

Supraclavicular Approach Is an Easy and Safe Method of Subclavian Vein Catheterization Even in Mechanically Ventilated Patients

Analysis of 370 Attempts

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Background: Central venous catheters are commonly inserted for hemodynamic monitoring, volume monitoring, administration of medications, long-term total parenteral nutrition, access for renal replacement therapy, cardiopulmonary resuscitation, and difficult peripheral catheterization. The primary outcome of this study was to define venipuncture, catheterization and entire procedure success rates, and finally complication rate of subclavian venous catheterization *via* the supraclavicular approach with special focus on mechanically ventilated patients. The secondary outcome was to potentially make recommendations regarding this technique of central venous catheterization in mechanically ventilated patients.

Methods: The methodology of this prospective cohort study included subclavian venous catheterization *via* the supraclavicular approach. The technique of cannulation was the same for both the right and left sides, but the right claviculosternocleidomastoid angle was the preferred catheterization site. All procedures were performed by the first three authors, each of whom had different levels of experience. Each physician had performed at least 20 procedures before starting the study.

Results: In the majority of patients, venipuncture occurred during the first attempt. In 362 patients, catheterization attempts were performed, in whom 311 catheterizations (85.6%) were successful during the first attempt. The overall subclavian venous catheterization *via* supraclavicular approach procedure complication rate reached 1.7% (95% confidence interval 0.6–3.6%). The overall subclavian venous catheterization *via* the supraclavicular approach procedure success rate reached 88.9% (95% confidence interval 85.1–91.9%, n = 359).

Conclusions: Subclavian venous catheterization *via* the supraclavicular approach is an excellent method of central venous access in mechanically ventilated patients. The procedure success rate and the significant complication rate are comparable to other techniques of central venous catheterization.

THE subclavian vein puncture technique was initially described and published by Aubaniac in 1952, and subclavian venous catheterization *via* an infraclavicular approach was performed for the first time in 1962 by Wilson and colleagues.¹ Performance of this procedure

ushered in the modern era of percutaneous central venous catheterization in medicine, especially in anesthesia, critical care, and surgery. Central venous catheters are commonly inserted for hemodynamic monitoring, volume monitoring, administration of medications, long-term total parenteral nutrition, access for renal replacement therapy, cardiopulmonary resuscitation, and difficult peripheral catheterization.²

Catheterization of the subclavian vein is viewed by physicians as a potentially dangerous procedure; in inexperienced hands, it can lead to life-threatening complications.^{3–6} Subclavian venous catheterization *via* the supraclavicular approach was first introduced to clinical practice by Yoffa in 1965.⁷ According to his original work, the supraclavicular approach is reliable, relatively safe, and easy to perform, especially by experienced hands. Unfortunately, the observations and opinions of Yoffa have not been uniformly confirmed, notwithstanding a few publications with significant number of catheterizations performed.^{8–15} Studies of supraclavicular approach complication rate in patients treated with positive pressure ventilation are lacking.¹⁶

The popularity of subclavian venous catheterization started to decline, especially in anesthesia, when the internal jugular route was popularized in the early 1970s and because of a fear of potential complications, mainly pneumothorax in patients treated with positive pressure ventilation.¹⁰ The primary outcome of our study was to define venipuncture, catheterization and entire procedure success rates, and the complication rate of subclavian venous catheterization *via* the supraclavicular approach with special focus on mechanically ventilated patients. The secondary outcome was to potentially make recommendations regarding this technique of central venous catheterization in mechanically ventilated patients.

Materials and Methods

The study was approved by the institutional review board (Komisja Bioetyczna przy Okręgowej Izbie Lekarskiej w Opolu, Opole, Poland). Informed consent was obtained from the patient or the patient's closest relative.

