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Risk factors for inadvertent arterial puncture during subclavian vein catheterization

Y.-H. ZHOU[1], W.-S. JIANG[1], J.-W. SHAO[1], W.-J. ZHOU[1], H.-Q. SHENG[1], T. SHEN[2], E.-Q. MAO[1], Y.-H. WANG[1]

[1]Department of Emergency Medicine, Rui Jin Hospital, Shanghai Jiao Tong University School of Medicine, Shanghai, China
[2]School of Public Health, Shanghai Jiao Tong University, Shanghai, China

Abstract. – OBJECTIVE: Central vein catheterizations facilitate the establishment of reliable venous pathways in emergent medical situations. The subclavian is an important vein for central venous catheterizations. But, inadvertent arterial punctures during subclavian vein catheterizations are more dangerous than those during jugular or femoral vein catheterizations, because of the lack of a reliable compression site. We aimed to identify risk factors for the occurrence of inadvertent arterial puncture during subclavian vein catheterizations in crowded emergency rooms.

PATIENTS AND METHODS: We evaluated 190 patients undergoing bedside subclavian vein catheterizations in our emergency room, from which 62 patients experienced inadvertent arterial punctures. We evaluated possible risk factors from basic physical or laboratory tests that can easily be obtained in the ER, and performed Chi-square test, Kruskal-Wallis ANOVA, non-conditional logistic regression analysis, and receiver-operating characteristic curves to determine the cut-off values of the identified risk factors.

RESULTS: We identified age, BMI, and serum pre-albumin level as significant risk factors for inadvertent arterial puncture during subclavian vein catheterization ($p<0.05$) through regression analyses (odds ratios of 1.043, 0.719 and 0.989; and receiver-operating characteristic curves with AUCs of 0.741, 0.818, and 0.717, respectively). The cut-off values for age, BMI and serum pre-albumin level were 66.5 years old, 21.12 and 109.5 mg/L, respectively.

CONCLUSIONS: We found that patients with poor nutritional status (BMI <21.12 and serum pre-albumin <109.5 mg/L) or older than 69.5 years tended to experience more accidental arterial punctures during subclavian vein catheterizations, probably due to atrophy or diminished peri-vascular support tissues in patients with poor nutritional statuses that make it difficult to obtain adequate chest extensions.

Key Words:
Subclavian vein, Inadvertent arterial puncture, Risk factors, Central vein catheterization.

Abbreviations

CVCs: Central vein catheterizations; MAP: mean arterial pressure; BMI: body mass index; HB: blood hemoglobin; ROC: receiver-operating characteristic curves.

Introduction

Central vein catheterizations (CVCs) are an essential technique for establishing a reliable venous pathway for fluid resuscitation, anti-shock therapy, maintenance of hemodynamic stability, and drug administrations[1-4]. Three anatomic sites including the subclavian, internal jugular, and femoral veins are frequently selected for catheterization. Compared with the internal jugular and femoral veins, we usually choose the subclavian vein in our department. The subclavian access site offers advantages when compared to other access sites, like lower occurrence of thrombosis and infectious complications, better patient comfort, and patency in hypovolemic states[5-8]. However, the subclavian access is not without complications. Mechanical complications, like arterial puncture, hematoma, pneumothorax, and hemothorax, have been reported to be more common with this access route than with others[9].

Inadvertent arterial punctures are a common mechanical complication during CVC placements. A subclavian artery puncture is usually treated by a simple tube removal due to the lack of compressible anatomical sites near the puncture site, but severe consequences can ensue if uncontrollable arterial bleeding occurs[10-12]. Acute hemorrhages and hemothorax are the most common complications following arterial puncture, and they can become severe in the presence of coagulopathy[13]. In most cases, these complications are controllable because of normal vessel wall tension. However, prolonged operating times and pa-

Corresponding Author: Yihui Wang, MD; e-mail: wyh11902@rjh.com.cn

tient discomfort from the puncture are inevitable and may cause the delay of other treatments. The execution of the procedure has been improved under ultrasound guidance, but no studies have compared outcomes of ultrasound-guided subclavian catheterizations with those of jugular and femoral catheterizations, and sometimes mispunctures occur even under ultrasound guidance[14,15]. In addition, ultrasound devices can be inaccessible in the crowded ERs common in China, and anatomical landmark-guided punctures are the only available option for catheterizations.

