Proper Shoulder Position for Subclavian Venipuncture

A Prospective Randomized Clinical Trial and Anatomical Perspectives Using Multislice Computed Tomography

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Background: Although the Trendelenburg position and shoulder bracing are recommended for safe subclavian venipuncture, the optimal shoulder position remains unclear. The current study observed spatial relations between the subclavian vein and surrounding structures using multislice computed tomography to determine optimal shoulder position for safe subclavian venipuncture and then conducted a small follow-up clinical trial to confirm these findings.

Methods: Thoracic multislice computed tomography was performed for seven adult volunteers at three shoulder positions: elevated (up); neutral; and lowered caudally (down). Overlap and distance between the clavicle and the subclavian vein and the diameter of the subclavian vein were measured. Anatomical relations between the subclavian artery and vein were also observed. The success rate for subclavian venipuncture was then compared between the up and down shoulder positions in 30 patients.

Results: In the multislice computed tomography study, the mean overlap ratios between clavicle and subclavian vein in the up, neutral, and down positions were 33.5, 36.9, and 40.0%, respectively. Overlap increased with lower shoulder position (up < neutral < down; P < 0.05). The mean distances between the clavicle and subclavian vein in the up, neutral, and down positions were 6.8, 5.0, and 3.6 mm, respectively. Again, distance decreased with lower shoulder position (up < neutral < down; P < 0.05). The diameter of the subclavian vein did not differ among the three shoulder positions. The success rate for subclavian venipuncture was significantly higher in the down position compared with the up position (P = 0.003).

Conclusions: Lowered shoulder position increases both overlap and proximity between the clavicle and the subclavian vein, producing a more constant relation between the clavicle and the subclavian vein, without affecting vein diameter. Proper use of a lowered shoulder position should thus increase the safety and reliability of subclavian venipuncture compared with other shoulder positions.

Since its introduction by Aubaniac in 1952,1 percutaneous catheterization of the subclavian vein using an intracavicular approach has seen widespread application for intravenous hyperalimentation, assessing cardiac function and drug administration. Although this procedure is well established as a relatively safe method of accessing the central vein, serious complications such as pneumothorax or puncture of the subclavian artery can still arise.2,3 Numerous studies using venous angiography, magnetic resonance imaging, ultrasonography, or cadaver dissection have attempted to identify optimal procedures for safe subclavian venipuncture.4–7 Most clinicians now recognize that both patient position and needle insertion technique are extremely important for safe subclavian venipuncture. The Trendelenburg position,6 with arms by the side and shoulder braced with a small pillow beneath the vertebral column between the scapulae, is recommended,8 allowing dilatation of the subclavian vein and facilitating needle insertion. However, optimal shoulder position (elevated, neutral, or lowered caudally) remains contentious. Numerous investigators have stated that a neutral shoulder position is preferable for subclavian venipuncture.1,4,5,9 However, some recent reports have described an elevated shoulder position (up)9 or conversely, a caudally retracted position (down) as advantageous for venipuncture.7

The current study first examined anatomical relations between the subclavian vein and shoulder position using multislice computed tomography (MSCT) and then undertook a small-scale clinical trial to verify the results of the imaging study. MSCT enables the collection of more spatial anatomical information compared with other methods, because of the high resolution achieved using multiple detectors.10,11 We investigated optimal shoulder position for safe and reliable subclavian venipuncture by comparing changes in relations between the subclavian vein and the surrounding structures in three different shoulder positions.

Materials and Methods

MSCT Study

The MSCT study was performed at Saga Medical School (Nabeshima, Saga, Japan). Examinees comprised seven Japanese adult male volunteers with median age, height, and weight of 34 yr (range, 27–46 yr), 173 cm (range, 168–178 cm), and 65 kg (range, 58–79 kg), respectively. Subjects had neither undergone surgery nor experienced injuries between the neck and thoracic area, including the shoulder and clavicle. The imaging study protocol was approved by the Institutional Ethical Committee, and written informed consent was obtained from...
all examinees. MSCT without contrast medium from the neck to the suprathoracic area was performed using a Light Speed QX/i scanner (GE Yokogawa Medical System, Tokyo, Japan), with the following scanning parameters: rotation time, 500 ms; tube current, 360 mV; tube voltage, 120 kV.

