An Anatomic Landmark to Simplify Subclavian Vein Cannulation: The "Deltoid Tuberosity"

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The subclavian vein is frequently used to obtain central venous access. Several landmarks exist to determine the puncture site and angle, but they may require patient manipulation and anatomic measurements. We studied the feasibility of using the deltoid tuberosity, located on the lateral aspect of the clavicle, as an anatomic landmark. This would not necessitate these maneuvers and could therefore facilitate subclavian vein access. To systematically investigate this landmark, we conducted a study in four phases: 1) Two blindfolded examiners determined the distance between the tuberosity's medial border and the clavicle's lateral end in 100 dried clavicles and then 2) performed subclavian vein cannulation in 20 fresh human cadavers using the tuberosity and the suprasternal notch as landmarks. 3) Three-dimensional reconstructions of the subclavian artery and vein and surrounding structures were derived from computed tomography datasets of 10 patients. The length of the path of a virtual subclavian vein cannulation with the deltoid tuberosity landmark was measured bilaterally. 4) In a prospective, randomized trial, subclavian vein cannulation was performed in 60 patients with a standard approach or with the deltoid tuberosity as landmark. Interobserver difference between measurements in phase 1 was 3 ± 1 mm (mean ± SD); subclavian vein cannulation was achieved in 19 of 20 cases, whereas the subclavian artery was cannulated in one case (phase 2). In phase 3, there was no significant difference in skin-vein distance between the left (4.9 ± 0.5 cm) and right (4.7 ± 0.6 cm) sides. In phase 4, subclavian vein cannulation could be performed in all patients; moreover, subclavian vein cannulation was significantly ($P < 0.01$) faster in the deltoid tuberosity group versus the standard approach group (23 ± 16 versus 34 ± 14 s). We conclude that the clavicle's tuberosity may reflect an alternative anatomic landmark to simplify subclavian vein cannulation by minimizing patient manipulation and anatomic measurements.

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Subclavian vein cannulation is an established maneuver to obtain venous access, but it may result in serious or even life-threatening complications such as a pneumothorax and intrathoracic hemorrhage. When subclavian vein cannulation is not regularly performed, it may lead to infrequent success and major complications (1,2); not surprisingly, physician experience reduces the risk of complications (3). For example, physicians who had performed ≥50 subclavian vein cannulations encountered 50% fewer complications (4). Although this may suggest that only experienced health care professionals should perform this procedure, this may not be practical in emergency situations or in teaching and small hospitals. Accordingly, any strategy to simplify subclavian vein cannulation may result in fewer complications, and therefore, greater patient safety.

Several landmarks for determination of the subclavian vein cannulation site are recommended, such as the midpoint of the clavicle (5), the junction between the middle and the medial border of the clavicle (6), the lateral aspect of a tubercle palpable on the medial part of the clavicle (7), and landmarks other than the clavicle (8–10) (Fig. 1). Each of these landmarks requires an exact measurement and may therefore pose difficulties for an inexperienced physician, particularly in obese patients. An easily palpable anatomical structure on the anterior surface of the lateral third of

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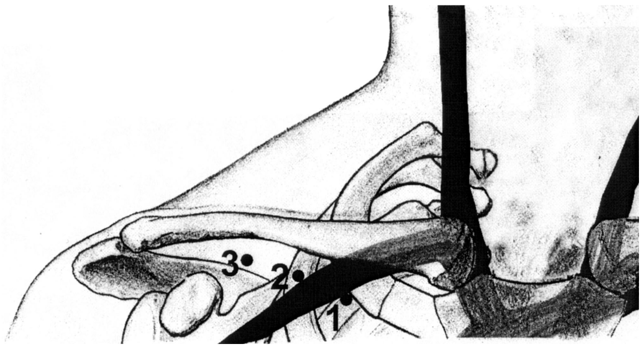

Figure 1. Infraclavicular approaches to the subclavian vein (dark gray stucture). 1 = junction between the middle and the medial border of the clavicle (6); 2 = medioclavicular line (5); 3 = deltoid tuberosity.

the clavicle, presenting as a tuberosity or tubercle, may be useful for determination of a possible subclavian vein cannulation site. In contrast to other morphological features that are easily recognized on the clavicle, this structure does not appear in the international anatomical terminology (11). However, it is described in early 19th century anatomy publications as the "Tuberositas deltoidea" or "Tuberculum deltoideum" (12,13). Because determining the subclavian vein cannulation site via the clavicle's tuberosity does not require measurements but can be readily achieved by palpation, this landmark could be helpful in simplifying the technique. Accordingly, using this landmark in improving and simplifying subclavian vein cannulation was the purpose of this study.

