artery. However, assessment of this secondary outcome proved infeasible as a substantial number of patients, post-consent but prior to catheterisation, declined to undergo central venous catheterisation.

Post hoc analyses: Given the inability to assess the planned secondary outcome, we conducted additional exploratory analyses to examine factors affecting the relative CSA change (CSAγ), calculated as [(CSA in PLR40 - CSA in S0) / CSA in S0]. The main independent variables were neck circumference and BMI. Age, sex, ASA physical status and heart rate were included as covariates to control for potential confounding effects.

Statistical analysis

Sample size calculations were performed using the PASS software. The primary observational indicator is the difference in the CSA between S0 and PLR40 positions, designated as the main variable for calculating the sample size. Reference literature reports that the average CSA of the jugular vein in the S0 position is approximately 1.4 cm^2, with a SD of about 0.5 cm^2. It is hypothesised that the PLR position can increase the CSA by 20%, leading to an average CSA of about 1.68 cm^2 in the PLR40 position.

For the primary outcome analysis, CSA comparisons between positions were made using the Wilcoxon signed-rank test because the paired differences did not conform to a normal distribution ($p<0.05$ by the Shapiro–Wilk test). 95% confidence intervals (CIs) were calculated using non-parametric Wilcoxon signed-rank test procedures in Statistical Package for the Social Sciences (SPSS).

For the post hoc analyses, we conducted a multivariable linear regression analysis to examine factors affecting CSAγ. The independent variables included neck circumference, BMI, age, sex, ASA physical status and heart rate.

In addition to assessing the CSA among patients, we also recorded instances where a decrease in CSA was observed. Continuous data are presented as mean ± SD or median (IQR) as appropriate. Categorical data are presented as frequencies and percentages. A two-tailed p-value <0.05 was considered statistically significant. All analyses were performed using SPSS 26.0.

Patient and public involvement

Due to the highly specialised nature of this study in critical care, anaesthesia and emergency medicine, direct patient or public involvement in the research design, conduct or reporting was not feasible. The technical complexity and clinical expertise required for conducting and interpreting the study precluded direct involvement of non-specialists. However, we are committed to patient engagement in the following ways: participants with obesity who were part of the study will receive a summary of the research findings, we plan to support the dissemination of research results to patient communities, particularly those interested in obesity-related medical procedures, and the research aims to directly benefit patients by potentially improving central venous catheterisation techniques for individuals with obesity. While we recognise the importance of Patient and Public Involvement in research, the specialised nature of this clinical intervention study necessitated a research team with specific medical expertise. Future research may explore more extensive patient involvement in study design and implementation.

RESULTS

A total of 40 obese patients were screened for eligibility and enrolled, observed in two positions in a randomised sequence. All 40 enrolled patients completed observations in both positions and were included in the final analysis, with no dropouts or exclusions. The demographic and baseline characteristics of the patients are summarised in table 1. For more detailed data, please refer to online supplemental table 1.

Comparison of right IJV-CSA between PLR40 and S0 positions

The CSA of the right IJV was significantly larger in the PLR40 position compared with the S0 position (p=0.003,

Table 1 Baseline Characteristics of Patients

Characteristic	Value
Age (years)	48 (38,56)*
Sex (man%/female%)	57.5/42.5
BMI (kg/m^2)	34±2.9
Fasting time (hours)	10.2±3.1
Preoperative infusion volume (mL)	0 (0, 575)*
Haemoglobin (mmol/L)	138.1±16.7
ASA (II%/III%)	72.5/27.5
Heart rate (BPM)	78.9±8.7
Systolic pressure (mm Hg)	136.0±14.8
Neck circumference (cm)	49.1±3.7

*median (interquartile range)
ASA, American Society of Anesthesiologists; BMI, body mass index; BPM, beats per minute.

Wilcoxon signed-rank test). The median CSA in the S0 position was 1.67 cm² [95% CI: 1.13, 2.26], and in the PLR40 position was 2.05 cm² [95% CI: 1.40, 2.35]. These findings are also illustrated in figure 2.

Regression analysis

Multivariate linear regression analysis was conducted to examine the association of multiple factors (age, gender, BMI, fasting time, preoperative infusion volume, haemoglobin, ASA grade, heart rate, systolic pressure and neck circumference) with CSAγ. Analysis of individual predictors within the model revealed that neck circumference was significantly and positively associated with CSAγ (β=0.066, p=0.023), and BMI showed a non-significant trend towards a negative correlation with CSAγ (β=–0.071, p=0.062). Scatter plots of CSAγ against neck circumference and BMI are shown in figure 3. The detailed results of the regression model, including coefficients and significance values for all predictors, are presented in table 2.

