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SHORT COMMUNICATION

# Cannulation needle-induced anterior wall tenting of internal jugular vein causing posterior wall penetration

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**Abstract** Unintentional posterior venous wall penetration during internal jugular vein (IJV) cannulation may cause critical arterial injuries in spite of ultrasound guidance. We aimed to evaluate whether small venous diameter and anterior venous wall tenting by a needle would be associated with posterior venous wall penetration, and to seek factors related to the venous wall tenting. We conducted a retrospective review in patients who underwent IJV cannulation. Using an ultrasound view obtained when puncturing, venous diameter, venous wall thickness, anterior venous wall tenting length, and needle angle were measured, and posterior venous wall penetration was determined. Eleven cannulations in 56 patients were assigned to posterior venous wall penetration. Small venous diameter ($p = 0.004$), and long anterior venous wall tenting ($p = 0.007$) were associated with posterior venous wall penetration. The longer anterior venous tenting would be expected with reducing needle angle ($p = 0.004$) or increasing anterior venous wall thickness ($p = 0.006$). In conclusion, small IJV and anterior venous wall tenting lead to posterior venous wall penetration. Anterior venous wall tenting is longer with reducing needle angle, or increasing the anterior venous wall thickness.

**Keywords** Internal jugular vein cannulation · Ultrasound guidance · Anterior venous wall tenting · Posterior venous wall penetration

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Unintentional penetration of the posterior venous wall during internal jugular vein (IJV) cannulation may occur despite the use of ultrasound guidance, especially with the short-axis view, and cause inadvertent injuries of posteriorly positioned arteries to the IJV [1, 2]. Such injuries can lead to critical cervical hematoma [3, 4]. However, previous clinical studies of IJV cannulation with the short-axis view, which indicate that small venous diameter of the IJV is associated with decreased cannulation success in patients, have not focused on posterior venous wall penetration during IJV cannulation [1, 5]. In contrast, ultrasound imaging with the longitudinal axis view shows that the tip of the cannulation needle compresses and 'tents' the anterior venous wall of the IJV [6]. Not only small venous diameter but also the needle-induced anterior venous wall tenting may lead to failed cannulation because of penetration of the anterior and posterior wall simultaneously without aspiration of blood into the syringe [7]. However, it remains unknown whether small venous diameter or anterior venous wall tenting causes posterior venous wall penetration, and to what extent the needle tents the anterior venous wall. Thus, the aims of this study using the longitudinal axis view on ultrasound were to evaluate whether small venous diameter and anterior venous wall tenting would be associated with posterior venous wall penetration, and to seek factors related to the anterior venous wall tenting.

The study was approved by the Ethics Committee of Hirosaki University Graduate School of Medicine in June 2012, and the Ethics Committee of Hirosaki Chuo Hospital in July 2012. The requirement for written informed consent was waived by the committees. A retrospective review of medical records and ultrasound image records was conducted on patients receiving general anesthesia for cardiovascular surgery at Hirosaki Chuo Hospital between January 1, 2008 and May 15, 2012. We included patients who required right IJV cannulation during general anesthesia, and whose ultrasound images during the cannulation were recorded. All cannulations were performed by the first author in the following manner. After the patient's head was rotated to the left in the supine position, an 18-G catheter over introducer needle (Arrow International, Reading, PA, USA) was inserted with imaging the short-axis view of the IJV using Aloka Prosound α5 and a 7.5-MHz linear probe (Aloka, Tokyo, Japan). When, subsequently, the tip of the needle reached the anterior venous wall of the IJV (Fig. 1a), the longitudinal view was obtained by rotating the probe (Fig. 1b). The needle was then advanced until the anterior venous wall was penetrated, which was detected off-line as releasing the compression and tenting of anterior venous wall (Fig. 1C). Ultrasound measurements including diameter of the IJV, tenting length, and needle angle to the anterior venous wall were determined using a longitudinal view obtained just before puncturing the anterior venous wall, as shown in Fig. 1D with Microsoft Excel (Microsoft Corp., Redmond, WA, USA). Posterior venous wall penetration was defined as penetrating the posterior wall by the needle. In addition, thickness of the anterior venous wall in the short-axis view was measured. To consider the influence of operator experience on posterior venous wall penetration, we divided the reviewed period into two halves.