Methods

After IRB approval, we conducted the present study systematically in four parts. 1) First, we sought to determine the presence and location of the stipulated tuberosity in dried cadaveric clavicles. 2) Second, the usefulness of the landmark for subclavian cannulation was ascertained in a cadaver study. 3) Third, the distance between skin and subclavian vein following the cannulation pathway was determined based on computed tomography (CT) data. 4) Finally, a controlled, prospective, randomized trial of subclavian vein cannulation was performed in patients.

1) Fifty left and 50 right human clavicles of unknown gender were investigated. Exclusion criteria were signs of former fractures and degenerative changes. Two blindfolded examiners (both board certified anesthesiologists, each with an experience of >500 subclavian vein cannulations) were instructed to palpate each clavicle and to determine the presence and location of the tuberosity beginning from the medial third of the clavicle. Subsequently, the distance from the medial border of the tuberosity to the lateral end of the clavicle and the total length of the clavicle were measured using a caliper with an accuracy of 1 mm.
2) In the second part of the study, both examiners palpated the tuberosity on the clavicle in 20 fresh human cadavers (11 women, 9 men) unilaterally. The cadavers were investigated 6 to 24 h postmortem, ranged in age from 38–89 (mean ± SD, 67 ± 13) yr, in height from 155–192 (169 ± 10) cm, in weight from 48–109 (71 ± 17) kg, in body mass index from 19–31 (25 ± 4) kg/m^2 body surface, and were in the supine neutral position. Ten attempts to cannulate the subclavian vein were performed on the right and left sides, respectively. Subclavian cannulation was performed using a 6.35 cm long, 18-gauge introducer needle attached to a non-Luer-lock syringe. The skin was punctured ~1.5 cm caudad of the medial border of the tuberosity; the needle was then advanced as horizontal as possible in the direction of the suprasternal notch amounting to the sternoclavicular joint; gentle suction was applied by retracting the syringe plunger. Once blood was aspirated, the syringe was removed, and a guidewire was advanced into the blood vessel. When the first attempt was unsuccessful, the needle was retracted into the subcutis and then redirected in a ~10° more cranial angle in the coronal plane. Venipuncture was then successful in all cases. The position of the guidewire was confirmed by palpation in the subclavian vein during autopsy. We defined a successful attempt as venous access in either the first or second attempt using the technique described.
3) Three-dimensional (3D) CT datasets (2.5 mm slice thickness, 30 cm field of view) of 10 patients whose upper thorax and lower neck was investigated for different reasons were processed using the Treon optical navigation system (Medtronic, Louisville, KY). Three-dimensional reconstructions of the subclavian artery and vein, the skin, and the bony structures were derived from these datasets. The deltoid tuberosity on the clavicle was identified on the 3D reconstruction and on reformatted planes. This point was projected through the skin using semitransparent 3D reconstruction mode of the skin. The skin puncture point was defined ~1.5 cm caudad of the projected tuberosity. The target point was defined in the center of the subclavian vein. Using reformatted two-dimensional multiplanar images, the path as described above was defined on the 3D dataset. The length of the path was measured on every 3D dataset bilaterally totaling 20 measurements.
4) Sixty adult patients (ASA physical status I–III; age 21–89 yr) presenting for subclavian vein cannulation during general anesthesia were enrolled