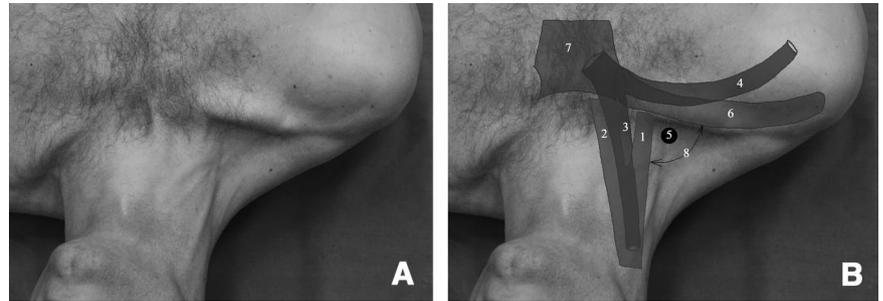
The methodology of this prospective cohort study included subclavian venous catheterization *via* the supraclavicular approach, according to the original de-

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Fig. 1. (A) Catheterization site. (B) Anatomical structures at the catheterization site: 1 = clavicular head of the clavicolosternocleidomastoid muscle; 2 = sternal head of the clavicolosternocleidomastoid muscle; 3 = internal jugular vein; 4 = subclavian vein; 5 = point of needle insertion; 6 = clavicle; 7 = sternum; 8 = clavicolosternocleidomastoid angle.



scriptions of Yoffa and Brahos.^{7,8} Before the procedure, the patient was placed in the Trendelenburg position to avoid an air embolus and to distend the subclavian vein. The patient's head was turned slightly to the contralateral side, and the arm was kept to the side. The mainstay of the supraclavicular technique has been the proper identification of the clavicular head of the sternocleidomastoid muscle. In obese conscious patients, the lateral border of the clavicolosternocleidomastoid muscle was identified by active elevation of the head (applying pressure to the muscle). After identification of the anatomical landmarks, wide preparation of the surgical field, including infraclavicular and jugular area sterilization, was performed. The skin was anesthetized with 2 ml of 1% lidocaine in conscious patients. The point of needle insertion was identified 1 cm cephalad and 1 cm lateral to the junction of the lateral margin of the clavicular head of the sternocleidomastoid muscle with the superior margin of the clavicle (clavicolosternocleidomastoid angle) (fig. 1). The direction of the needle was indicated by the line that bisects the clavicolosternocleidomastoid angle with elevation 5–15 degrees above the coronal plane. The needle was advanced slowly with a constant negative pressure in the syringe. The vein was usually punctured between the clavicle and the attachment of the anterior scalene muscle to the first rib. The finder needle was not used. The subclavian artery is situated posterior and slightly superior to the vein; if palpable, the pulse of the artery could be the important landmark.¹³ The dome of the pleura is located behind the artery and lateral to the site of needle insertion; with correct identification of anatomical structures, the risk of pleural injury could be minimized. After entering the subclavian vein, the Seldinger catheterization procedure was performed. The technique of cannulation was the same for both the right and left side, but the right clavicolosternocleidomastoid angle was the preferred catheterization site because of the absence of the thoracic duct and a more direct route of the subclavian and innominate veins on the right. The left side was chosen if contraindications to right side catheterization or an unsuccessful right side attempt occurred.

The depth of catheter insertion was 14 cm for right side and 18 cm for left side catheterization. Chest radiographs were obtained 2 h after the procedure or imme-

diately after the operation to confirm the proper position of the catheter and exclude potential complications. The catheter tip position on the chest radiograph was assessed by measuring the distance between the lower margin of the sternoclavicular joint and the tip of the catheter. All procedures were performed by the first three authors, each of whom had different levels of experience (Dr. Czarnik, lowest; Dr. Gawda, average; Dr. Perkowski, highest). Each physician had performed at least 20 procedures before starting the study.