Student's $t$ test, Mann–Whitney $U$ test, $\chi^2$ test, and Fisher's exact test were used for comparison of patient characteristics, operator experience, and ultrasound measurements. Multiple logistic regression was used to identify factors significantly related to posterior venous wall penetration. Stepwise multiple linear regression was used to identify factors significantly related to tenting length. All statistical analyses were performed with SPSS statistical software (version 21.0, SPSS, Chicago, IL, USA), and R statistical software (version 2.15.2). $p < 0.05$ was considered significant.

Fifty-six patients were included in this study. IJV cannulation was accomplished without posterior venous wall penetration in 45 patients, whereas those in 11 patients were assigned to posterior venous wall penetration. Diameter of the IJV was significantly smaller, anterior venous wall tenting was significantly longer, and anterior venous wall was significantly thicker in the group with posterior venous wall penetration ($p$ = 0.001, 0.013 and 0.002, respectively, Table 1). The following variables were entered into the final model of multivariable analysis with considering multicollinearity: diameter of the IJV and tenting length of the anterior venous wall into the multiple regression

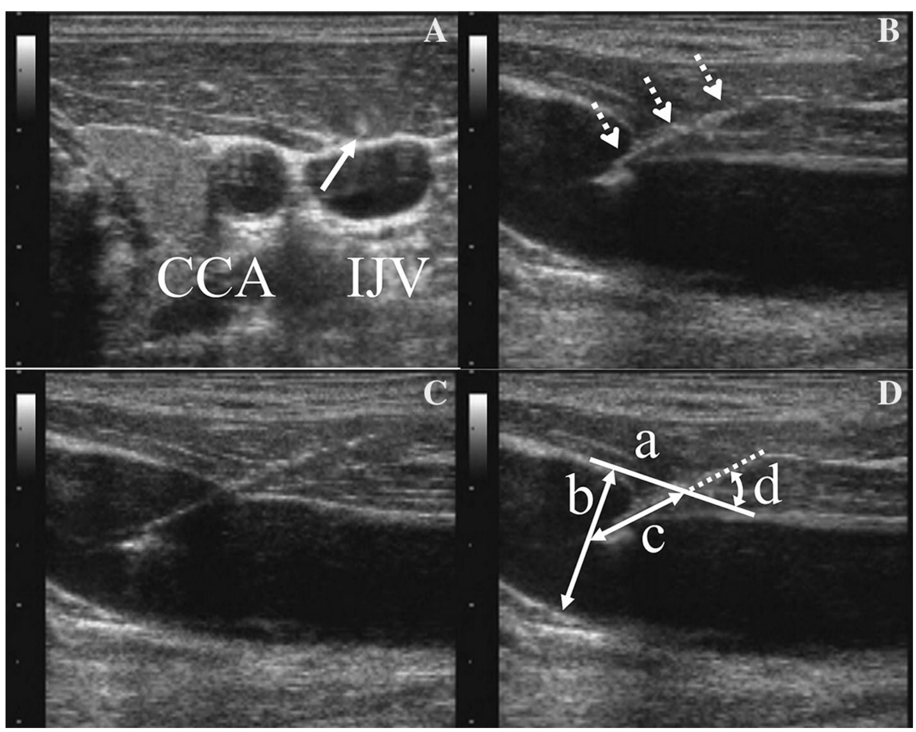


**Fig. 1** Ultrasound image during right internal jugular vein cannulation. **A** Short-axis view of the internal jugular vein when the tip of the needle reached to the anterior wall. The *arrow* indicates the tip of the needle. *CCA* common carotid artery, *IJV* internal jugular vein. **B**–**D** The longitudinal view just before (**B** and **D**), or when (**C**) puncturing the anterior wall of the internal jugular vein. The *dashed arrows* indicate the path of the needle. *a* the vertical anterior wall, *b* diameter of the internal jugular vein, *c* anterior wall tenting and *d* needle angle to the anterior venous wall