We hypothesized that unintended arterial punctures are more common in patients with obesity and in those with unstable hemodynamic parameters because determining the pulse position and identifying suitable anatomical landmarks in them is harder than in other patients. In our clinical practice, we have encountered similar problems when accessing jugular and femoral sites. In a supine position, the subclavian artery may mask the vein in patients with low body weight regardless of their hemodynamic status. In other words, subclavian catheterization in malnourished patients is likely to fail even if they have a clear bony mark; moreover, this situation does not improve under ultrasonic guidance. The high incidence of arterial punctures in thin patients in our ER has attracted our attention. Low BMI and clear bony landmarks are usually indicative of easy jugular and femoral accesses but represent obstacles to the insertion of subclavian catheters. As a result, the subclavian vein is most commonly catheterized in our ER. Potential risk factors that can be screened from ER medical records or that are readily available from routine blood or biochemical tests need to be identified to optimize catheterization strategies for different ER patients regardless of whether operations are performed under ultrasonic guidance or not.

Patients and Methods

Ethics Statement

The Ethics Committee of our hospital approved this study. All patients undergoing conventional subclavian catheterization in our ER and EICU signed formal consent forms for the invasive procedure detailing its purpose, methods, benefits, and risks. The indications for central catheterization were thoroughly evaluated. Therefore, the enrolled patients had clear catheterization indications due to their clinical conditions. Only well-trained operators conducted all the procedures in accordance with the standard guidelines for central venous catheterization. We obtained all laboratory data discussed in this article after admission, on the basis of appropriate indications in ER. We only obtained relevant information from medical records and laboratory results for our analysis, keeping identifying patient information or adjustments in clinical treatments out from the collected data.

Patient Enrollment and Study Design

We used records from 190 patients seen from January 2015 to January 2018. We performed all operations at the bedside in our resuscitation room at the Rui Jin hospital. We discussed indications to avoid unnecessary invasive operations before the procedure. All the patients enrolled received clinical interventions such as fluid resuscitation, hypertonic drug injection, parenteral nutrition, and vasoactive agent administration as necessary. All patients undergoing catheterizations were conscious and cooperated with the operators during the puncture. We did not enroll patients under general anesthesia and supportive mechanical ventilation or those with psychiatric illnesses. Among all the patients, 62 patients with inadvertent subclavian artery punctures were classified as positive regardless of whether the arterial puncture resulted in a failed catheter insertion or in a prolonged operative time. The other patients with successful catheter insertions and without arterial involvement were assigned to the control group if they met the inclusion criteria (n = 126). We divided the data into three categories according to medical history, hemodynamic, and nutritional statuses for comparison. We evaluated eight clinical features (gender, age, heart rate, mean arterial pressure [MAP], body mass index [BMI], serum albumin, serum pre-albumin, and blood hemoglobin [HB]) as possible risk factors for inadvertent arterial puncture during subclavian vein catheterization. We collected all information at catheter insertion and blood samples less than one hour before the operation. Although other advanced parameters may be more appropriate for catheter optimization, we chose to study only those available under crowded emergency room conditions.

Statistical Analysis

To determine differences between the selected variables in the two groups, we used a Pearson chi-squared test and Kruskal-Wallis ANOVA.

Table I. Clinical characteristics of the study group according to the occurrence of inadvertent subclavian artery puncture.

	Total	Artery punctured		*p*-value
		+ (n=62)	– (n=128)	
Male gender	118 (62.1%)	41 (66.1%)	77 (60.2%)	0.426
Mean age, years	64.0 (46.0-81.0)	83.0 (62.2-87.0)	59.0 (41.0-69.5)	<0.001*
BMI, kg/m^2	22.2 (19.7-26.4)	18.9 (17.6-21.4)	24.2 (21.5-27.4)	<0.001*
HR, beat/min	98.0 (80.0-112.8)	90.0 (80.0-110.0)	100.0 (81.5-115.0)	0.099
MAP, mmHg	95.8 (85.4-106.2)	94.3 (85.7-106.0)	97.0 (85.6-106.4)	0.993
Pre-albumin, mg/L	127.0 (89.0-180.0)	100.0 (68.5-129.5)	139.5 (109.8-200.0)	<0.001*
Albumin, g/L	30.0 (25.0-34.0)	26.5 (22.2-29.0)	31.5 (27.0-35.0)	<0.001*
Hemoglobin, g/L	105.0 (90.0-124.0)	97.0 (84.2-120.8)	107.0 (92.0-126.2)	0.024*