Subjects were placed in a supine position with the arms by the sides and the head rotated approximately 30° to the left. A small rolled towel was placed under the back of the patient as the arms were retracted slightly backward. MSCT was undertaken for three positions of the right shoulder: up (5 cm cranial from neutral); neutral; and down (5 cm caudal from neutral). Up and down were the postures where the examinee moved the tip of right middle finger in a brace from the neutral position to 5 cm cranial or caudal, respectively (fig. 1). Subjects performed light inspiratory-phase breath holding for approximately 25 s during each scan. After MSCT, positions of the right subclavian, internal jugular, and brachiocephalic veins were projected onto an image from three-dimensional bone computed tomography and reconstructed by tracing those veins from a coronal MSCT image using image-analyzing software (Advantage Workstation 3.1; GE Yokogawa Medical System). From the computed synthesized computed tomography image, the distance between the sternoclavicular joint and the point on the lower border of the clavicle at which the subclavian vein crosses was measured as overlap length (OL). The OL ratio was defined as OL divided by total clavicle length. Distances between the subclavian vein and the clavicle, between the clavicle and the first (or second) rib, and between the subclavian artery and vein and the maximum and minimum diameters of the subclavian vein were determined at both the midclavicular line and the clavicular head of the sternocleidomastoid muscle using sagittal MSCT images. The distance between the subclavian vein and pleura was also obtained from sagittal MSCT at the area from the medial border of the first rib to the confluence of the subclavian and internal jugular veins.

**Prospective Randomized Clinical Trial**

After the study protocol was approved by the local Institutional Review Boards of Saga Medical School and Kohseikan Hospital (Mizugae, Saga, Japan), written informed consent was obtained from 30 patients already scheduled to undergo central venous catheter placement in Saga Medical School or Kohseikan Hospital surgical center. Patients were then randomly assigned to either up or down groups (n = 15 each), with positions as described above (fig. 1). The right shoulder was kept up or down during subclavian venipuncture. No patients had experienced trauma or a surgical procedure at or around the clavicle. After tracheal intubation following induction of general anesthesia, patients were placed in a supine, head-down (approximately 20°) position with the arms by the sides and the head rotated approximately 30° to the left. A small rolled towel was placed under the back of the patient as the arms were slightly retracted backward. A 22-gauge needle (Microneedle Seldinger Kit; Nippon Sherwood, Tokyo, Japan), approximately 7 cm long, was used to puncture the subclavian vein for placement of a guide wire. In all cases, the needle was inserted at approximately 1 cm below the midclavicular point of the lower border of the right clavicle and was advanced toward the sternal notch, keeping close to the undersurface of the clavicle, with constant slight negative pressure on the syringe. Identifi-
fication of smooth venous blood return was considered indicative of successful venipuncture. If the procedure was unsuccessful, direction of needle advancement was altered slightly cephalad or caudad. If no obvious venous aspiration was seen within three attempts in one shoulder position (step 1), the shoulder was moved to the opposite position (step 2). Success rates in each step were compared.

**Statistical Analysis**

The difference in subclavian venipuncture success rate between the up and down positions was assumed to be approximately 50% on the basis of the preliminary trial results. A sample size of 15 patients in each group was thus considered necessary to detect any significant differences between groups as calculated with a power of 0.8 and a significance level of 0.05 using SamplePower 1.02 software (SPSS, Chicago, IL). The Mann–Whitney U test and Fisher exact probability test were used to compare patient characteristics and rate of successful subclavian venipuncture between the up and down groups, respectively. Wilcoxon single-rank testing was used for statistical analysis of MSCT parameters, and values of \( P < 0.05 \) were considered significant. All analyses were performed using Statview 5 software (SAS Institute, Cary, NC).

**Results**

**MSCT Study**

**Overlap between Clavicle and Subclavian Vein.** All subjects displayed the subclavian vein overlapping the inner third of the clavicle. Figure 1 shows projections of the right subclavian vein onto images from three-dimensional bone computed tomography for different shoulder positions. Mean OL ratios in the up, neutral, and down positions were 33.5, 36.9, and 40.0%, respectively. OL increased significantly with lowered shoulder position (up < neutral < down; \( P < 0.05 \)).