The clinical indications for central venous catheterization were regarded as patient inclusion criteria for the study. The indications for catheterization in the study group were: craniotomy (n = 165), difficult peripheral cannulation (n = 56), coronary artery bypass grafting (n = 54), central venous pressure monitoring in critical care unit (n = 43), laparotomy (n = 24), cardiac valve replacement (n = 19), thoracotomy (n = 4), others (n = 5). Data collected included age, gender, weight, hospital number, side of cannulation, indication for central line placement, parameters of mechanical ventilation, depth of venipuncture, number of skin punctures, number of catheterization attempts, visibility of the clavicular head of the clavicolosternocleidomastoid muscle, the depth of the catheter tip position, and early complications. Patients with significant trauma or hematomas in the clavicolosternocleidomastoid angle or neck, a history of multiple central venous catheterizations (three or more), chest wall deformities, major blood coagulation disorders, a history of neck surgery, anatomical abnormalities and signs of infection at the catheterization site, and age less than 14 yr have been excluded.

The current study was conducted in the Department of Anesthesia and Critical Care of the Regional Medical Centre in Opole, Poland. The Regional Medical Centre in Opole is the main trauma center in the Opole region and serves a population of 1 million.

Statistical Analysis

Quantitative parameters are summarized in terms of means, medians, interquartile ranges (25th to 75th percentile), and ranges. The 95% confidence intervals (CI) for the event rates were computed by using the Clopper-Pearson method. The Pearson linear correlation coefficient was assessed to define the relationship between

Table 1. Descriptive Statistics of Patient and Measurement Characteristics

	Mean	Median	IQR	Range
Patient characteristic (n = 370)				
Age, yr	58.2	61.0	20.0	15.0–90.0
Height, cm	167.8	169.0	15.0	147.0–205.0
Weight, kg	73.8	72.5	15.0	39.0–150.0
ASA score	2.6	3.0	1.0	1.0–5.0
Measurement characteristic				
Number of venipuncture attempts (n = 362)	1.3	1.0	0.0	1.0–6.0
In terms of visibility of the clavicular head				
Invisible (n ₀ = 133)	1.5	1.0	1.0	1.0–5.0
Visible after applying pressure (n ₁ = 100)	1.2	1.0	0.0	1.0–4.0
Visible (n ₂ = 129)	1.2	1.0	0.0	1.0–6.0
In terms of venipuncture side				
Right (n ₀ = 297)	1.3	1.0	0.0	1.0–6.0
Left (n ₁ = 65)	1.4	1.0	1.0	1.0–5.0
Depth of venipuncture, cm (n = 362)	3.0	3.0	1.0	1.0–5.0
Depth of catheter tip location, cm (n = 319)	8.0	8.0	2.0	3.0–12.0
Number of catheterization attempts (n = 362)	1.1	1.0	0.0	1.0–3.0

ASA = American Society of Anesthesiologists classification of physical status; IQR = interquartile range (25th to 75th percentile).

the catheter tip position on the chest radiograph and the height of patients. The Spearman rank-order correlation was calculated to determine the correlation between the depth of the subclavian vein puncture, the height, and the weight. The Kruskal-Wallis test was performed to assess the relationship between the number of subclavian vein puncture attempts and the visibility of the clavicular head of the sternocleidomastoid muscle. The Mann-Whitney U test was used to assess the relationship between the number of subclavian vein puncture attempts and the cannulation side. The chi-square maximum likelihood test was used to determine the relationship between the successful catheterization attempt and the cannulation side and the relationships between the catheterization procedure success and the skill of the physician, the gender of the patient, the visibility of the clavicular head of the sternocleidomastoid muscle, and the catheterization circumstances (emergency or planned). The chi-square Pearson test was used to assess the relationship between catheterization procedure success and the cannulation side. Dependencies were regarded as significant with $P < 0.05$. All statistical calculations were performed using Statistica version 8.0 (StatSoft, Inc., Tulsa, OK).

Results

A total of 370 patients (165 women [44.6%] and 205 men [55.4%]) were enrolled in the trial. We performed 302 right-side (81.6%) and 68 left-side (18.4%) catheterization attempts. In 276 patients (74.6%), the catheterization procedure was performed under conditions of general anesthesia; 290 patients (78.4%) were mechanically ventilated at the time of the procedure. The tidal volume in these patients ranged between 380 and 900 ml, the peak inspiratory pressure ranged between 11 and

30 mmHg, and the positive end expiratory pressure ranged between 0 and 5 mmHg.