in this prospective, randomized study. Written informed consent was obtained from all study participants. Exclusion criteria were prior surgery in the subclavian vein region and prior radiotherapy at the cannulation site. All catheters were inserted in the supine neutral position with routine monitoring applied, under sterile, nonemergency, controlled conditions. Four examiners (2 residents with an experience of <50 subclavian vein cannulations and 2 board certified anesthesiologists, as mentioned above) performed cannulation. Patients were randomized using the sealed envelope method to either the medioclavicular line landmark or the deltoid tuberosity landmark and the side of subclavian vein cannulation. The following factors were evaluated: age, sex, body mass index, number of skin puncture attempts (defined as separate needle advances), time from the beginning of landmark determination until skin puncture, time from skin puncture until the guidewire was positioned, complications during the procedure, and the chest radiograph after catheterization. Subclavian cannulation was performed using a 6.35 cm, 18-gauge introducer needle attached to a non-Luer-lock syringe (Arrow-Howes Multi-Lumen Central Venous Catheterization Set; Arrow, Reading, PA). The skin was punctured ~1.5 cm caudad of the medial border of the tuberosity or the medioclavicular line crossing the clavicula. The needle was advanced in the direction of the suprasternal notch/sternoclavicular joint, and gentle suction was applied by retracting the syringe plunger. Once blood was aspirated, the syringe was removed, and a guidewire was advanced into the blood vessel. If blood flow was pulsatile, arterial puncture was assumed, the needle was removed, and the puncture site was compressed for 2 min. A new attempt was then performed through the same skin puncture with the needle redirected in a ~10° more cranial angle in the coronal plane. Subsequently, the catheter was positioned over the guidewire and fixed to the skin, and central venous position was confirmed by chest radiograph.

Interobserver reliability in assessing clavicular distances was analyzed using intra-class correlation coefficient. Scores for statistical measurements with the intra-class correlation coefficient range from 0 to 1, where the former shows no reliability and the latter perfect reliability. Values less than 0.4 represent poor reliability, values between 0.4 and 0.75 represent fair to good reliability, and a value >0.75 is graded as an excellent reliability (14). Data from CT datasets are expressed as mean ± SD and range. The difference between the right and left sides was analyzed using a paired Student's t-test. Data from patient cannulation

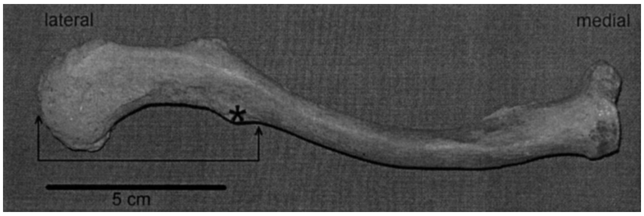

Figure 2. Right clavicle seen from cranial. Asterisk shows location of the tuberosity on the anterior surface. Arrows delineate the distance between the medial border, and the most lateral aspect of the articular facet.

are expressed as mean ± SD or frequency. Differences between medioclavicular line and the deltoid tuberosity as landmark were analyzed using Mann-Whitney U-test (for continuous data) and χ^2 Test (for categorical data). Statistical significance was defined as $P < 0.05$. SPSS for Windows 12.0 software (SPSS, Chicago, IL) was used for all analysis.

Results

A deltoid tuberosity was present in all clavicles (Fig. 2). Without visual control, both examiners palpated the tuberosity in all clavicles. The results of location measurements are presented in Table 1. The intra-class correlation coefficients for the total length of the clavicle and the determination of the medial border of the tuberosity were 0.93 and 0.68, respectively. Depending on the examiner, the tuberosity was located at ~35% and ~37% of the clavicle's total length as measured from the lateral border; the mean difference between the 2 examiners was 3 ± 1 mm. Successful placement of a guidewire into the subclavian vein was achieved in 19 of 20 cadavers using the clavicle tuberosity as an anatomical landmark; in one case, the guidewire was located in the subclavian artery. In 3D reconstruction the distance from the entrance point 1.5 cm caudal of the projected deltoid tuberosity to the target point in the middle of the subclavian vein was 4.9 ± 0.5 (4.2–5.6) cm on the left and 4.7 ± 0.6 (3.8–5.5) cm on the right side (mean ± SD [range]) (not significant) (Fig. 3). In both groups, all subclavian vein catheterizations were performed successfully and all chest radiographs were uneventful. There were no significant differences among the four examiners or between right and left side cannulation in intragroup or intergroup comparisons. The results of the subclavian vein cannulation are presented in Table 2.

Discussion

The present study systematically investigated the feasibility of a new landmark (the deltoid tuberosity) in optimizing the site for subclavian vein cannulation.

Table 1. Measurements of the Clavicle's Total Length, and the Location of the Deltoid Tuberosity

	Examiner 1 (n = 100)	Examiner 2 (n = 100)
Total length of the clavicle (mm)	146 ± 11	146 ± 11
Medial border of the tuberosity (mm)	51 ± 7	54 ± 6
Medial border of the tuberosity (%)	35 (27–44)	36.9 (29–44)

Data are mean ± SD or mean (range).