**MSCT Findings at the Clavicular Head of the Sternocleidomastoid Muscle.** Figure 2 (left) shows MSCT findings at the clavicular head of the sternocleidomastoid muscle. The mean distances from the clavicle to the subclavian vein for the up, neutral, and down positions were 6.8, 5.0, and 3.6 mm, respectively. The proximity between the subclavian vein and clavicle increased significantly with lower shoulder position (up > neutral > down; \( P < 0.05 \)). The mean distances from the clavicle to the first rib for the up, neutral, and down positions were 17.6, 13.0, and 9.9 mm, respectively, and the space between the clavicle and the first rib narrowed significantly with lower shoulder position (up > neutral > down; \( P < 0.05 \)). The mean distances between the subclavian vein and artery for the up, neutral, and down positions were 1.6, 2.9, and 3.1 mm, respectively, with only up versus down displaying a significant difference (\( P = 0.04 \)). No significant differences in mean subclavian vein diameter (maximum, minimum) were observed between the up (17.7 and 13.4 mm), neutral (16.7 and 12.6 mm), and down (16.8 and 12.2 mm) positions.

**MSCT Findings at the Midclavicular Line.** The MSCT findings at the midclavicular line (fig. 2 [right]) resembled those at the clavicular head of the sternocleidomastoid muscle, with lower shoulder position resulting in closer proximity between the clavicle and the subclavian vein and significantly narrowed space between the clavicle and the second rib. The subclavian vein tended to display increased separation from the artery with lower shoulder position but did not become...
Table 1. Anatomical Changes in Subclavian Vein and Surrounding Structures in Three Shoulder Positions (n = 7)

<table>
<thead>
<tr>
<th>Shoulder Position</th>
<th>Up (n = 7)</th>
<th>Neutral (n = 7)</th>
<th>Down (n = 7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>%OL*</td>
<td>33.5 ± 2.5%</td>
<td>36.9 ± 2.6%</td>
<td>40.0 ± 3.6%</td>
</tr>
<tr>
<td>cl-sv*</td>
<td>6.8 ± 2.8 mm</td>
<td>5.0 ± 1.7 mm</td>
<td>3.6 ± 1.6 mm</td>
</tr>
<tr>
<td>cl-1rb*</td>
<td>17.6 ± 6.0 mm</td>
<td>13.0 ± 4.8 mm</td>
<td>9.9 ± 3.1 mm</td>
</tr>
<tr>
<td>sa-sv†</td>
<td>1.6 ± 1.8 mm</td>
<td>2.9 ± 2.3 mm</td>
<td>3.1 ± 1.7 mm</td>
</tr>
<tr>
<td>sv diameter, max.§</td>
<td>16.8 ± 2.3 mm</td>
<td>16.7 ± 2.0 mm</td>
<td>17.7 ± 3.9 mm</td>
</tr>
<tr>
<td>sv diameter, min.§</td>
<td>13.4 ± 3.5 mm</td>
<td>12.6 ± 2.7 mm</td>
<td>12.2 ± 2.7 mm</td>
</tr>
<tr>
<td>cl-sv‡</td>
<td>27.8 ± 9.4 mm</td>
<td>18.9 ± 10.1 mm</td>
<td>15.0 ± 6.1 mm</td>
</tr>
<tr>
<td>cl-2rb*</td>
<td>38.0 ± 5.7 mm</td>
<td>27.1 ± 4.5 mm</td>
<td>23.7 ± 3.9 mm</td>
</tr>
<tr>
<td>sa-sv§</td>
<td>14.0 ± 1.8 mm</td>
<td>12.8 ± 1.8 mm</td>
<td>14.4 ± 1.9 mm</td>
</tr>
<tr>
<td>sv diameter, max.§</td>
<td>10.6 ± 1.5 mm</td>
<td>9.7 ± 1.3 mm</td>
<td>11.1 ± 1.1 mm</td>
</tr>
<tr>
<td>sv diameter, min.§</td>
<td>2.4 ± 0.8 mm</td>
<td>2.5 ± 0.9 mm</td>
<td>2.4 ± 0.8 mm</td>
</tr>
</tbody>
</table>

Data are presented as mean ± SD.
* P < 0.05, up vs. neutral; P < 0.05, neutral vs. down. † P > 0.05, up vs. neutral; P > 0.05, neutral vs. down; P < 0.05, up vs. down. ‡ P > 0.05, neutral vs. down. § no significant difference among any of the three shoulder positions.

