Incidence of posterior vessel wall puncture during ultrasound guided vascular access: Short axis versus long axis approach

Niraj Kumar, Ashish Bindra, Gyaninder Pal Singh, Keshav Goyal, Arvind Chaturvedi, Naveen Yadav¹, Arun Kumar Yadav²

Department of Neuroanesthesiology and Critical Care, All India Institute of Medical Sciences, New Delhi, India, ¹Trainee Medical Officer, Mount Gambier Hospital, Adelaide, Australia, ²Department of Community Medicine, Armed Forces Medical College, Pune, Maharashtra, India

Abstract

Background and Aims: Posterior vessel wall puncture (PVWP) is a common complication of ultrasound (US) guided central venous cannulation. We evaluated and compared the frequency of PVWP of internal jugular vein using short axis (SA) and long axis (LA) approach of US-guided needle cannulation. As a secondary objective incidence of carotid puncture was assessed.

Material and Methods: Prospective, single-blinded, cross over, observational study at Urban Level I Neuroanesthesiology and Critical Care Department. Residents receiving standard education on ultrasound-guided central venous cannulation were asked to place an US-guided catheter using either short axis or long axis approach on a human torso mannequin. During the procedure, the path of the needle was carefully observed by the investigator for any PVWP and carotid puncture without interference with the placement procedure. The confidence level of the resident for the intraluminal placement of the needle tip was measured on a 10-point Likert scale.

Results: Forty residents participated in the study. The incidence of PVWP in SA and LA group was 40% and 17.5% respectively and was statistically significant (p = 0.026). There was no incidence of carotid artery puncture in either of the group. The mean confidence of intraluminal placement of needle was significantly higher in the LA group (8.32) as compared to the SA group (5.95).

Conclusion: Lower incidence of PVWP was seen in LA as compared to the SA approach during US-guided IJV cannulation in phantom in residents having previous experience of CVC (central venous cannulation) in landmark technique only. Participants were more confident about intraluminal needle placement in the LA group compared to the SA group.

Keywords: Central venous cannulation, long axis view, posterior vessel wall penetration, short axis view, ultrasound guided catheter placement

Introduction

Central venous cannulation (CVC) is a vital and frequently done procedure in the operating and emergency rooms as well as intensive care units.[1] The most popular and preferred site for CVC is the right internal jugular vein (IJV) due to a relatively straight course, low incidence of thrombosis, and easy compressibility.[2] Multiple studies have reported that Ultrasound (US) guided CVC improves success and decreases complication rate compared to landmark-based technique.[3,4] Although the US decreases the complication rate significantly, it does not eliminate it.[5] US-guided CVC can be done using a short-axis (SA) or long axis (LA) approach. There are advantages and disadvantages to each...
approach. In the SA approach, both artery and vein can be visualized simultaneously, but the entire shaft and the tip of the needle cannot be seen [Figure 1]. Lack of visualization of the needle tip can result in posterior vessel wall puncture (PVWP) and injury to other vital structures underneath. In the LA approach needle is inserted in the plane of the transducer and the whole shaft and tip of the needle can be seen [Figure 2]. The superiority of one approach over the other is debatable.

We assumed, since the entire needle length can be visualized during CVC using the LA approach, it should be associated with a lower incidence of PVWP as compared to the SA approach. The objective of this study is to measure the incidence of PVWP during US-guided CVC in phantom and to compare its incidence between SA and LA approach. We also measured the incidence of carotid puncture and the level of confidence of residents for intraluminal placement of needle tip on a 10-point Likert scale.

**Material and Methods**

Institute Ethics Committee Approval Number and Date: IEC/NP -322/07-08-2015. It was a prospective, randomized, crossover study to compare the incidence of PVWP between SA and LA approach during US-guided CVC in a human torso phantom model (Blue Phantom, CAE Healthcare, USA). The study was conducted at Department of Neuroanesthesiology and Critical Care, All India Institute of Medical Sciences, New Delhi, India. Forty participants were enrolled for this study. Participants (anesthesia residents) having previous experience of CVC with the landmark technique only participated in the study. Written consent was obtained from the participants. Residents not willing to participate in the study were excluded. All participants received standard education on US-guided CVC consisting of a one-hour lecture and an additional 15-minute didactic hands-on training for both SA and LA approach on commercially available simulators within a week of enrolment in the study. The participants were evaluated by the investigator with more than three years of experience in the field of US-guided CVC and had performed more than 200 US-guided vascular access procedures.

