Original Article

A manikin-based evaluation of a teaching modality for ultrasound-guided infraclavicular longitudinal in-plane axillary vein cannulation in comparison with ultrasound-guided internal jugular vein cannulation: A pilot study

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Abstract

Background and Aims: Ultrasound (US)-guided infraclavicular approach for axillary vein (AXV) cannulation has gained popularity in the last decade.
Material and Methods: In this manikin study, we evaluated the feasibility of a training model for teaching AXV cannulation. The learning pattern with this technique was assessed among attending anesthesiologists and residents in training.
Results: A faster learning pattern was observed for AXV cannulation among the attending anesthesiologists and residents in training, irrespective of their prior experience with US. It was evident that a training modality for this technique could be easily established with a phantom model and that hands-on training motivates trainees to embrace US-based central venous cannulation.
Conclusion: A teaching model for US-guided infraclavicular longitudinal in-plane AXV cannulation can be established using a phantom model. A focused educational program would result in an appreciable change in preference in embracing US-based cannulation techniques among residents.

Keywords: Axillary vein cannulation, central venous catheterization, in-plane, manikin study

Introduction

Ultrasound (US)-guided infraclavicular axillary vein (AXV) catheterization has been shown to be an effective technique in establishing central venous access.[1,2] The benefits of this route compared to subclavian vein cannulation are the ability to provide direct external compression in the event of inadvertent arterial puncture, as well as a decreased risk of pneumothorax, hemothorax, and chylothorax.[1,2] AXV cannulation might benefit a selected subset of patients including those having neurosurgical procedures,[3] severe burns, or those have had a sternotomy or tracheostomy. Despite the potential benefits of this technique, many physicians are still unaware of this approach.[4] Data regarding the learning curve pattern for AXV cannulation are limited. We have previously described a real-time multimodal AXV imaging and cannulation method using a combination of transverse and longitudinal images,

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venous compression views, and Doppler color flow.[3] In this pilot manikin study, we evaluated the efficacy of a teaching tool where an US-guided longitudinal AXV cannulation was compared with transverse internal jugular vein (IJV) cannulation technique between attending anesthesiologists and residents in training.

We hypothesized that both attending anesthesiologists and residents would demonstrate a similar learning pattern for AXV cannulation. The primary end point was cannulation time as defined by the duration between the first probe placement on the model and successful placement of the guide wire within the lumen of the vein. Secondary end points were the number of cannulating attempts at each placement site as defined by the number of times the needle was inserted and withdrawn, even if the needle was never removed from the model. Subjective data on participants' perceptions and preferred site of cannulation before and after the study were also assessed.

Material and Methods

Study design

This study was a prospective, nonblinded, nonrandomized sample of attending anesthesiologists and residents (postgraduate year [PGY] 1–4 years) in an anesthesiology residency program. A total of twenty participants (ten in each group) participated over a 6-month period. A Life-Form® neck and thorax manikin model, with artificial blood vessels in the correct anatomic location, was used in this study. Ethics Committee's approval was waived by the Institutional Review Board.

Study setting

The study was conducted at a tertiary university teaching hospital with an anesthesiology residency program. Anesthesiology residents in PGYs 1–4 and attending anesthesiologists having prior experience with US-guided central venous cannulation (CVC) volunteered to participate in the study. Residents in their 5th year of training, fellows and overseas trained residents were excluded from the study. The degree of US training varied within each group and was not quantified as part of this study.

Study protocol

Participants completed a prestudy questionnaire, which included questions regarding their perceptions and preferred site of CVC cannulation. The same questionnaire was completed at the end of the study to assess any change in perceptions. All participants watched a 5 min video tutorial demonstrating placement of a central line using both the IJV approach (transverse US view) and the AXV approach (longitudinal US view).

Participants were then allowed unlimited time to familiarize themselves with the anatomy of the Life-Form® phantom, the US machine, and the CVC kit. A 6- to 13-MHz linear US probe was used (HFL38, SonoSite; Bothell, WA). The Life-Form® phantom is an anatomically correct model with arteries and veins filled with red or blue fluid easily visualized with US [Figure 1]. After familiarization with the phantom and the US machine, participants practiced visualizing and cannulating both the IJV (out of plane) and AXV (in plane). During the practice, consistent, scripted information was given by the researchers to the participants when requested. Neither the video tutorial nor the questionnaire recommended one approach for CVC placement over the other. The actual study commenced when participants felt comfortable going through the entire process.

