



Original Contribution

# Ultrasound validation of maneuvers to increase internal jugular vein cross-sectional area and decrease compressibility

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## Abstract

**Objectives:** The aim of this study is to determine which maneuvers result in greatest cross-sectional area (CSA) of the internal jugular vein (IJV) and reduce collapsibility as measured by ultrasound during simulated venipuncture.

**Methods:** A total of 52 healthy adult volunteers were prospectively studied in an academic emergency department. Cross-sectional area of the IJV was recorded at baseline, with Valsalva, hepatic pressure, and a combination of hepatic pressure plus Valsalva. Subjects were studied in supine and Trendelenburg. Measurements were repeated using pressure applied to the ultrasound transducer to simulate venipuncture and evaluate degree of IJV collapse. Repeated measures analysis of variance models were used to assess the effects of the maneuvers on the diameter equivalent of the cross-sectional area (GRADE).

**Results:** With simulated venipuncture, both Valsalva and Trendelenburg position were significantly ( $P < .0001$ ) associated with increased CSA of the IJV. Valsalva in either Trendelenburg or supine position was associated with the largest GRADE (1.20 and 1.13 cm, respectively). Without simulated venipuncture, CSA of the IJV were increased in all settings ( $P < .0001$ ), but the relative impacts of Valsalva and Trendelenburg position were similar. Hepatic pressure had no impact on CSA of the IJV ( $P = .94$ ).

**Conclusions:** All maneuvers with the exception of hepatic pressure led to a statistically significant increase in IJV CSA as compared with baseline with and without simulated venipuncture. Valsalva was the only maneuver, when used alone or in combination, to increase the CSA by greater than 50% and prevent collapse by 50% or more under simulated venipuncture.

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## 1. Introduction

Internal jugular vein (IJV) cannulation is frequently performed by emergency physicians and is facilitated by

use of ultrasound [1,2]. However, successful placement of an IJV catheter remains difficult in patients with veins of small cross-sectional area (CSA). Pressure from venipuncture may lead to jugular vein collapse resulting in puncture of both the anterior and posterior walls of the vein (Fig. 1). This makes placement of a catheter more difficult and increases the risk of carotid artery puncture if the 2 structures overlap [3-5].

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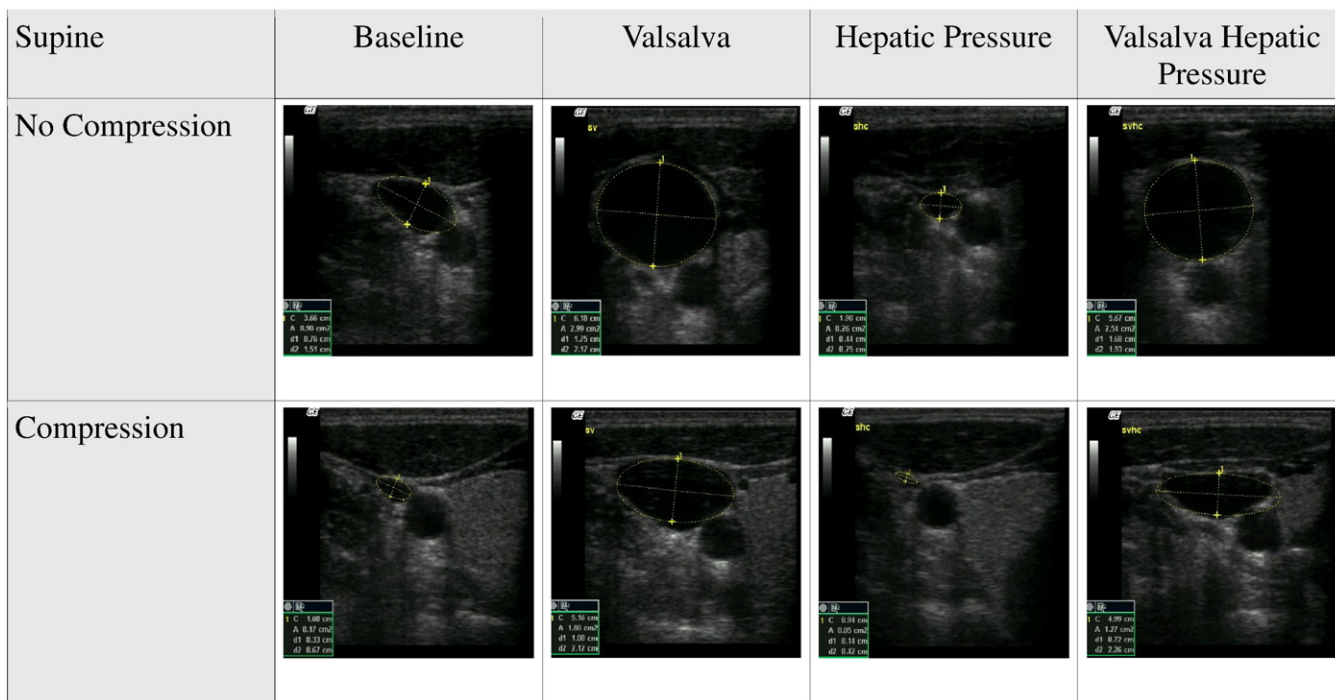