Out of the total participants, nine (22.5%) patients experienced a decrease in CSA rather than an increase.

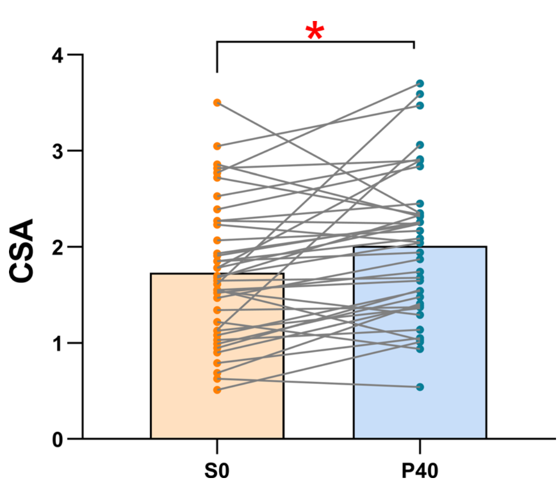

Figure 2 Illustrates the comparison of CSA between the two positions. *p<0.05.

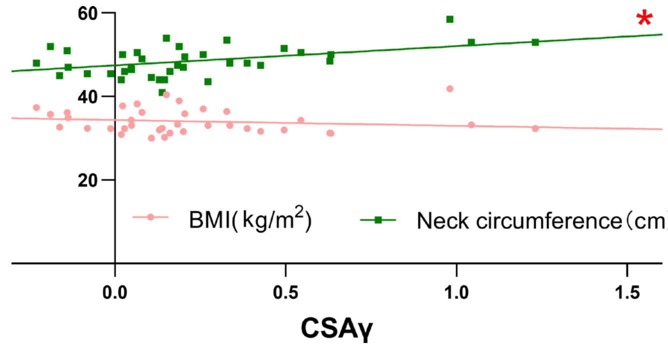

Figure 3 Scatter plot illustrating the relationship of neck circumference and BMI with CSAγ in the multivariate linear regression model. *p<0.05

Comparative analysis of the S0 baseline measurements showed no statistically significant differences between patients with increased CSA and those with decreased CSA. The reduction in CSA did not correlate with factors such as BMI, neck circumference or age.

DISCUSSION

Our study observed that the CSA of the right IJV was significantly larger in the PLR40 position compared with the S0 position in patients with obesity. This finding is particularly important because previous studies have shown conflicting results regarding the effectiveness of the Trendelenburg position in patients with obesity.[13] The larger CSA observed in the PLR position suggests that this technique could be a viable alternative for improving venous access in patients with obesity.

The Trendelenburg position is known to increase intrathoracic and intra-abdominal pressure, leading to a decrease in cardiac output, which may be a factor affecting the increase in IJV-CSA in patients with obesity.[21–24] In contrast, PLR has a much weaker effect on intrathoracic and intra-abdominal pressure than the Trendelenburg position and more effectively increases cardiac preload, allowing us to observe effects similar to those in non-obese patients.[25]

Multivariate linear regression analysis showed a slight negative correlation between BMI and CSAγ, though it did not reach statistical significance (β=–0.071, p=0.062); despite having marginal significance, the effect size was minimal. Interestingly, there was a statistically significant positive correlation between neck circumference and the change in the right IJV CSAγ in obese patients. This suggests that obese patients with larger neck circumferences may experience a slightly more pronounced increase in IJV-CSA during PLR. Although the correlation coefficient was small (0.066) with limited enhancement effect, this finding suggests that PLR may be more beneficial in patients with larger neck circumference, a known risk factor for difficult IJV cannulation, potentially facilitating the procedure.[26] Further research is needed to explore this aspect.

Table 2 Multiple linear regression of various factors on CSA γ

Statistical indicators (variable unit)	β	95% CI	P value
Neck circumference(1 /cm)	0.066	(0.013, 0.119)	0.023*
BMI (m²/kg)	−0.071	(−0.143, 0.002)	0.062
Haemoglobin (L/mmol)	0.005	(−0.007, 0.017)	0.432
Age (1/year)	0.003	(−0.011, 0.017)	0.643
Fasting time (1/hour)	0.010	(−0.039, 0.059)	0.678
Systolic pressure (1/mm Hg)	−0.001	(−0.011, 0.009)	0.864
Heart rate (1/BPM)	0.004	(−0.012, 0.020)	0.678
ASA	0.054	(−0.316, 0.424)	0.776
Sex	0.142	(−0.283, 0.567)	0.518
Preoperative infusion volume (1/mL)	0	(0, 0)	0.338

β: regression coefficient
*p<0.05.