Each participant performed five sequential central line placements at each anatomical location (IJV and AXV) for a total of ten line placements. Each cannulation attempt was conducted in an alternating fashion with the starting location determined by a computer-generated randomized list. Each cannulation was deemed complete with the placement of the guide wire in the respective vein as confirmed by the researchers. A poststudy questionnaire evaluating the participants' anatomical site preference for CVC cannulation was also completed.

Measurements

Each placement attempt was analyzed, and the outcome measures were recorded by a single investigator (Michael Fortunato) to avoid inter-investigator differences. Participants' performance was monitored by the researchers.

Statistical analysis

Data were analyzed using STATA 14 statistical software (StataCorp LP, College Station, TX, USA). Values are

Figure 1: The Life-Form® phantom used in this study

presented as median and interquartile range (IQR) for cannulation times, and mean with standard deviation for the number of attempts. Wilcoxon signed rank test was used to compare median cannulation times at both locations for all participants as well as between groups. $P < 0.05$ was considered statistically significant.

Results

Among all participants, the first attempt cannulation time was shorter for IJV cannulation compared with AXV (median 47 s [IQR: 33–64 s; range: 13–71 s] vs. median 63 s [IQR: 49–91 s; range: 30–132 s], $P = 0.01$). A 34% reduction in the cannulation time was observed with IJV cannulation with the second attempt. No further reductions were observed with subsequent attempts until the fifth attempt (median 26 s, IQR: 18–40 s; range: 14–68 s). This translated to a total of 45% reduction in cannulation time for IJV cannulation. With the longitudinal in-plane AXV cannulation, an improvement was observed at the third attempt, and there was a progressive decline in cannulation time until the fifth attempt. Overall, cannulation time at the fifth attempt (median 34 s, IQR: 27–66 s; range: 18–120 s) was reduced by 46%. Across all attempts, cannulation time for IJV was significantly shorter than that for AXV cannulation ($P = 0.046$) [Figure 2].

Among attending anesthesiologists, median cannulation time for the first attempt of IJV cannulation was 46 s (IQR: 37–50 s; range: 32–53 s). While this was shorter than for residents (62 s), it was not statistically significant ($P = 0.37$). There was no progressive improvement observed among attending anesthesiologists. For residents, however, there was a significant reduction in cannulation time with subsequent attempts. By the fifth attempt, median cannulation time for residents was reduced by almost 66% (from 62 s [first attempt] to 21 s [fifth attempt]). Residents had significantly reduced cannulation times at the fifth attempt when compared with attendings (21 s vs. 36 s; $P = 0.02$) [Figure 3].

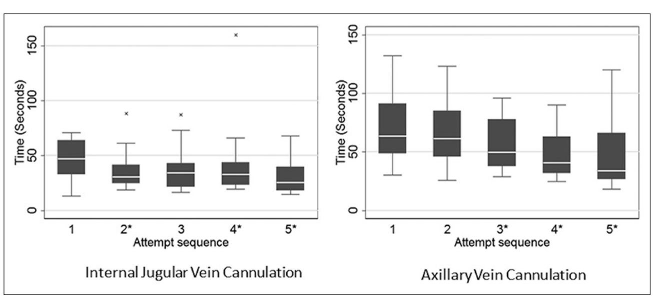

Figure 2: Overall cannulation time at individual locations for consecutive attempts among all operators, crosses indicate outliers. *(Next to the n^{th} attempt) indicates $P < 0.05$ against the first attempt

Median cannulation time for AXV among attending anesthesiologists on their first attempt was 60 s (IQR: 49–63 s; range: 30–99 s). While this was shorter than for residents (86 s), the difference was not statistically significant ($P = 0.037$). An improvement was observed for both attending anesthesiologists and residents across the five attempts. For attendings, this improvement was progressive, and by the fifth attempt, the median cannulation time was reduced by 43% (from 60 s [first attempt] to 34 s [fifth attempt]). For residents, there were successive improvements in each of the second and the third attempts, but no further reduction was observed after the third attempt. Overall, cannulation time was reduced by about 49% (median cannulation time was reduced from 86 s [first attempt] to 44 s [fifth attempt]). There was no statistically significant difference between attendings and residents at the fifth attempt ($P = 0.94$) [Figure 3].