Fig. 1 Ultrasound of the IJV and carotid artery while the subject is supine and exposed to various maneuvers.

Although ultrasound is useful for localizing the IJV and defining its anatomy, it does not prevent vascular compression or collapse. Studies have validated methods to increase CSA of the IJV; however, none have validated methods of

decreasing compressibility or preventing collapse [6-15]. Our study objective was to determine which maneuver or combination of maneuvers decreases compressibility of the IJV during simulated venipuncture.

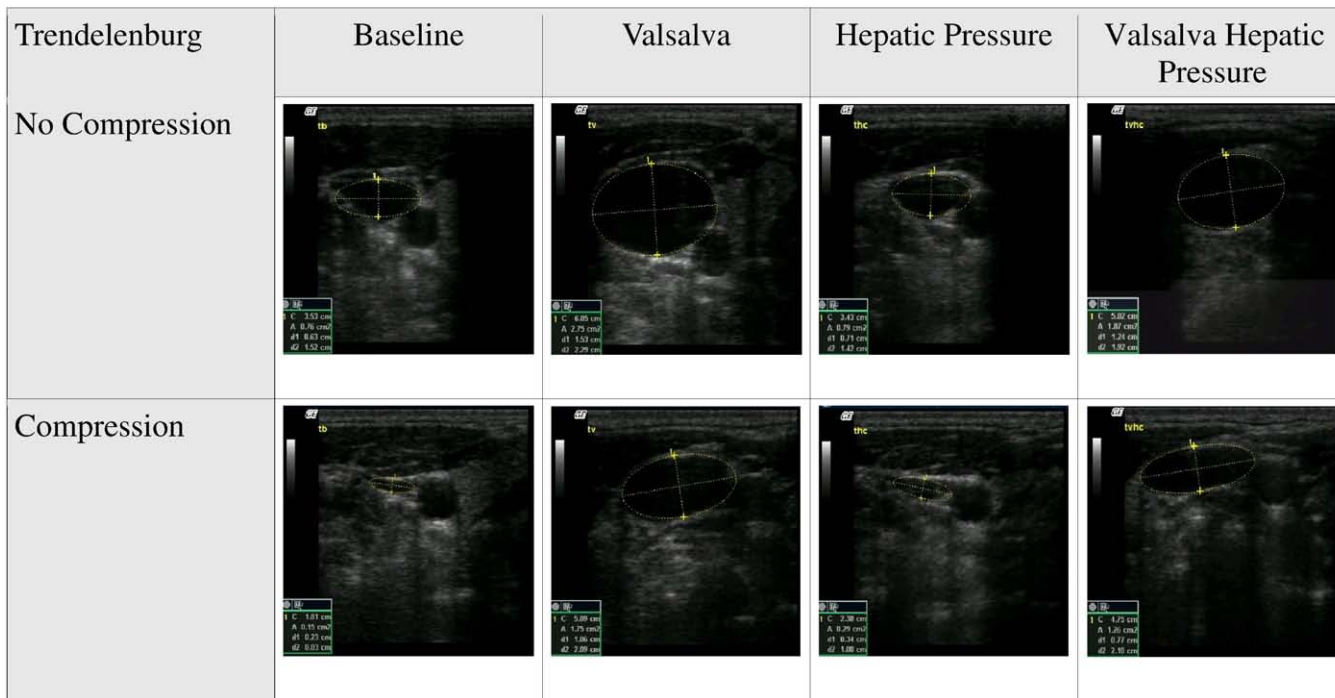
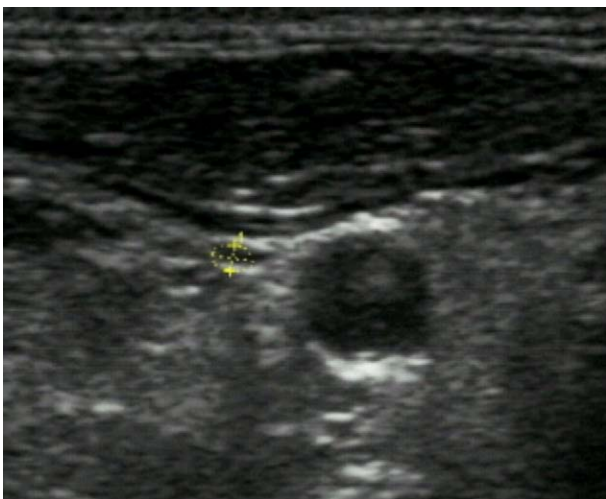