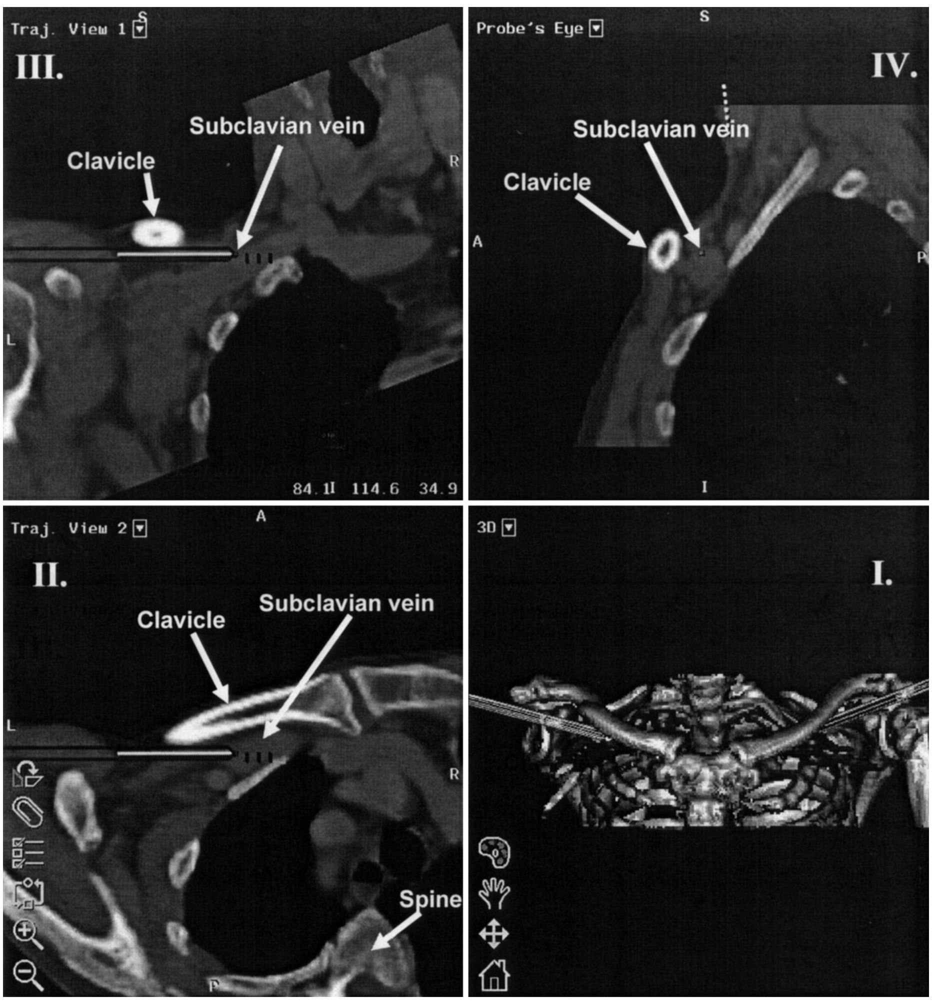

Figure 3. Multiplanar reconstructions of the three-dimensional dataset and surface shaded display three-dimensional reconstruction (I). White = bone; red = subclavian artery; blue = subclavian vein. The needle path is visualized as a blue-green (right) or a yellow (left) line. Note an old fracture of the right clavicle with callus formation. II shows reformatted plane along the horizontal level of the needle path during left subclavian vein cannulation. III shows reformatted plane on a rectangular level to image II. VI shows reformatted plane perpendicular to the needle path at the target (left subclavian vein).

The main results are that the new landmark appears to offer similar safety while simplifying and significantly shortening the procedure of subclavian vein cannulation.

The tuberosity was consistently identified in both anatomical and clinical study phases. Furthermore, the location of the tuberosity was unambiguous. Although the intra-class correlation coefficient yielded in phase 1 may appear somewhat low (0.68), the average of the absolute difference between the two investigators was approximately 3 mm; this difference would be negated by different finger sizes alone. In cadavers, 19 of 20 (95%) attempts to cannulate the subclavian vein were successful when the needle was inserted ~1.5 cm caudad to the medial border of the deltoid tuberosity and subsequently advanced towards the suprasternal notch; the subclavian artery was cannulated only once. In patients, however, the medioclavicular line landmark technique was associated with two arterial cannulations versus one with the deltoid tuberosity as landmark. This frequency of arterial punctures of ~5% is in accordance with current literature (15). Although the numbers of patients enrolled in the present study are too small to draw final conclusions, it seems that the new landmark offers a similar safety profile.