Forty participants were randomized into two groups of 20 each, using a computer-generated randomization table. Group SA, used SA followed by LA approach, and Group LA, used LA followed by SA approach for right IJV cannulation in a phantom torso. Participants were not allowed to observe the procedure performed by others during the conduct of the study. Subjects were unaware of study objectives and data being recorded by the observer during the procedural session. US images were obtained using a 6-12-MHz linear array transducer (Sonosite M-turbo, Fujifilm). Investigator carefully observed and followed the path of the needle during US-guided cannulation by participants and recorded the occurrence of PVWP and carotid artery puncture during the procedure. Participants were asked to feed a guidewire and the incidence of PVWP was again noted during insertion of the guidewire through the needle. Investigator also confirmed the final intra or extra-luminal position of the guidewire with US machine. Successful IJV cannulation was defined as the passage of introducer needle into the target vein and aspiration of colored (blue) fluid into the syringe. One of the investigators filled the standard data collection sheet during the procedure session and recorded the occurrence of PVWP, carotid artery puncture, and confidence level of residents for intraluminal placement of needle tip at the end of the procedure.
The primary outcome was to see the incidence of PVWP which was defined as posterior wall penetration by the needle after penetrating the anterior wall of the vessel once. The absence of guidewire in IJV as confirmed by the investigator with the US at the end of the procedure was also considered as PVWP. The secondary outcome was to see the incidence of carotid artery puncture and confidence level of resident for intraluminal placement of needle tip. The confidence level was measured on a 10-point Likert scale; with one being the lowest and 10 the highest score. Sample size calculation was based on the study by Blaivas and Adhikari[6], in which the incidence of PVWP was 64% during the SA approach of US-guide IJV cannulation. Thirty-eight subjects (seventy-six cannulations) were needed for an alpha error of 5%, power of 80% and to detect a 33% difference in PVWP between the SA and LA groups. The continuous data were presented as mean and standard deviation (SD). The categorical data were presented as numbers and percentages. The "t" test was used to compare mean of two groups. A Chi-square test was used for the categorical variables. The data were analyzed using STATA software version 13/IC. The P value of less than 0.05 was considered significant.

Results

Forty Anesthesia residents were enrolled in the study. Each resident performed cannulation in both the axis successfully. There was an equal distribution of participants and their previous cannulation attempts in both the groups (SA and LA). The consort flow diagram of the study is shown in Figure 3.

The difference in the mean number of previous lines inserted by the residents was not significant between both the groups.

The internal jugular vein was successfully cannulated in all the 80 procedures done by 40 participants.

The incidence of PVWP was 40% (16 out of 40) and 17.5% (7 out of 40), in SA and LA group respectively, and was statistically significant (p = 0.026). [Figure 3]. There was no incidence of carotid artery puncture in either group. The mean confidence score for intraluminal needle placement was 5.95 ± 2.18 (95% CI; 5.25-6.64) and 8.32 ± 1.62 (95% CI; 7.80-8.84) in SA and LA group respectively.

The difference of mean of 2.37 (95% CI; 3.23-1.51) for the confidence score was statistically significant (P-value < 0.001) [Figure 4].

Discussion

CVC using Seldinger’s technique (i.e. catheter-over-the guidewire) is a commonly done procedure in operating rooms as well as other critical care areas. The common sites include IJV, subclavian vein, and femoral veins.

IJV is a preferred site by clinicians.[2] Traditionally CVC was done blindly using anatomical landmark and palpation method. With the advent of the US, several studies reported a higher success rate and decreased arterial puncture with US-guided CVC as compared to traditional methods.[1,3,4,10‑13] However, the US also has its limitation and one such is the occurrence of PVWP. Srinivasan et al. in a randomized study compared the US versus anatomical landmark guided IJV cannulation using the SA approach. They found that US reduced the incidence of PVWP (through-and-through puncture) but was not able to eliminate it. An incidence of up to 46% and 21% have been reported in their study on patients in whom CVC was done using anatomical landmark approach and US-guided approach, respectively.[14] In a gelatine-based US
model, an overall incidence of PVWP was 34%.\textsuperscript{[5]} PVWP continues to be a reported complication during US-guided CVC.\textsuperscript{[6]} Blaivas \textit{et al}. reported a 64% incidence of PVWP during IJV cannulation in a simulator using the SA view.\textsuperscript{[5,6]} Thereafter studies have been undertaken using SA, LA, and oblique view for US-guided CVC.\textsuperscript{[15]} However, the approach commonly used by a novice is either SA (Out-of-plane technique) or LA (In-plane technique) for vessel visualization and puncture. Whereas the SA approach is considered an easier and faster approach to CVC wherein both artery and vein can be visualized simultaneously, but the entire shaft and the needle tip cannot be seen.\textsuperscript{[5,6,15]} The needle is seen as a single dot which is the part of the needle crossed by the US beam. In LA approach needle is inserted along the plane of the transducer and the whole shaft and tip of the needle can be seen.\textsuperscript{[7,8,16,17]} The major disadvantage of the LA approach is that both artery and the vein cannot be seen simultaneously, hence the operator must be sure that the vessel in the US image in the vein before making a cannulation attempt. The superiority of one view over others is still debatable. Hence, we studied the incidence of PVWP and confidence levels of novice US users during the US-guided CVC using both LA and SA approach on a mannequin.