Fig. 2 Ultrasound of the IJV and carotid artery while the subject is in Trendelenburg and exposed to various maneuvers.

## 2. Methods

This was a prospective study performed in an academic emergency department on a convenience sample of 52 healthy adult volunteers. Data were collected from July 12, 2006, through October 1, 2007. The study was approved by our hospital Institutional Review Board. Written consent was obtained from all subjects. The mean age of the study participants was 37 years (SD = 11), and mean weight was 166 lb (SD = 35). Fifty-six percent of the participants were women.

A GE LOGIQ Book with an 8L (3-10 MHz) vascular probe was used to identify and measure the right IJV. Subjects were positioned with the head rotated left at approximately 20° to 30°. The apex of the anatomic triangle formed by the sternocleidomastoid muscle was located by palpation, and the probe was placed transversely to obtain a cross-sectional view of the IJV. The maximal CSA was recorded. Measurements were recorded at baseline, with Valsalva, hepatic pressure, and a combination of hepatic pressure plus Valsalva. Subjects were studied in supine and Trendelenburg positions. All measurements were repeated using moderate pressure applied to the transducer over the IJV to simulate venipuncture and to evaluate degree of IJV collapse (Figs. 2 and 3). Each measurement was repeated 3 times. The average of the 3 measurements was used for comparison. Measurements were performed by 1 of 3 investigators. The principal investigator (M.A.B.) performed 29 studies; the research nurse (P.M.R.), 20 studies; and our resident, 3 studies. Our data collection sheet is summarized in Table 1. Images were saved to a USB key storage device in JPG format and transferred to a secure desktop computer. Data were tabulated and stored in OpenOffice Calc 2.3.0 spreadsheet for Linux (Sun Microsystems).



**Fig. 3** Example of IJ collapse in a supine subject with mild pressure applied to the transducer.

**Table 1** Mean diameter equivalent of the CSA (GRADE) (95% CI) of the right IJV in centimeters for all combinations of factors

|                                  | No compression   | IJ compression   |
|----------------------------------|------------------|------------------|
| Supine                           |                  |                  |
| Resting baseline                 | 1.02 (0.94-1.10) | 0.53 (0.45-0.61) |
| Valsalva                         | 1.39 (1.31-1.47) | 1.13 (1.05-1.22) |
| Hepatic compression              | 1.03 (0.95-1.12) | 0.55 (0.47-0.63) |
| Valsalva and hepatic compression | 1.38 (1.30-1.47) | 1.12 (1.04-1.21) |
| Trendelenburg                    |                  |                  |
| Resting baseline                 | 1.22 (1.14-1.31) | 0.74 (0.66-0.83) |
| Valsalva                         | 1.44 (1.35-1.52) | 1.20 (1.12-1.19) |
| Hepatic compression              | 1.21 (1.13-1.30) | 0.75 (0.66-0.83) |
| Valsalva and hepatic compression | 1.43 (1.34-1.51) | 1.20 (1.12-1.29) |