Distance between Subclavian Vein and Pleura. The mean distances between the subclavian vein and the pleura in the up, neutral, and down positions were 2.4, 2.5, and 2.4 mm, respectively, showing no significant differences among positions.

Prospective Randomized Clinical Trial
No significant differences in patient characteristics were identified between the two groups (table 2). In step 1 for the up group, successful venipuncture was achieved in 7 of 15 patients (47%). In the remaining 8 patients, the vein was not successfully punctured within three attempts, so venipuncture was attempted in the down position (step 2). This resulted in successful venipuncture in 7 patients (88%) on the first or second attempt (on the first attempt in 5 patients, on the second attempt in 2 patients). In 1 patient from the up group, subclavian venipuncture was not successfully completed in either shoulder position. In the down group, venipuncture was successfully achieved on the first attempt in 12 of 15 patients and on the second attempt in the remaining 3 patients, thus yielding a 100% success rate for step 1. Therefore, no patients moved to step 2. The rate of successful subclavian venipuncture was obviously higher for the down group than for the up group (P = 0.003). All results are shown in table 3. No patients displayed pneumothorax or hemothorax on chest radiography several hours after attempted venipuncture.

Discussion
The issue of proper shoulder position for safe and reliable subclavian venipuncture remains controversial. Numerous investigators have recommended that the shoulder should be maintained in a neutral position during venipuncture. Advantages have also been reported for shoulder elevation during the procedure. Conversely, our experience has led us to consider a lowered shoulder position as optimal for subclavian venipuncture. Tan et al. have already suggested the advantages of lowering the shoulder but did not mention lowering the shoulder to the degree suggested in the current study. However, no previous imaging studies or

Table 2. Demographic Data for Patients Participating in the Clinical Trial

<table>
<thead>
<tr>
<th>Shoulder Position</th>
<th>Up</th>
<th>Down</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex, male/female</td>
<td>10/5</td>
<td>11/4</td>
<td>NS</td>
</tr>
<tr>
<td>Age, yr</td>
<td>64.9 ± 9.6</td>
<td>62.8 ± 11.5</td>
<td>NS</td>
</tr>
<tr>
<td>Height, cm</td>
<td>162.6 ± 8.9</td>
<td>161.3 ± 7.7</td>
<td>NS</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>56.5 ± 10.7</td>
<td>57.3 ± 9.5</td>
<td>NS</td>
</tr>
</tbody>
</table>

Data are presented as mean ± SD (excluding sex). NS = not statistically significant.

Table 3. Rate of Successful Subclavian Venipuncture

<table>
<thead>
<tr>
<th>Initial Shoulder Position</th>
<th>Up (n = 15)</th>
<th>Down (n = 15)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Success rate in step 1</td>
<td>7/15 (47%)</td>
<td>15/15 (100%)</td>
<td>0.003</td>
</tr>
<tr>
<td>Success rate in step 2</td>
<td>7/8 (88%)</td>
<td>—</td>
<td></td>
</tr>
</tbody>
</table>

When the procedure was unsuccessful within three attempts in one shoulder position (step 1), the shoulder position was changed to the other position (step 2). Success rates in each step were compared.
clinical trials have investigated the characteristics or efficacy of various shoulder positions. The results of the current imaging studies and small-scale clinical trial suggest that lowering the shoulder under arm traction can significantly facilitate subclavian venipuncture compared with other positions. However, this clinical study was limited by a small subject population and comparison between only two positions (up and down), and larger studies would be beneficial in the future.

Various methods have been used for anatomical studies regarding safe subclavian venipuncture. However, conventional computed tomography, magnetic resonance imaging, and ultrasonography display limited resolution, and venous angiography does not provide useful spatial information. Cadaveric studies can facilitate a clearer understanding of spatial anatomy but may display substantial differences from living human anatomy because tissues must be dissected to observe the target region, resulting in the disappearance of essential linkages between the subclavian vein and surrounding structures in the intact human body. MSCT, even without using contrast medium, offers high-resolution imaging with little flutter, because the short scan time enables subjects to use breath-holding techniques. This technique therefore seems useful for exploring spatial relations in living subjects.