Our study did not observe any effects of preoperative infusion volume on CSA increase. This differs from Xie's study,[18] which showed a correlation between preoperative infusion volume and CSA increase. This discrepancy may be due to the relatively larger blood volume in patients with obesity, making them less susceptible to the effects of infusion and fasting. Specifically, in our multivariable linear regression analysis, the regression coefficient for preoperative infusion volume was 0 with a 95% CI of (0–0), reflecting the lack of association with CSAγ in our sample. This result is likely influenced by the non-normal distribution of the data and the fact that most patients received no preoperative infusion (median 0 mL, IQR 0–575 mL).

In our study, we observed that nine (22.5%) patients experienced a decrease in CSA rather than an increase. When comparing the S0 baseline measurements between patients who exhibited an increase in CSA and those who showed a decrease, no statistically significant differences were found. The reduction in CSA appeared to be unrelated to factors such as BMI, neck circumference or age. Similarly, in Nassar *et al*'s study of critically ill patients receiving treatment in the intensive care unit (ICU), nine (17.6%) patients with less severe conditions demonstrated a decrease in CSA when placed in the Trendelenburg position.[27] A potential mechanism for this phenomenon may involve complex interactions between haemodynamics and the autonomic nervous system resulting from short-term positional changes. Additionally, a potential carry-over effect from one position to another cannot be completely ruled out. Although previous studies, as referenced in our Methods section, have used a 1-min interval between positional changes and reported rapid haemodynamic stabilisation without significant carryover effects,[18–20] this duration may not be sufficient for full haemodynamic stabilisation in all patients, particularly in obese individuals with potentially altered vascular dynamics. This could also contribute to the observed decrease in CSA in some participants (22.5%). Further research is needed to elucidate these mechanisms, and future studies could explore longer intervals between positional changes to minimise such potential carryover effects.

Our study has several limitations that should be considered when interpreting the results:

1. As an observational study, our findings indicate an association between PLR and increased IJV-CSA but cannot establish causality. Future randomised controlled trials are needed to confirm whether PLR directly causes an increase in CSA and improves clinical outcomes such as cannulation success rates.
2. Limited patient population: Our study focused on Asian patients with obesity undergoing elective surgery. The effects of PLR on IJV-CSA may differ in other patient populations or clinical scenarios.
3. Original protocol planned to assess right IJV cannulation success rate as a secondary outcome. However, due to a high rate of patient declination of central venous catheterisation after informed consent, we were unable to collect data for this outcome. While this does not affect the primary conclusion regarding the effect of PLR on IJV-CSA, it means we could not verify if the increased CSA translates to improved cannulation success rates, which is a limitation. Future research could explore more effective methods to assess the potential impact of PLR on cannulation success.
4. Short-term observation: Our study focused on short-term differences in CSA between positions. Prolonged positional changes, such as extended leg elevation, might lead to haemodynamic adaptations that could alter CSA over time, especially in obese patients who may experience discomfort or circulatory issues. Future studies should explore the sustainability and safety of long-term positional changes in this population.

FUTURE RESEARCH DIRECTIONS

While our study provides valuable insights into the effectiveness of PLR in increasing IJV-CSA in obese patients, several areas warrant further investigation:

1. Larger-scale, multi-centre studies are needed to confirm our findings and enhance the generalisability of results across diverse patient populations.
2. In-depth investigations into the biomechanical properties of neck tissues in patients with obesity and their impact on IJV dynamics could provide valuable insights into the mechanisms underlying the effectiveness of positioning techniques.

CONCLUSION

The CSA of the right IJV was significantly larger in the PLR40 position in obese patients. Although neck circumference showed only a weak correlation with the magnitude of CSA enhancement by PLR, individuals with larger neck circumferences may benefit more from this manoeuvre. Further studies are warranted to validate its clinical utility in optimising vascular access for this population.

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Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, conduct, reporting or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval This study involves human participants and was approved by The Ethics Committee of Tongren Hospital, Shanghai Jiao Tong University School of Medicine. Approval number: 2023-083-02. Participants gave informed consent to participate in the study before taking part.

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Data availability statement All data relevant to the study are included in the article or uploaded as supplementary information.

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