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REVIEW ARTICLE

Real-time Ultrasound-guided Axillary Vein Cannulation

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ABSTRACT

The axillary vein has been shown to be a safe and effective cannulation site for patients requiring central venous access. Compared to subclavian vein cannulation, axillary vein cannulation may reduce the rate of pneumothorax and hemothorax. Long-term complications, including the rate of infection or deep vein thrombosis, are comparable to internal jugular vein cannulation. The use of ultrasound for cannulation at traditional central vein sites, such as the internal jugular and femoral veins has been shown to aid in successful cannulation and potentially reduce complications. For axillary vein cannulation, however, when ultrasound is used only for localization of the axillary vein precannulation, it has not been shown to improve successful cannulation or decrease the rate of arterial puncture.

Real-time ultrasound-guided axillary vein cannulation has been described and may increase the rate of successful cannulation and decrease complications. Various techniques of real-time ultrasound-guided axillary vein cannulation have been studied over the past decade. They differ in various characteristics including technique for needle imaging (in-plane *vs* out-of-plane) and upper extremity positioning (neutral *vs* abducted). The in-plane technique, which images the axillary vein in longitudinal view and allows the needle to be visualized at all times, has been found to result in greater first-attempt success and easier overall placement than the transverse view technique. As for upper extremity positioning, 90° abduction may result a decreased risk of catheter misplacement after proximal axillary vein cannulation.

Ultrasound-guided axillary vein cannulation has many emerging uses, including use in oncology, cardiology, and nephrology.

Keywords: Axillary vein, Central venous access, Ultrasound.

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INTRODUCTION

Given the potential complications of subclavian vein cannulation,[1] including pneumothorax and mediastinal hematoma, axillary vein cannulation techniques, have been described as an alternative.[2-11] The use of ultrasound for axillary vein localization was first described in critical care patients for which the landmark-based technique was deemed suboptimal.[7,8] Real-time ultrasound-guided axillary vein cannulation was first described over a decade ago.[9] Since then, it has been studied in a wide range of patients, including critically ill patients.[10-14] In this article, we will review axillary vein cannulation, including techniques for placement with real-time ultrasound-guidance, benefits, risks and emerging uses.

AXILLARY VEIN ANATOMY

A thorough understanding of anatomy is essential to appreciate the potential benefits of cannulation of the axillary vein. The axillary vein is the continuation of the basilic and brachial veins and extends from the outer margin of teres major to the lateral border of the first rib, at which point it becomes the subclavian vein. Along its course, it receives tributaries from the cephalic, subscapular, circumflex humeral, lateral thoracic and thoracoacromial veins. The vein is accompanied by the axillary artery, which lies slightly superior and posterior to the vein.

When a vein is to be punctured for cannulation, the structures posterior to the vein are of great importance. The medial portion of the axillary vein, like the subclavian vein, is bordered posteriorly by the ribs and lung. More laterally, the anterior chest wall moves posteriorly, resulting in a larger distance between the vein and lung. At the most lateral aspect of the axillary vein, there are no clinically significant posterior structures that may be inadvertently injured during cannulation.

HISTORY OF AXILLARY VEIN CATHETERIZATION

Multiple landmark-based approaches to axillary vein access have been described.[2-6] Studies using these techniques found axillary vein catheterization to be equally effective and safe as cannulation at other central vein sites. The reported failure rate ranged from 4 to 11%. Of the complications, the most frequent of was arterial puncture.[6]

The first described use of ultrasound in axillary vein cannulation was for vein localization only.[7] The investigators used ultrasound to locate and mark the axillary vein prior to cannulation attempt. Although

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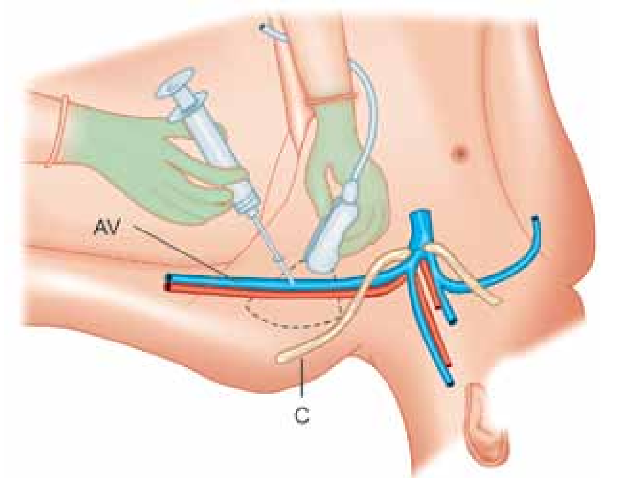