We found a higher incidence of PVWP with SA as compared to the LA approach for US-guided IJV cannulation by novice US users in a phantom. There was no incidence of carotid artery puncture in either group, which is otherwise expected to be high in the LA view. Though literature mentions that the SA approach is easier to learn for physicians not familiar with the US, in our study we found higher confidence for intraluminal placement of needle by a novice using the LA approach. Though we did not measure the time taken for CVC in both the groups. While comparing SA with LA approaches for IJV cannulation by experienced anesthetist Chittodon \textit{et al}. found a higher first-pass success rate and lesser carotid artery puncture by SA approach as compared to LA approach.\textsuperscript{[18]} Blaivas \textit{et al}. found faster cannulation with the SA approach compared to the LA approach in novice US users on an inanimate model of peripheral venous access.\textsuperscript{[19]} However, it was difficult to see the needle tip in the SA approach. In a vascular access phantom model, Stone \textit{et al}. found that the LA approach was associated with increased visibility of needle tip at the time of venepuncture as compared to the SA approach.\textsuperscript{[17]} Lack of visualization of the needle tip can result in PVWP and injury to other vital structures. In a leaf-like vascular access model, Blaivas and Adhikari found 64% of the residents accidentally penetrated PVW during the simulated SA approach of USG-guided IJV cannulation. In 20% of the cases, the carotid artery was accidentally penetrated.\textsuperscript{[6]} They suggested the LA approach is better for visualization of the needle tip and avoids procedure-related complications. Vogel \textit{et al}. also demonstrated the superiority of the LA approach in terms of fewer redirection and lesser PVWPs during subclavian vein cannulations.\textsuperscript{[21]} During US-guided IJV cannulations, Rath \textit{et al} found lower rate of complications with LA as compared to the SA approach.\textsuperscript{[20]} Watanabe \textit{et al} suggested a shallow angle approach for reducing posterior wall injuries while performing US-guided CVC using SA approach.\textsuperscript{[21]} In a manikin study Takeshita \textit{et al} found that combined SA – and LA approach significantly increased the success rate as compared to SA approach during US-guided IJV cannulations.\textsuperscript{[22]} However, few authors were not able to detect any difference in PVWP with either approach.\textsuperscript{[5]}

Our study clearly shows a lesser incidence of PCWP and a higher confidence level for intraluminal needle placement while using the LA approach. Our study was aimed at determining the incidence of PVWP and carotid puncture only. The mannequin model used allowed the most realistic simulation for performing US-guided CVC cannulation. Using a single model in which position of the IJV and carotid artery is fixed offers a similar level of difficulties to all the participants thus contributing to the standardization of the procedure and provides useful suggestions in the field of education. There are some limitations to our study. Our study was conducted on a mannequin. The incidence of carotid artery puncture may not be equated to actual human tissues where the relationship between the IJV and carotid artery may vary. Tissues in the simulator especially the artificial vessel may need a variable application of force to puncture the vessel which in itself can increase the risk of PVWP. The participants had experience in the landmark method and not US-guided cannulation thus, the results of this study may not be extrapolated for experienced US operators. However, beginners and practitioners with limited training in US will be benefitted by the study findings that are likely to give them confidence in using LA approach for CVC cannulation to decrease the incidence of PVWP.

The investigators were not blinded to the study objective. The incidence of other complications between the two approaches would have been more informative. There is a scope of intrapersonal variation in the complication rate while switching from one method to another. First, pass success rate, the number of attempts, and procedural time was not noted in this study.

**Conclusion**

Lower incidence of PVWP was seen in LA approach as compared to the SA approach during US-guided IJV cannulation in phantom by residents having previous experience.
of CVC (central venous cannulation) with landmark technique only. No difference in the incidence of carotid artery puncture was seen with either approach. Our participants had higher confidence for intraluminal needle tip placement using the LA approach, which may translate into fewer CVC-related complications. Our findings suggest that even with limited training in US the incidence of PVWP can be reduced by using LA approach for CVC cannulation.

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Conflicts of interest
There are no conflicts of interest.

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