The descriptive statistics of patient and measurement characteristics are presented in table 1. In the majority of patients (292 [78.9%]), venipuncture occurred during the first attempt. The vein was not localized in only 8 patients (2.2%). More venipuncture attempts were required in patients with an invisible clavicular head of the sternocleidomastoid muscle (n₀ = 133) than in patients with visible after applying pressure (head elevation) (n₁ = 100) or visible (n₂ = 129) clavicular head ($P = 0.001$; Kruskal-Wallis test for three groups and n = 362 observations; table 1). The relationship between the number of venipuncture attempts and the cannulation side was not significant ($P = 0.350$; U Mann-Whitney test; n = 362). The overall venipuncture success rate was 97.8% (95% CI 95.8–99.1%; table 2 for summary). A positive correlation was observed between the venipuncture depth and the patient's height ($r = 0.12$; $P = 0.023$; Spearman rank-order test; n = 362) and weight ($r =$

Table 2. Summary of Main Results

	Event Rate (95% CI)
Venipuncture success rate (n = 370)	97.8% (95.8–99.1%)
In the first attempt	78.9% (74.4–83.0%)
Catheterization success rate (n = 362)	92.0% (88.7–94.6%)
In the first attempt	85.6% (81.6–89.1%)
Entire procedure success rate (n = 359)	88.9% (85.1–91.9%)
In terms of physician's experience	
Lowest (n ₀ = 187)	88.8% (83.1–92.8%)
Intermediate (n ₁ = 125)	86.4% (79.1–91.9%)
Highest (n ₂ = 47)	95.7% (85.5–99.5%)
In terms of visibility of the clavicular head	
Invisible (n ₀ = 135)	85.2% (78.1–90.7%)
Visible after applying pressure (n ₁ = 98)	92.9% (85.8–97.1%)
Visible (n ₂ = 126)	89.7% (83.0–94.4%)
Complication rate	1.7% (0.6–3.6%)

95% confidence intervals (CI) for the event rates are provided in parentheses.

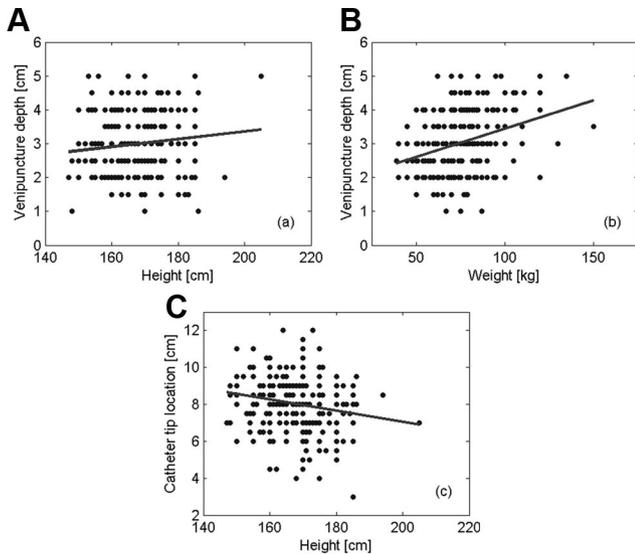


Fig. 2. Scatterplots of venipuncture depth versus patient (A) height and (B) weight and (C) catheter tip location versus height. Linear regression lines are superimposed on the plots indicating the dependence relations.

0.29; $P < 0.001$; Spearman rank-order test; $n = 362$). Pearson linear regression yielded nearly identical values ($r = 0.12$, $P = 0.025$; $r = 0.30$, $P < 0.001$, respectively). This dependence is visualized in panels a and b of figure 2.