For analysis, CSAs of the IJV were transformed into diameter equivalents. Repeated variance analysis of variance models were used to assess the effects of Valsalva, hepatic pressure, position (supine or Trendelenburg), and simulated IJV pressure on the diameter equivalent of the CSA (GRADE) of the IJV. Models included main effects and all possible interactions between the predictors. Analyses were performed using Proc Mixed in SAS (SAS Institute, Inc, Cary, NC).

## 3. Results

Mean GRADE for combinations of factors are given in Table 1. The CSA, confidence intervals (CIs), and CSA percent change are given in Table 2 to allow for comparison to previous studies looking at IJV CSA.

Hepatic compression had no impact on GRADE of the IJV, either overall ( $P = .95$ ) or for any combination of the other factors ( $P \geq .39$ ). With simulated venipuncture, Valsalva in the Trendelenburg position was associated with the largest ( $P < .0001$ ) GRADE (1.20 cm; 95% CI, 1.12-1.28). With Valsalva, the Trendelenburg position was associated with a significantly greater increase in GRADE (0.08 cm; 95% CI, 0.04-0.11) than the supine position; without Valsalva, the difference was much larger (0.20 cm; 95% CI, 0.17-0.24). The use of Valsalva was associated with substantial increases in GRADE regardless of position (supine: 0.59 cm; 95% CI, 0.56-0.62; Trendelenburg: 0.46 cm; 95% CI, 0.43-0.49).

In the absence of simulated venipuncture, GRADE increased in all situations ( $P < .0001$ ). Valsalva in the Trendelenburg position was still associated with the largest GRADE (1.43 cm; 95% CI, 1.35-1.51). Similar to results with simulated IJV pressure, there was a small, but statistically significant, increase in GRADE with the Trendelenburg position (0.05 cm; 95% CI, 0.01-0.08) as

Table 2 Graphical summary and rank of CSA of IJV ordered from smallest to largest supine position

|                                      | SB          | SH          | TH          | TB          | SHV         | SV          | THV         | TV          |
|--------------------------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| CSA, cm <sup>2</sup> ± SD            | 0.90 ± 0.56 | 0.93 ± 0.62 | 1.23 ± 0.70 | 1.26 ± 0.69 | 1.58 ± 0.69 | 1.58 ± 0.65 | 1.68 ± 0.75 | 1.70 ± 0.79 |
| 95% CI                               | 0.75-1.05   | 0.76-1.10   | 1.04-1.42   | 1.07-1.44   | 1.39-1.77   | 1.40-1.76   | 1.48-1.88   | 1.48-1.91   |
| Percent increase from baseline       |             | ↑0.03       | ↑37         | ↑40         | ↑76         | ↑76         | ↑87         | ↑89         |
| CSA, cm <sup>2</sup>                 | 0.9         | 0.93        | 1.23        | 1.26        | 1.58        | 1.58        | 1.68        | 1.70        |
| Percent decrease with IJ compression | ↓68         | ↓65         | ↓54         | ↓59         | ↓29         | ↓30         | ↓26         | ↓28         |
| CSA, cm <sup>2</sup> compression     | 0.29        | 0.33        | 0.5         | 0.5         | 1.12        | 1.11        | 1.25        | 1.23        |
| Percent increase from baseline       |             | ↑14         | ↑93         | ↑79         | ↑286        | ↑283        | ↑331        | ↑324        |
| 95% CI                               | 0.21-0.37   | 0.22-0.44   | 0.41-0.71   | 0.38-0.66   | 0.93-1.31   | 0.94-1.28   | 1.04-1.46   | 1.06-1.40   |
| CSA, cm <sup>2</sup> ± SD            | 0.29 ± 0.27 | 0.33 ± 0.39 | 0.56 ± 0.63 | 0.52 ± 0.47 | 1.12 ± 0.70 | 1.11 ± 0.61 | 1.25 ± 0.77 | 1.23 ± 0.63 |