Fig. 1: In-plane technique: The position of ultrasound transducer to obtain a longitudinal image of axillary vein and the needle is advanced in plane to reach the vein to puncture it (AV: Axillary vein; C: Clavicle)

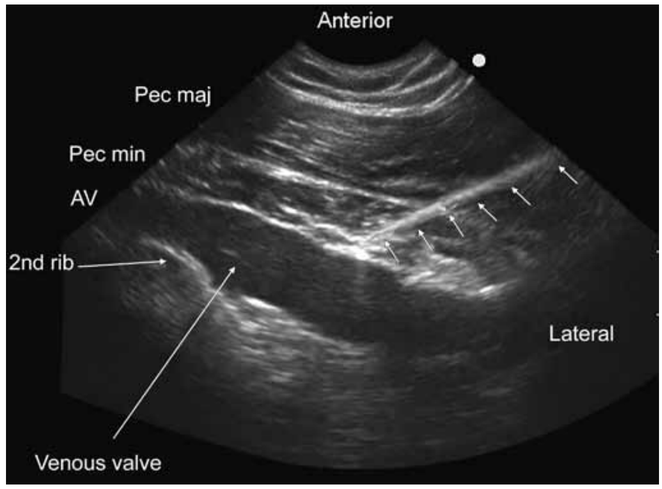

Fig. 2: In-plane technique: Ultrasound image with a curvilinear probe. The arrows point to needle. The needle tip has just made contact with anterior wall of vein (Pec maj: Pectoralis major muscle; Pec min: Pectoralis minor muscle; AV: Axillary vein). A venous valve is seen just lateral to 2nd rib. Guide wire tip may monitored across the venous valves when they are visible or resistance to guide wire advance is encountered

the use of ultrasound for cannulation of other central veins has been found to aid in accurate cannulation and potentially reduce complications,[17,18] ultrasound used only for vein localization did not have these benefits. Cannulation failure rate was 14%[12] and rate of complications including arterial puncture remained.[7] Real-time needle ultrasound guidance may have avoided some of these complications.

REAL-TIME ULTRASOUND-GUIDANCE

Over a decade ago, axillary vein cannulation under continuous ultrasound guidance was first described in a series of five patients.[9] In this technique, the patient's arm is abducted 90° and a 4 to 7 MHz Sonosite 180® C 11 probe (Sonosite, Bothell, WA) is used to distinguish the axillary vein from the artery in the short-axis view. The axillary vein is centered in the ultrasound view and the probe is rotated 90°. With the axillary vein viewed in long-axis, the needle is positioned under the middle of the probe so as to view the needle in-plane (Fig. 1). Care should be taken to select a vein puncture site a few inches lateral to the rib cage to minimize the risk of pneumothorax. The introducer needle is advanced with care taken to avoid the axillary artery and the surrounding nerves. Once the needle contacts the anterior surface of the vein, a short, jabbing motion is used to puncture the anterior vein wall (Fig. 2). After venous puncture is confirmed, the catheter is then inserted using the standard Seldinger technique. It is noted that the needle should enter the vein at an acute angle to minimize the risk of a soft catheter kinking once the dilator is removed.

This technique was successful in all five patients with no adverse effects. It was suggested that this technique and real-time imaging might offer several advantages over traditional techniques including decreasing the rate of arterial puncture and aiding in troubleshooting potential difficulties with catheter placement. For example, if excessive resistance is met with guidewire advancement, real-time ultrasound imaging can be used to identify wire malposition in the pectoral muscles or wire coiling at a venous valve. The longitudinal view of the vein allows for continuous imaging of the needle and lines during all maneuvers.