Catheterization attempts were performed in 362 patients; 310 catheterizations (85.6%) were successful during the first attempt, 22 (6.1%) during the second attempt, and 1 (0.3%) during the third attempt. In 29 patients (8.0%), catheterization attempts were unsuccessful because of an inability to advance the guidewire; *i.e.*, the overall catheterization success rate was 92.0% (95% CI 88.7–94.6%). The relationship between the successful catheterization attempt and the cannulation side was not significant ($P = 0.424$; chi-square test; $n = 333$).

Successful subclavian venous catheterization *via* the supraclavicular approach procedure has been defined as proper catheterization without major or minor complications. Patients in whom a chest radiograph has not been done (11 [3%]) were excluded from the catheterization procedure success rate calculation. The catheter tip position on the chest radiograph has been assessed by measuring the distance between the lower margin of the sternoclavicular joint and the tip of the catheter; this distance ranged between 3.0 and 12.0 cm (median, 8.0 cm; interquartile range, 2.0 cm), and a negative correlation between the catheter tip position on the chest radiograph and the height of patients was observed ($r = -0.20$; $P < 0.001$, Pearson linear correlation coefficient; $n = 319$), see panel c of figure 2.

Three major (subclavian artery puncture; 0.8%) and three minor (contralateral subclavian vein catheterization; 0.8%) early complications were observed in the study. No life-threatening complications (tension pneumothorax, hydrothorax, hemothorax, cardiac perfora-

tion/tamponade, massive air embolism, major bleeding, and fatal arrhythmias) occurred in the study group. The overall subclavian venous catheterization *via* supraclavicular approach procedure complication rate reached 1.7% (95% CI 0.6–3.6%; $n = 359$). Late complications (central venous thrombosis and catheter-related infection) have not been studied.

Although the most experienced physician had the highest success rate, the dependencies between the physician's level of experience (Dr. Czarnik, lowest; Dr. Gawda, average; Dr. Perkowski, highest) and the procedure success rate (Dr. Czarnik = 88.8%, $n_{CT} = 187$; Dr. Gawda = 86.4%, $n_{GR} = 125$; Dr. Perkowski = 95.7%, $n_{PT} = 47$) were nonsignificant ($P = 0.166$; chi-square test; $n = 359$). The procedure success rate in the female and male groups reached 87.0% ($n = 162$) and 90.4% ($n = 197$), respectively, but the relationship between the gender and procedure success rate was not significant ($P = 0.166$; chi-square test; $n = 359$). The correlations between the procedure success rate and the visibility of the clavicular head of the sternocleidomastoid muscle (invisible 85.2%, $n_0 = 135$; visible after applying pressure 92.9%, $n_1 = 98$; visible 89.7%, $n_2 = 126$), the cannulation side (right 89.7%, $n_0 = 292$; left 85.1%, $n_1 = 67$), and the procedure circumstances (emergency 89.0%, $n_0 = 310$; planned 87.8%, $n_1 = 49$) were also not significant ($P = 0.168$, $P = 0.275$, and $P = 0.794$, respectively; chi-square test; $n = 359$). The overall subclavian venous catheterization *via* the supraclavicular approach procedure success rate reached 88.9% (95% CI 85.1–91.9%; $n = 359$). The summary of correlation tests is presented in table 3.

Discussion

Most central venous catheters in mechanically ventilated anesthesia patients are inserted *via* the right internal jugular route when clinical indications exist.^{6,8,10,17} The high jugular approach is recognized by most physicians as the safest. The most frequent complication is arterial puncture (0.6–30%; commonly, 1–5%), whereas the pneumothorax rate is very low (0.2–1.3%) and is usually caused by a catheterization performed too close to the clavicle. The jugular catheterization success rate (successful catheter placement) is estimated to be 90–99%, with a low rate of malposition.^{2,17,18}

Subclavian catheter placement *via* an infraclavicular approach success rate is 80–95% and occurs mainly during the first attempt in most studies.¹⁸ The major complication rate for subclavian catheterization is 1–5%, whereas the overall complication rate ranges between 1 and 10%. The pneumothorax rate ranged between 0 and 5% (average overall incidence, 1–2%), whereas the pneumothorax rate for experienced physicians (more than 50 procedures performed) has been reported to be 0–0.5%.^{18–22} Subclavian artery puncture appears in 0.5–