SB indicates supine baseline; SH, supine hepatic compression; TH, Trendelenburg hepatic compression; TB, Trendelenburg baseline; SHV, supine hepatic Valsalva; SV, supine Valsalva; THV, Trendelenburg hepatic compression Valsalva; TV, Trendelenburg Valsalva.

compared with the supine position when Valsalva was used and a much larger effect (0.19 cm; 95% CI, 0.16-0.22) when Valsalva was not used. The use of Valsalva was still associated with substantial increases in CRADE regardless of position (supine: 0.36 cm; 95% CI, 0.33-0.39; Trendelenburg: 0.21 cm; 95% CI, 0.43-0.49), but these differences are smaller than observed with simulated IJV pressure.

#### 4. Limitations

Our study is limited to healthy adult volunteers. It did not evaluate patients with hemodynamic derangement or those at the extremes of age.

Pressure applied to the ultrasound transducer to simulate venipuncture was not standardized; therefore, the data may not be as precise as we would have liked. Development and use of an electronic pressure transducer to standardize measurement would solve this problem. In addition, the dispersed pressure of a vascular probe used to simulate venipuncture may not accurately represent the focal pressure generated by a needle.

Although we used moderate manual pressure applied to the right upper quadrant during the hepatic compression maneuver, we did not measure the amount applied. Using the inflated bladder of a blood pressure cuff to measure and apply a standard amount of pressure would alleviate this problem. Application of hepatic pressure to a subject performing the Valsalva maneuver with tensed abdominal muscles is also of questionable value. This combination of maneuvers would be more effective for someone undergoing positive pressure ventilation and a simultaneous breath hold to simulate Valsalva.

#### 5. Discussion

Valsalva was associated with the largest increases in CSA of the IJV with increases ranging from 38% without simulated venipuncture in the Trendelenburg position to 336% with simulated venipuncture in the supine position. Other studies support our findings and have shown that Valsalva or simulated Valsalva by ventilator breath hold is the best maneuver alone or in combination to increase IJV size. Increases in CSA in these studies ranged from 16.2% to 58.7% [6,15].

Trendelenburg alone (without Valsalva) increased IJV CSA by 96% with simulated venipuncture and 40% without simulated venipuncture. Others have shown similar increase in size with ranges from 22% to 36% without simulated venipuncture [6,9,10,12,14,15]. Schreiber [10] demonstrated that IJV CSA while in Trendelenburg does not significantly change after 20 minutes. Clenaghan [12] demonstrated that the amount of Trendelenburg tilt also does not significantly change IJV CSA up to 25°.

We did not observe any increase in IJV CSA when hepatic compression was applied. This differs from other studies that have shown significant increases in CSA ranging from 14.3% to 35% [6,15]. However, these studies were performed in intubated adults and children, not healthy volunteers. Hepatic compression is analogous to hepatojugular reflux, which is a common physical examination finding in patients with right ventricular failure. Hepatojugular reflux is not commonly found in healthy subjects. Therefore, hepatic compression may be a reasonable maneuver to try in a patient with elevated right ventricular pressure; however, this patient population was not explored in our study.

Most importantly, our research addressed a question not directly explored in other studies; what maneuver will decrease compressibility of the IJV during simulated venipuncture and to what degree? Although all maneuvers studied, with the exception of hepatic pressure, statistically reduced the degree of IJV collapse during simulated venipuncture, Valsalva was the most effective. During simulated venipuncture, Valsalva alone or in combination with Trendelenburg position increased IJV CSA by 161% to 336% as compared with baseline. Although not addressed in our research, a ventilator breath hold maneuver may produce comparable results in intubated patients. However, this requires scientific validation before a conclusion can be made.

#### 6. Conclusions

All maneuvers with the exception of hepatic pressure led to a statistically significant increase in IJV CSA as compared with baseline with and without simulated venipuncture. Valsalva was the only maneuver, when used alone or in combination, to increase the CSA by greater than 50% and prevent collapse by 50% or more under simulated venipuncture. Therefore, the Valsalva maneuver should be used when feasible when placing an IJV central venous catheter to decrease the risk of venous collapse and increase target vessel size.

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