The number of skin punctures remained consistent across the five attempts for IJV cannulation (ranging between 1.1 and 1.3) [Table 1]. Skin punctures for AXV cannulation decreased only after three attempts. While consistently minimal skin puncture rates were observed for the residents at both locations, the attendings had consistently more skin punctures for AXV cannulation with the first three attempts.

Seven of the ten (70%) attendings preferred the US IJV approach before beginning of the study; this perception remained the same at the completion of the study. Eight of the ten (80%) residents preferred the anatomical landmark IJV technique prior to the study; and after completion, seven of the ten (70%) preferred the US IJV technique.

Discussion

In this pilot study, we demonstrated the feasibility of establishing a training tool for US-guided AXV cannulation using an anatomically correct phantom model. Learning occurred quickly for this route regardless of previous exposure to US-guided vascular cannulation. As a result of this training technique, we demonstrated a shorter overall cannulation time with IJV cannulation among all participants. Attending anesthesiologists had consistently lower cannulation times across all attempts with IJV cannulation, reflecting their clinical experience. A clear learning pattern was observed among all operators for AXV cannulation, indicating easy acquisition of this skill. Not surprisingly, a short learning pattern was observed among trainees for both IJV and AXV cannulation. This is in keeping with previous reports indicating that a systematic teaching program of US-guided techniques should be incorporated in residency program to further enhance these skills.[5]

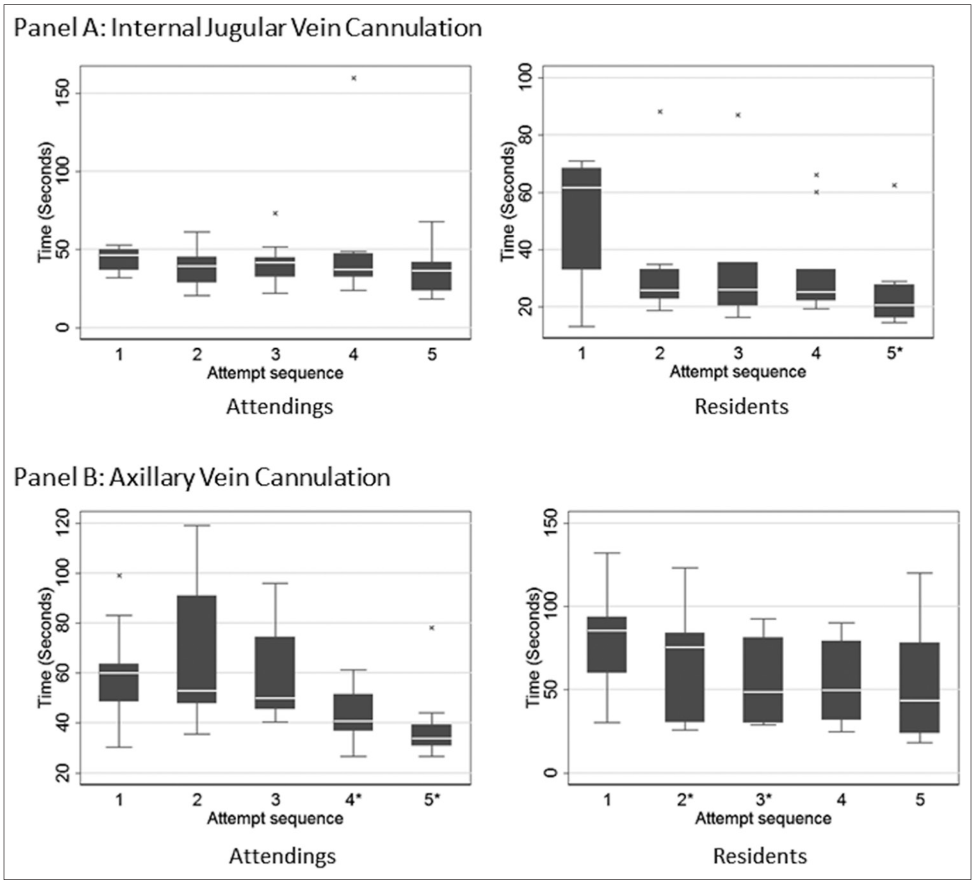

Figure 3: Cannulation time at individual locations for consecutive attempts: attending anesthesiologists versus residents. Crosses indicate outliers. *(Next to the n^{th} attempt) indicates $P < 0.05$ against the first attempt