BMI, body mass index; HR, heart rate; MAP, mean arterial pressure. Categorical variables presented as n (%), number, and percentage; continuous variables presented as medians (Q1; Q3), Q1, lower quartiles; Q3, upper quartiles; p-value is reported for comparison between two groups (in Pearson chi-squared test or Kruskal-Wallis ANOVA).

In addition $p<0.05$, and the Chi square test, and Kruskal-Wallis ANOVA could not determine the independent correlations and the significance of each value[16,17]. Moreover, we calculated receiver-operating characteristic curves (ROC) to evaluate the sensitivity and specificity of the factors identified by logistic regression and calculated their cut-off values to define factor thresholds indicating an increased risk of experiencing inadvertent arterial punctures[18-20]. We performed all statistical tests using the SPSS 19 (IBM, Armonk, NY, USA) software, and considered *p*-values <0.05 as statistically significant for all results.

Results

We analyzed data from 190 patients in our study; the male-to-female ratio in the study cohort was 118/72. We recorded clinical information data from 62 patients, who experienced inadvertent arterial punctures during subclavian vein intubation. Among these patients, although the location of the subclavian vein was confirmed, most artery punctures occurred during the first catheterization attempt and only 2 patients' arteries were punctured after a repeated attempt. We divided all enrolled patients into two groups according to the occurrence of inadvertent arterial puncture and performed a two-step statistical analysis. First, we compared all data separately: we compared the incidence of arterial puncture between men and women using a quadruple chi-square test and found non-significant differences (Table I). We compared other variables (age, BMI, MAP, HB, albumin and pre-albumin levels) using a Kruskal-Wallis ANOVA and found significant differences in terms of age, BMI, and pre-albumin level between the two groups (Table I). Second, in order to determine and describe the association between the selected data and the occurrence of arterial puncture, we applied an unconditional logistic regression analysis to confirm the results of the first analysis. We observed that age, BMI, and pre-albumin level were significantly different between the groups with *p*-values <0.001, <0.001, and =0.003, respectively (Table II). The odds ratios were 1.043, 0.719 and 0.989, respectively. We included these three factors in the regression formula and excluded the hemodynamic-related factors (MAP, heart rate and blood pressure). Thus, we included variables showing significant differences in both chi-square and Kruskal-Wallis ANOVA in the logistic regression equation (low BMI, low pre-albumin levels, and old age).

Moreover, we used receiver-operating characteristic curves (ROC) to analyze the sensitivity and specificity of age, BMI and pre-albumin as potential risk factor for inadvertent artery punctures. Figure 1 shows the ROCs of age, BMI and pre-albumin. BMI had an AUC of 0.818 and a cut-off value of 21.12; age had an AUC of 0.741 and a cut-off value of 69.5 years old; and pre-albumin had an AUC 0.717 and a cut-off value of 109.5 mg/L.

Discussion

In the ER, CVC is routinely performed in patients with severe pathological conditions[1,21]. Compared with jugular and femoral vein punc-