Shortly thereafter, Sharma et al described another ultrasound-guided technique for axillary vein cannulation in a prospective series of 200 patients.[10] Patients were positioned in 15° of Trendelenburg with their arms at their sides. The axillary vein was visualized in all patients with either a Site Rite 7.5 MHz probe (Dymax/Bard, Pittsburgh, PA, USA) or a SonoSite iLook with a 5/10 MHz probe (SonoSite, Biggleswade, UK). The vein and artery were imaged in short-axis with the chest wall visible. Unlike the original technique, the introducer needle was advanced at a steep angle out-of-plane (Fig. 3). The needle was visualized as a moving hyperechoic spot associated with tissue distortion. Gentle movements were used to identify the needle tip position. The needle was advanced into the vein or, if the needle had also penetrated the posterior wall, was withdrawn until blood could be aspirated freely. A guidewire was threaded and a catheter was tunneled subcutaneously from an exit site on the anterior chest wall to the puncture site. Of the 200 patients enrolled, four patients were deemed unsuitable for axillary vein cannulation secondary to narrow or thrombosed axillary veins. Catheterization was successful in 194 patients and on the first, second, and

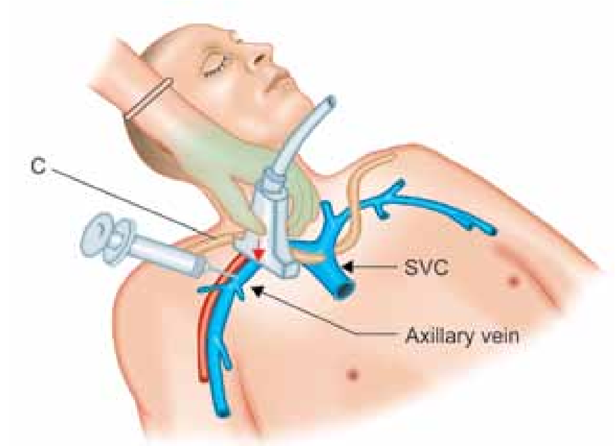

Fig. 3: Out-of-plane technique: The position of transducer in relation to needle (C: Clavicle; SVC: Superior vena cava)

third needle pass in 76, 16, and 6% of cases respectively. Complications included arterial puncture in three (1.5%) patients, which was treated with 5 minutes of manual compression as well as transient neuralgia during guidewire or dilator insertion in two (1%) patients.

This out-of-plane technique with real-time ultrasound guidance for vessel puncture resulted in successful axillary vein cannulation in 96% of patients. Through and through puncture of the vein was known to have occurred in 54 (28%) cases. This is likely attributable to the out-of-plane needle imaging that was employed in this technique. With the out-of-plane technique, it may be difficult to confirm that the tip of the needle is being visualized and the authors relied distortion of tissue to help localize the needle advancement. The out-of-plane technique may have also attributed to the 5.4% of cases in which the needle was inadvertently advanced even more posteriorly and contacted the rib cage. Even though there were no cases of pneumothorax, lung injury does appear possible with this technique. This may be because the chest wall was visible in the ultrasound view in which venous puncture was attempted. A more lateral cross-section would have allowed the anterior chest wall to move more posteriorly, and perhaps, completely out of view. Finally, ultrasound was only used until aspiration of blood was confirmed. The authors note that the rate of arterial puncture and transient neuralgia might have been decreased with the use of dynamic ultrasound guidance during the rest of the procedure.

CLINICAL USE

Since the description of these two techniques, real-time ultrasound-guided axillary vein cannulation has been described in a wide range of patients.[11-14] The first reported case in which this technique was reproduced was in an emergency department patient who had septic shock and dementia.[11] The patient had difficulty remaining stationary for a traditional central venous cannulation. To minimize the risk of injury to structures in the thorax and neck, the authors chose to approach central venous access via the more distal axillary vein. The arm was abducted 120° and secured with a soft restraint. The axillary vein and artery were visualized in the axilla with a high frequency linear ultrasound probe. An 18-gauge catheter was inserted in the skin 2 centimeters distal to this site. After presence of venous blood was confirmed, a triple-lumen catheter was threaded using Seldinger technique. Radiography confirmed that the tip of the catheter was in the superior vena cava. The authors also describe having used this approach in patients with severe coagulopathy to allow for central venous access through a compressible peripheral site. The authors did not specify whether the procedure was performed with the axillary vein viewed in short-axis or long-axis.