Table 1: Skin puncture rates across consecutive attempts

Group	Approach	Attempt				
		1	2	3	4	5
Attendings and residents	IJV	1.3 (±0.5)	1.2 (±0.5)	1.1 (±0.4)	1.4 (±0.4)	1.2 (±0.5)
	AXV	1.6 (±0.6)	1.6 (±0.8)	1.6 (±0.8)	1.4 (±0.5)	1.3 (±0.4)
Attendings only	IJV	1.1 (±0.3)	1.3 (±0.7)	1.1 (±0.3)	1.5 (±1.3)	1.3 (±0.7)
	AXV	1.7 (±0.7)	1.9 (±0.9)	2.0 (±0.9)	1.3 (±0.5)	1.2 (±0.4)
Residents only	IJV	1.5 (±0.5)	1.1 (±0.3)	1.2 (±0.4)	1.2 (±0.4)	1.1 (±0.3)
	AXV	1.5 (±0.5)	1.3 (±0.5)	1.3 (±0.7)	1.5 (±0.5)	1.3 (±0.5)

Data are mean (±SD). IJV=Internal jugular vein, AXV=Axillary vein, SD=Standard deviation

Prior to this study, the majority of residents preferred the landmark IJV technique. Similar results were reported by Mukherji *et al*., analyzing residents' attitude toward CVC placement.[5] This was attributed to a lack of both experience and knowledge, apart from difficulty in accessing US machines. The complete change in the perception of trainees favoring a US-based technique after the study session suggests that a hands-on teaching tool for US techniques has a positive impact in developing this skill. In addition, this study highlights the ease in learning the unfamiliar and underutilized transverse approach in CVC cannulations.

US-guided AXV cannulation has a wider application outside the peri-operative setting, in particular in the critically ill,[6] venous access for permanent pacemakers,[7] placement of totally implantable venous access devices,[8] as well as access for renal replacement therapy.[9] A longitudinal approach to AXV cannulation has been shown to be superior to the transverse approach in both manikin and clinical studies;[1,10,11] this was the rationale for utilizing an in-plane distal/lateral longitudinal approach in our study.

In general, experts recommend 1 year of US-guided training with traditional cannulation at the IJV before embarking AXV cannulation.[4] US-guided CVC cannulation training on anatomically correct vascular models is strongly recommended by a consensus task force and is supported by high-quality evidence.[12] In the absence of a common guideline on US training, the task force recommends 6–8 h of didactic education, 4 h of hands-on training with anatomic models, and 6 h of practice on normal human volunteers to familiarize with the US machine and normal US anatomy.[12] It is also vital to maintain competency with each different approach for vascular access.

There were several limitations to our study. Participants' prior experience with US-guided vascular access was not quantified. Single observer-initiated observer bias could not be ruled out. Sampling bias due to volunteer participation and response bias to the questionnaire concerning the perception of the techniques influenced by investigator's expectations are the additional limitations. Although we used anatomically correct vascular phantom models, real-time features such as adjusting depth and gain; the use of color Doppler could not be applied. Further, a phantom cannot identify other useful landmarks in the vicinity such as the pectoralis muscle, brachial plexus, and pleura. Real patients exhibit anatomical variations thus limiting the clinical application of these results. In the absence of a power analysis and sample size calculation, the results of this pilot study need to be tested further in a real-life scenario.

Conclusion

A teaching model for US-guided infraclavicular longitudinal in-plane AXV cannulation can be established using an anatomically correct phantom model. Trainees could then be encouraged to scan in patients to get acquainted with the relevant anatomy before embarking this technique under supervision. A focused US-based educational program would improve the residents' preference in adapting these techniques.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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