Overlap between Subclavian Vein and Clavicle

The current study focused on the right subclavian vein. The OL ratio was 33–40% at all shoulder positions, indicating that the subclavian vein passes beneath the inner third of the clavicle and that OL ratio increases with lower shoulder position. Our findings resemble those of venographic and dissection studies reported by Land and Tam et al., respectively.

Since the introduction of subclavian catheterization, most practitioners have inserted a needle at 1–2 cm inferior to the infracavicular edge of the midclavicular line. Inserting the needle from this site and advancing toward the sternal notch while keeping close to the undersurface of the clavicle, insertion into the subclavian vein is typically achieved beneath the inner third of the clavicle, where the subclavian vein is closest to clavicular undersurface. As our results show, a lower shoulder position increases OL. Needle insertion according to the standard technique mentioned above therefore will achieve more reliable subclavian venipuncture if a lowered shoulder position is adopted.

Diameter of the Subclavian Vein

We initially suspected that lowering the shoulder would decrease the diameter of the subclavian vein because of compression against the clavicle and first rib at the clavicular head of the sternocleidomastoid muscle. This would presumably exert a negative impact on safe venipuncture. However, minimum and maximum diameters of the subclavian vein did not differ significantly between the three shoulder positions. Although venous cross section tends to become slightly elliptical with a lowered shoulder position, the diameter of the subclavian vein does not change when shoulder movement is within 5 cm up or down from neutral. From the perspective of vein diameter, a lowered shoulder position seems unlikely to exert any real adverse impact on safe venipuncture.

Distance between Clavicle and Subclavian Vein

To avoid arterial puncture or pneumothorax during subclavian venipuncture, needle insertion technique is important. Inserting the needle along the clavicular undersurface and advancing parallel to the coronal plane prevents excessive posterior advancement. This decreases the risk of serious complications because the subclavian artery lies just behind and superior to the subclavian vein, with the pleura only 5 mm posterior to the subclavian vein. Our study demonstrated that a lower shoulder position decreased the distance between the clavicle and subclavian vein, ensuring anatomical consistency of the relation between bone and vein. A high success rate for subclavian venipuncture using safe needle insertion technique as described above is therefore expected with caudal traction on the arm to lower the shoulder.

Shoulder retraction by placing a pillow beneath the vertebral column between the scapulae reduces the distance between the clavicle and subclavian vein, in addition to preventing interference of the humeral head with passage of the needle by altering the position of the shoulder posteriorly. As reported by Jessep et al., however, retraction of shoulder in this maneuver is associated with a risk of anteroposterior compression of the subclavian vein. To reduce the distance between the clavicle and subclavian vein, properly lowering the shoulder using arm traction in a caudal direction seems desirable because the diameter of the vein is unaffected by lowered shoulder position.

Relation between Subclavian Artery and Vein

The subclavian artery lies behind and slightly superior to the path of the subclavian vein. Although the subclavian artery is in close contact with the subclavian vein in the up and neutral positions, the tendency for contact between the subclavian artery and vein decreases at the clavicular head of the sternocleidomastoid muscle with a lowered shoulder position (fig. 2). This is because the subclavian vein undergoes a relatively greater inferior shift than the subclavian artery in the lowered shoulder position. A needle advanced along the undersurface of the clavicle usually enters the subclavian vein beneath the inner third of the clavicle, particularly near the clavicular head of the sternocleidomastoid. The risk of
accidental arterial puncture is thus reduced using a lowered shoulder position.

**Shoulder Position and Venous Tension**

As described by Land, upward shoulder movement produces bending and reduced tension in the walls of the subclavian vein. This may reduce the appearance of immediate blood return to the syringe because the tip of the needle may push the vessel wall rather than penetrating. In fact, despite the absence of visible blood return to the syringe during needle advancement, visible blood return is often experienced during needle withdrawal, particularly when using a large-bore needle. This situation is associated with a risk of excessive needle advancement, potentially leading to puncture of the subclavian artery. A lowered shoulder position produces caudal traction of the subclavian vein, increasing tension on walls of the subclavian vein to the point where the junction of the brachiocephalic and jugular veins shifts laterally to the right (fig. 1). A lowered shoulder position is therefore expected not only to facilitate needle insertion into the vein, but also to decrease the risk of excessive needle advancement.