Real-time ultrasound-guided axillary vein catheterization was also described in a retrospective review of six neurosurgical intensive care patients.[12] The authors stated that the axillary vessel anatomy was confirmed using combined transverse, longitudinal, and Doppler color flow images, but that the procedure itself was performed using the in-plane technique, presumably with a longitudinal view of the axillary vein. The catheter was inserted using the Seldinger technique and chest radiograph was obtained after the procedure. Five of the six central lines were inserted easily without complication. One central line was inserted without complications but more proximally because of difficulty in visualizing the axillary vein secondary to the patient's morbid obesity and severe hypovolemia. The authors noted that the technique of real-time ultrasound-guided axillary vein cannulation requires minimal additional training and is reasonable option for many critically ill patients in whom other central venous catheter approaches may not be ideal.

Large-scale clinical studies on have also been conducted based on the real-time ultrasound-based technique. In a prospective study of mechanically ventilated intensive care patients,[13] the placement of ultrasound-guided axillary catheters was evaluated. All catheters were inserted using real-time ultrasound guidance with an out-of-plane technique. One hundred and twenty-five consecutive procedures occurred in 119 patients. Successful line placement was achieved in 94% of procedures. Complications consisted of one arterial puncture and four procedures that required repeating due to catheter malposition. The authors concluded that the technique of ultrasound-guided axillary vein cannulation could be undertaken successfully in ventilated intensive care patients, even in challenging circumstances. Given the utility and safety of this technique, they suggested that it be adopted more widely in the intensive care population.

In a large analysis of ultrasound-guided tunneled axillary vein catheterizations,[14] cannulation was successful in 99.5% of 1923 patients. The vein and the axillary artery were first imaged in short axis to determine the depth from the skin. The probe was then rotated to perform a long-axis examination to identify other structures, such as branches of the axillary artery, which can cross the axillary vein. The probe was then returned to the short-axis and the introducer needle was advanced out-of-plane at a steep angle toward the vein until the tip was seen to indent the vein wall. Vein puncture was identified by free aspiration of nonpulsatile blood. Guidewire was seen by fluoroscopy to ensure that the tip was in a satisfactory position in the superior vena cava or right atrium. Cannulation was successful on the first attempt in 94% of patients. The authors reported that patients undergoing axillary vein cannulation demonstrated a low rate of complications. Arterial puncture occurred in eight cases (0.004%), one in which a 6.6 French sheath was inserted then withdrawn immediately. The superior vena cava was punctured by the guidewire in one patient and was identified by fluoroscopy, however, there were no issues after guidewire removal. Additionally, the authors noted four cases of pneumothorax and one case in which a pre-existing pleural effusion was aspirated. These specific complications may have resulted from utilizing the technique of directing the needle steeply in short-axis in which the needle itself is not seen at all times. Given the high success rate and low complication rate, the authors concluded that the axillary vein route of access appears to be a safe and effective alternative to the internal jugular vein.

PROCEDURAL FACTORS

The clinical descriptions of real-time ultrasound-guided axillary vein cannulation differ in regards to several factors, including needle visualization (in-plane *vs* out-of-plane technique) and arm position (abducted or neutral).

In terms of needle visualization, both techniques have been endorsed clinically, one study[15] sought to determine whether the longitudinal (in-plane) or transverse (out-of-plane) view of the axillary vein during cannulation is advantageous. In this prospective study, 57 emergency medicine physicians were asked to cannulate the axillary vein in an anatomically correct torso phantom model using each technique. The investigators compared the two techniques in regard to the rate of successful cannulations on first skin puncture, the number of needle redirections, the number of complications, and the time to successful cannulation. The investigators found that the longitudinal method of visualizing the axillary vein is associated with greater first-attempt success, fewer needle redirections, fewer skin punctures and a trend of fewer arterial punctures compared with the transverse orientation. For successful attempts, the time spent for the longitudinal method was less than for the transverse method. Although this was a single-center study, it is surprising to note that the physicians at this center historically favor and more often perform a transverse approach to central venous access.