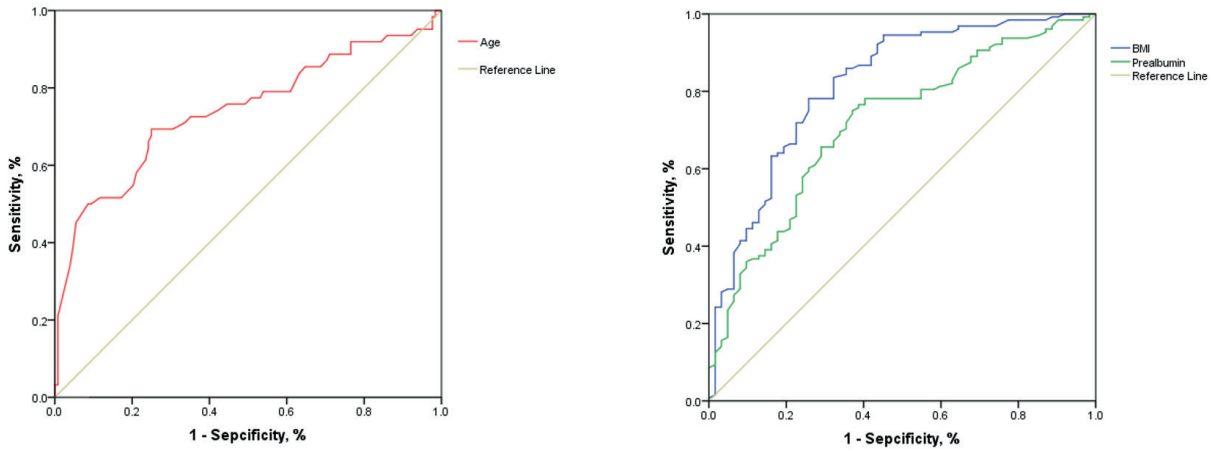

Figure 1. Receiver-operating characteristic curves of the age, BMI, and pre-albumin level in prediction of arterial punctures. Age AUC = 0.741 (cut-off value, 69.5 years). BMI AUC = 0.818 (cut-off value, 21.12). Pre-albumin AUC = 0.717 (cut-off value, 109.5 mg/L).

ture sites, we prefer the subclavian vein catheterization in our department due to its lower rate of vascular position variability, relatively fixed puncture site, and stable vascular filling status[7,22]. However, patients with a thin body often present a difficult access, which may lead to arterial puncture and possibly severe consequences[7,23,24]. Based on our practice we hypothesized that patients with chronic wasting diseases or poor nutrition are more likely to experience unintentional arterial punctures than those who are overweight. In these patients, a central vein seems to be a reliable method for drug administration, but the possibility of serious acute complications needs to be considered.

Thus, we designed this study to determine the correlation between the nutritional/hemodynamic status and the occurrence of unintended arterial puncture and identify risk factors that need to be considered during the preoperative evaluation for subclavian vein catheterizations. We tested variables that are "readily available after a quick glance" by physicians in the ER like BMI, hemoglobin concentration, HR, MAP, serum pre-albumin, and albumin levels. The CVC outcomes are significantly influenced by the hemodynamic status[21,25].

We calculated the statistical parameter sets between the two groups using a *t*-test in two independent samples. Our results showed that patients who experienced unintended arterial punctures were of older age, and had low BMIs, low serum pre-albumin, or low albumin levels. Conversely, we found similar hemodynamic parameters in both groups of patients ($p>0.05$). The influence of age, BMI and serum pre-albumin remained sig-

Table II. Logistic regression analysis of high-risk factors for inadvertent subclavian artery punctures.

	univariate			multivariate		
	OR	95% CI	*p*-value	OR	95% CI	*p*-value
Male gender	1.293	0.686-2.437	0.427			
Mean age, years	1.043	1.025-1.062	<0.001*	1.027	1.008-1.046	0.005*
BMI, kg/m^2	0.719	0.644-0.804	<0.001*	0.770	0.687-0.863	<0.001*
HR, beat/min	0.986	0.971-1.001	0.066			
MAP, mmHg	0.999	0.981-1.018	0.927			
Pre-albumin, mg/L	0.989	0.982-0.996	0.003*	0.992	0.986-0.999	0.019*
Albumin, g/L	0.951	0.891-1.015	0.133			
Hemoglobin, g/L	0.995	0.982-1.009	0.491			

BMI, body mass Index; HR, heart rate; MAP, mean arterial pressure. Categorical variables presented as n (%), number and percentage.

nificant after selection by Wald Forward according to the logistic regression analysis. These data indicate that the arterial puncture rate increases with older age and lower BMI and serum pre-albumin values. In addition, the OR values (0.742) for BMI suggest a close association to the occurrence of inadvertent arterial puncture during a subclavian vein catheterization, and that it is the most important independent risk factor, independently of the influence of the hemodynamic status.