Table 3. Summary of Correlation Tests

	Procedure Success Rate	Venipuncture Depth
Visibility of the clavicular head of the sternocleidomastoid muscle	Not significant; $P = 0.168$	
Catheterization side	Not significant; $P = 0.275$	
Procedure circumstances	Not significant; $P = 0.794$	
Gender	Not significant; $P = 0.166$	
Physician's level of experience	Not significant; $P = 0.166$	
Height		
Spearman rank-order		Positive ($r = 0.12$); $P = 0.023$
Pearson linear regression		Positive ($r = 0.12$); $P = 0.025$
Weight		
Spearman rank-order		Positive ($r = 0.29$); $P < 0.001$
Pearson linear regression		Positive ($r = 0.30$); $P < 0.001$

7.8% of cases, and catheter malposition rate reached 5–20%.^{18–22} Successful venipuncture on the first attempt rate is estimated to be 64.2%.³

Subclavian venous catheterization *via* the supraclavicular approach success rate has been estimated to be from 74 to 98% and has been estimated at 80% during the first attempt, with significant complication rates (pneumothorax and arterial puncture) from 0.56% to 2% of cases.^{7–16,21} The reported results are comparable to the results reported herein, *i.e.*, venipuncture during the first attempt (78.9%; 95% CI 74.4–83.0%), overall catheterization success rate (92%; 95% CI 88.7–94.6%), significant complication rate (arterial puncture 0.8%; catheter malposition rate 0.8%; in total 1.7%, 95% CI 0.6–3.6%). We have introduced in our study a new index of overall subclavian venous catheterization *via* the supraclavicular approach procedure success rate (not described in previous studies) defined as proper catheterization without major and minor complications (88.9% in our series; 95% CI 85.1–91.9%), which better reflects the overall procedure success rate. The comparison of complication and success rates of different approaches is presented in table 4.

Efficiency of catheterization of the internal jugular vein and subclavian vein *via* infraclavicular approach under two-dimensional ultrasound guidance is well documented.²³ Ultrasound guidance reduces technical failure and complication rates compared to the landmark method. Data regarding ultrasound guidance in supraclavicular approach are lacking. This technique seems to be effective in special circumstances (morbid obesity, first attempt failure, anomalies in anatomy, multiple catheterizations,

coagulation disorders), but clinical studies are needed. Because of short distance from the skin to the subclavian vein in supraclavicular approach it seems that two-dimensional ultrasound guidance technique should not be the routine in clinical practice but rather alternative method in difficult cases.

In conclusion, subclavian venous catheterization *via* the supraclavicular approach is an excellent method of central venous access in anesthesia. The procedure success rate and the significant complication rate are comparable to other techniques of central venous catheterization, especially to jugular access, which is regarded by most physicians as the safest one. Mechanical ventilation is not a risk factor associated with significant complications. The supraclavicular approach should be considered, especially in neuroanesthesia, where the right jugular approach could be associated with cerebral perfusion pressure reduction, intracranial pressure elevation, and venous stasis.²⁴ The supraclavicular approach seems to be more comfortable than the jugular approach in a conscious patient. This method can be successfully and relatively safely used as a primary or alternative technique when other catheterization sites are not available to augment the spectrum of catheterization possibilities, even in mechanically ventilated patients.

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Table 4. Complication and Success Rates of Different Approaches

	CS, % (95% CI)	SCA, %	ICA, %	IJA, %
Complication	1.7 (0.6–3.6)	0.56–2*	1–10†	1–5‡
Catheterization success rate	92 (88.7–94.6)	74–98*	80–95†	90–99‡

* References 7–16,21. † References 18–22. ‡ References 2,17,18.

CS = current study; ICA = infraclavicular approach; IJA = internal jugular approach; SCA = supraclavicular approach.

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