**Distance between Clavicle and First Rib**

Lowered shoulder position increases the OL between the clavicle and subclavian vein, bringing the subclavian vein closer to the undersurface of the clavicle and resulting in advantages for safe subclavian venipuncture. However, this position also narrows the space between the clavicle and first rib, which may make needle insertion difficult. This problem can be overcome by shifting the puncture site to slightly lateral from the midclavicular line. In fact, this lateral approach was described by Tofield and is advantageous for safe and reliable subclavian venipuncture from the perspective of the clavicular contours. Puncture slightly lateral to the midclavicular line facilitates needle insertion and parallel advancement in the coronal plane, due to both the anterior convexity of the medial two thirds of the clavicle and the fact that the clavicle is thinner lateral to the midclavicular point (fig. 3). Conversely, an elevated shoulder position increases the distance between the clavicle and the first rib, resulting in easier needle insertion. A less constant anatomical relation between the bone and the vein is also produced, compared with other shoulder positions that widen the distance between the clavicle and the vein. An elevated shoulder position thus seems less reliable for subclavian venipuncture. However, the rate of successful subclavian catheterization under shoulder elevation was reported as 87%

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Fig. 4. Relation between shoulder position and angles composed of the great veins. Angles were obtained from great veins in the coronal plane scanned by multislice computed tomography. $\alpha =$ angle between subclavian vein (sv) and brachiocephalic vein (bc); $\beta =$ angle between subclavian vein and internal jugular vein (jv). (A) $\alpha = 114^\circ$, $\beta = 89^\circ$ in elevated shoulder position; (B) $\alpha = 108^\circ$, $\beta = 107^\circ$ in neutral shoulder position; (C) $\alpha = 99^\circ$, $\beta = 117^\circ$ in lowered shoulder position. Values are presented as means. Lower shoulder position results in a reduced angle between the subclavian and brachiocephalic veins.
by Baltalarli et al., a value much higher than achieved in the up group in the current study. This may result from differences in puncture sites between the studies. Baltalarli et al. punctured the subclavian vein at the junction between the middle and inner thirds of the clavicle, a more medial position than ours, and where a relatively narrow space between the clavicle and the first rib results in greater anatomical constancy of the clavicle-vein relation than seen when using a lateral approach. Catheterization of the subclavian vein was thus achieved with a high success rate despite shoulder elevation. This indicates that anatomical constancy of the bone-vein relation is extremely important for reliable subclavian venipuncture.

Subclavian Vein and Pleura

The distance between the subclavian vein and the pleura is also important regarding the risk of accidental pleural injury and pneumothorax in particular. When a needle is advanced toward the sternal notch along the clavicular undersurface parallel to the coronal plane, the area from the clavicular head of the sternoclavicular muscle to the medial side of clavicle seems to offer an area of high risk for pleural injury because the protection of the pleura by the first rib disappears in this region (fig. 1). The current study showed no significant differences in the distance between the subclavian vein and the pleura among the three shoulder positions. A lowered shoulder position therefore does not seem to increase the risk of pneumothorax.

Properly Lowered Shoulder Position

As mentioned above, possible disadvantages for safe subclavian venipuncture with a lowered shoulder include the decrease in subclavian vein diameter and narrowing of the space between the clavicle and the first rib. Lowering of the shoulder position should therefore not be excessive. The current results suggest that the optimal shoulder position for reliable and safe subclavian venipuncture seems to be within 5 cm below neutral.

Catheter or Guide Wire Insertion

After successful needle insertion into the subclavian vein using a lowered shoulder position, catheter or guide wire advancement under a neutral or elevated shoulder position seems to facilitate placement in the superior vena cava because of increased overlap between the clavicle and subclavian vein and formation of a consistently close anatomical relation between the clavicle and subclavian vein, with increased tension on the vessel walls and no significant changes in vein diameter.

In conclusion, proper lowering of the shoulder seems advantageous for safe and reliable subclavian venipuncture, because of increased overlap between the clavicle and subclavian vein and formation of a consistently close anatomical relation between the clavicle and subclavian vein, with increased tension on the vessel walls and no significant changes in vein diameter.

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