Our ROC analysis disclosed the sensitivity and specificity of the risk factors (age, BMI, and pre-albumin). BMI had the largest AUC in the ROC analysis, and this suggests it may be a good screening parameter to prevent puncturing the artery inadvertently in patients with a BMI below 21.12. Age and pre-albumin are both two other important factors increasing the risk of inadvertent artery puncture in patients over 69.5 years old and in those with low serum pre-albumin levels (<109.5 mg/L).

We think the increased risks may be explained by different mechanisms: The degeneration of intervertebral and shoulder joints that are common in elderly patients, make it difficult to achieve full chest extension, leaving the subclavian vein unexposed. Also, a chronic nutritional deficiency status results in atrophy or reduction of the perivascular supportive tissue, contributing to displacement of the subclavian vein[26].

According to the OR and AUC in ROC values, BMI (OR=0.749, AUC=0.818) is the most important risk factor for unintended arterial punctures during subclavian vein catheterization. BMIs help classify individuals as being underweight, normal weight, overweight, or obese[27]. In the emergency room, the BMI is suitable for urgent preoperative risk assessments. Age, another valuable variable for pre-operation evaluation (OR = 1.027, AUC = 0.741), is also an easily obtained factor during an initial examination. The pre-albumin level also showed meaningful OR values in our logistic regression analysis. However, the non-significant albumin levels in either the *t*-test or regression analysis were not reliable values for predicting the risk of arterial puncture. Unlike the prealbumin level (a stable marker of chronic nutritional status), the albumin level is greatly influenced by many factors, such as recent dietary habits, intravenous drug administration, and blood or plasma transfusions[28-30]. The prealbumin level is obtained with the advanced blood biochemical examination that is usually ordered for the patients in the ward.

Unlike the jugular and femoral veins located on the posterior or anterior side of their corresponding arteries, the subclavian vein cannot be localized by feeling the arterial pulse, and it is more difficult to find during catheterizations. In addition, the lack of a compression site to prevent hemorrhage, means repeated attempts may lead to deterioration of the patient's condition, especially in the presence of coagulopathy.

In all, despite the risk of acute complications, the subclavian vein is chosen for catheterization in many patients, especially in those with hemodynamic instability. Our results disclose that under the limited ER or resuscitation room conditions, low BMI (<21.12) and old age (>69.5) are risk factors for inadvertent puncture during subclavian vein catheterizations and alternative catheterization sites should be considered under those circumstances. Our data also suggest that the low serum prealbumin is a risk factor for patients in ward and that the subclavian pathway should also be avoided in those patients. Finally, age, BMI, and serum prealbumin are risk factors for inadvertent arterial puncture during subclavian vein catheterization performed under ultrasonic guidance or without it. We are aware of our study's limitations. Our study population had a relatively low number of patients with successful subclavian vein catheterizations, although the total number of patients with successful catheterizations in our ER was higher. We only enrolled 190 patients with complete clinical data. Larger researches will be needed to confirm our conclusions.

The novelties of our study also need to be highlighted. Our results present clinically relevant data for identification of risk of inadvertent subclavian arterial punctures in settings where ultrasonic guidance may not be available. Our data may help clinicians working in overcrowded and austere conditions in identifying high-risk patients for this complication.

Conclusions

Overall, our results indicate that elderly or malnourished patients are more likely to experience unintended artery punctures when undergoing a subclavian catheterization. In the ER practice, recognizing these risks in a particular patient is as simple as looking at the physical appearance of the patient.

Ethics approval and consent to participate

All procedures performed in studies involving human participants were in accordance with the ethical standards of the Ethics Committee of Rui Jin Hospital, Shanghai Jiao Tong University School of Medicine and the 1964 Helsinki declaration and its later amendments or comparable ethical standards. All of the data were obtained from patient records. Formal consent was not required.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Conflict of Interest

The Authors declare that they have no conflict of interests.

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Authors' contributions

YW, WJ and YZ designed the project; JS, EM and WZ were involved in data collection and data analysis; HS and TS prepare the manuscript; YZ edited the manuscript; all authors read and approved the final manuscript.

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