Other strategies to locate the subclavian vein cannulation site may result in a more medial approach than

Table 2. Patient and Subclavian Vein Cannulation Characteristics of the Medio-Clavicular Line and the Deltoid Tuberosity as Landmark: Time From the Beginning of Landmark Determination Until Puncture (Landmark-Puncture) and Time From Puncture Start Until the Guidewire Is Positioned (Puncture-Wire Positioned)

Variable	Medio-Clavicular Line (n = 30)	Deltoid Tuberosity (n = 30)	P value
Age (yr)	62 ± 18	62 ± 14	NS
Body mass index (kg/m^2)	24.9 ± 3.5	25.4 ± 2.7	NS
Sex (M/F)	19/11	18/12	NS
ASA status I/II/III (n)	2/15/13	0/11/19	NS
Skin puncture attempts 1/2/3 (n)	18/11/1	25/5/0	NS
Landmark-Puncture (s)	25.2 ± 5.5	16.1 ± 4.3	<0.001
Puncture-Wire Positioned (s)	33.7 ± 14.3	23 ± 15.7	<0.01
Arterial puncture (n)	2	1	NS
Pneumo-/hemothorax (n)	0	0	NS

Data are mean ± SD or numbers.
NS = not significant.

ours (5–7), resulting in an initially steeper angle of needle insertion to reach the subclavian vein, which may in turn increase the risk of a pneumothorax. When using a medial approach, researchers reported a cannulation failure rate of 6% to 20% (16,17); moreover, because the clavicle's thickness increases from lateral to medial, a more lateral puncture site, as suggested by our study, may allow a more shallow angle of needle insertion and therefore more space between the needle and pulmonary structures. With this approach the tip of the needle remains parallel to the chest surface and inferior to the clavicle in its anterior convex part during the entire procedure, which may in turn reduce the risk of a pneumothorax. No pneumothorax was noticed with either landmark technique in our study.

Using the deltoid tuberosity landmark, significantly less time was necessary to determine the puncture site and to perform the subclavian vein cannulation in comparison with a standard approach such as the medioclavicular line landmark. This may result from more time consuming anatomic measurements of the suprasternal notch-to-acromion distance in the latter situation. Thus, our approach may simplify subclavian vein cannulation because anatomic measurements of the suprasternal notch-to-acromion distance are unnecessary.

The success of subclavian vein cannulation is further influenced by shoulder, head and arm positioning. For example, Trendelenburg's position, a bedroll between the shoulder blades, and turning the head to the contralateral side are recommended (5,6). This could have affected our results because the fresh cadavers used in the present study may have exhibited an elevated shoulder as a result of *rigor mortis*. However, in our study only one subclavian vein cannulation attempt failed in the neutral position. Based on our results, we assert that the optimal position to perform subclavian vein cannulation is supine, horizontal with head and shoulders in a neutral position, as previously suggested (18). Slight shoulder retraction may be applied (19).

The use of ultrasound guidance during subclavian vein cannulation has been controversially discussed (2,20,21), the controversy most probably resulting from anatomical reasons. It has been suggested that the fixed anatomical relation between the subclavian vein and the clavicle makes ultrasound-guided catheter insertion more difficult and less reliable than a landmark-based insertion technique (15).

Some limitations of the present study should be noted. First, only two examiners performed subclavian vein cannulation in the cadavers and only four examiners performed subclavian vein cannulation in our patients. Second, degenerative changes or previous fractures of the clavicle may impair an accurate palpation of the tuberosity in a small number of patients. Third, only 60 patients were included in the clinical part 4 of our study comparing only two landmark techniques. Therefore, our study lacks power to determine the incidence of uncommon complications such as a pneumothorax and/or intrathoracic hemorrhage. Fourth, the investigation of the new landmark in children was beyond the scope of the present investigation; accordingly, future clinical studies are necessary to evaluate the efficacy and utility of this technique in children.

In conclusion, the clavicle's tuberosity may reflect an alternative anatomic landmark to simplify subclavian vein cannulation by minimizing patient manipulation and anatomic measurements.

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