**Table 1** Patient characteristics and ultrasound measurements

| | Posterior wall penetration | | *p* value | Difference between groups (95% CI) |
|---|---|---|---|---|
| | (+), $n = 11$ | (−), $n = 45$ | | |
| Age (years) | 70 (65–74) | 71 (61–78) | 0.665 | 1 (−5 to 7) |
| Gender (M/F) | 7/4 | 31/14 | 0.499 | NA |
| Height (cm) | 158.1 (11.1) | 159.6 (10.3) | 0.678 | 1.5 (−5.6 to 8.5) |
| Weight (kg) | 55.5 (10.7) | 59.8 (11.0) | 0.238 | 4.4 (−3.0 to 11.8) |
| BMI (kg $cm^{-2}$) | 22.1 (2.7) | 23.4 (2.7) | 0.159 | 1.3 (−0.5 to 3.1) |
| Operator experience (the first half/the second half of the reviewed period) | 5 (3–9) | 7 (5–10) | 0.272 | 1 (−1 to 4) |
| Venous diameter (mm) | 6.7 (6.2–8.8) | 9.1 (7.5–10.7) | 0.001 | 2.3 (0.8 to 3.6) |
| Anterior venous wall tenting (mm) | 10.7 (2.0) | 8.6 (2.4) | 0.013 | –2.0 (−3.6 to −0.4) |
| Needle angle (degree) | 37 (36–43) | 43 (39–47) | 0.119 | 4 (−1 to 8) |
| Anterior venous wall thickness (mm) | 0.73 (0.12) | 0.60 (0.12) | 0.002 | −0.13 (−0.20 to −0.05) |

Values are mean (SD), median (IQR) or number

*CI* confidence interval, *BMI* body mass index, *CVP* central venous pressure

analysis; needle angle to the anterior venous wall, thickness of the anterior venous wall, age, and body mass index into the multiple linear regression analysis. The results of the multiple logistic regression analysis for posterior venous wall penetration show that the significant and independent factors of observing posterior venous wall penetration were small diameter of the IJV (odds ratio 0.346, 95 % CI 0.168–0.714, $p = 0.004$), and long tenting of the anterior venous wall (odds ratio 1.837, 95 % CI 1.185–2.849, $p = 0.007$). The results of the multiple linear regression analysis for factors significantly related to tenting length ($R^2 = 0.216$) demonstrate that tenting length would be longer with reducing needle angle ($p = 0.004$), or increasing the anterior venous wall thickness ($p = 0.006$).

To our knowledge, this is the first study to focus on the relationship between posterior venous wall penetration and possible risk factors for failed IJV cannulation such as small venous diameter and cannulation needle-induced anterior wall tenting, although such a tenting detected with the longitudinal axis view was previously introduced [6]. Major findings in this historical cohort study were as follows: Anterior venous wall tenting (mean ± SD) reached 9.0 ± 2.5 mm in length. Long anterior venous wall tenting as well as small IJV diameter were significantly important factors related to failed cannulation. We also found that as the needle angle decreased, or the anterior venous wall thickness increased, the tenting length increased.

Our results suggest that previously reported methods of dilating IJV diameter to improve the success rate of cannulation may also be effective in preventing posterior venous wall penetration. Conventional techniques, such as applying Trendelenburg's position or positive end-expiratory pressure, are significantly effective in increasing the cross-sectional area of the IJV as revealed by a study with ultrasound imaging [8]. However, these techniques could not be applied during surgery or to a patient with unstable hemodynamics. In such situations, other reported methods including stretching the skin over the IJV [5, 9] or pulling the probe and skin upward by using double-sided adhesive tape affixed to the skin [10] may be effective. Dilating the IJV may stretch the venous wall, which in turn can make it thinner. In addition, introducing a needle at a more obtuse angle may be favorable for reduction of anterior venous wall tenting length, whereas increasing needle angle would potentially be restricted in order to avoid penetrating the posterior venous wall, especially in small IJV.

There are some limitations to consider. First, our study did not show adverse effects of IJV cannulation such as hematoma formation. We used posterior wall penetration of the IJV as an indicator of failed cannulation because it can increase the potential risk of accidental injuries of small arteries and nerves lying dorsal to the IJV [1, 2]. Second, we used an 18-G catheter over introducer needle, which may be thicker than the usual size in the clinically available cannulation kit. Maruyama et al. [11] indicated that a larger needle required a longer distance to the IJV until blood was aspirated, although they did not measure the distance between the skin and the IJV with ultrasound imaging. A thinner catheter, if used, could have provided less tenting. Third, the axial resolution of the liner probe we used is less than 1 mm. A higher-resolution probe might have been suitable to measure the venous wall thickness.

In conclusion, small IJV and anterior venous wall tenting lead to posterior venous wall penetration. Anterior venous wall tenting is longer with reducing needle angle, or increasing the anterior venous wall thickness.

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