Another study[16] investigated the influence of arm position during proximal axillary vein cannulation on catheter placement and complications. Four hundred and eighty-one patients undergoing real-time ultrasound-guided infraclavicular proximal axillary cannulation were randomized to either the neutral group (n = 240) or the 90° abduction group (n = 241). After cannulation was performed, misplacement of the catheter and complications were evaluated with ultrasound and chest radiography. The success rate of catheterization before evaluation with ultrasound or radiography was high in both groups and not statistically significant (97.1 *vs* 98.8%). The rate of arterial puncture was also not statistically different (1.7 *vs* 0%, $p = 0.061$). However, the incidence of catheter misplacement was higher in the neutral group than in the abduction group (3.9 *vs* 0.4%, $p = 0.01$). Most of the misplaced catheters were located in the right internal jugular vein. Only one catheter was located in the left subclavian vein, which occurred in the neutral group. The investigators concluded that 90° arm abduction might minimize the risk of misplacement of the catheter during real-time ultrasound-guided proximal axillary vein cannulation.

Long-term Safety

Studies of the long-term safety of axillary vein cannulation have all been performed on the landmark-based technique and have found similar complication rates as with other central venous catheterization. A prospective study[19] of 141 axillary vein catheters found that catheter-related infection was similar to that observed after internal jugular vein catheterization. When performed in critically ill patients, the chance of developing catheter-related sepsis was less than 10% with either route. A prospective study[20] of 60 patients found that axillary vein cannulation was associated with an 11.6% rate of upper-extremity deep vein thrombosis. This rate of thrombosis is similar to that observed after subclavian or internal jugular vein catheterization. Because, thrombosis is rare or absent in catheterizations lasting less than 15 days, the authors suggest that axillary catheters should be withdrawn after a maximum of 2 weeks.

EMERGING USES

Ultrasound-guided axillary vein access has been described for use outside the realm of traditional vascular cannulation. It has been used in placing totally implantable venous access devices,[21] venous access for permanent pacemakers and defibrillators[22] and cannulation for renal replacement therapy in the critical care unit.[23]

Authors of these descriptions cite several potential advantages of ultrasound-guided axillary vein techniques. For example, when used for permanent pacemaker or implantable cardioverter defibrillator placement, the ultrasound-guided axillary vein approach may be a favorable site when compared with the classical subclavian approach. It may reduce the rate of complications from venous access and device implantation as well as reduce the incidence of lead crush and the risk of damage to chronic leads when upgrading devices. In a study of 26 patients requiring pacemakers or defibrillators in which ultrasound-guided axillary approach was used,[22] there were no instances of lead failure or lead damage. The authors also noted that there was no difficulty in advancing the guidewire and 7F sheath attributable to the relatively steeper angle of entry of the needle into the vein. The authors concluded that ultrasound guidance provides a safe and rapid technique for axillary vein lead placement.

SUMMARY

Since real-time ultrasound-guided axillary vein cannulation was first described, it has been used in a wide range of patients. It has been shown to be safe, require minimal training, and have low rates of complications. Compared to subclavian vein cannulation, it has a decreased risk of pneumothorax or hemothorax. Long-term studies on axillary vein cannulation show comparable rates of infection and deep vein thrombosis to internal jugular catheterization.

The in-plane ultrasound technique, in which the axillary vein is seen longitudinally and the needle is completely visualized, may potentially be superior to the out-of plane technique. Although the rate of pneumothorax using the out-of-plane technique is extremely low, there have been no reports of pneumothorax with the in-plane technique. In a center where the physicians typically favor an out-of-plane view when performing central venous access, the in-plane technique to axillary vein cannulation was found to be preferable in terms of rate of success and a trend toward fewer complications. Large-scale studies of the in-plane technique in the clinical setting would need to be performed to confirm whether the in-plane technique would result in more successful placement or decreased complications.

Real-time ultrasound-guided axillary vein cannulation has been shown to be safe and effective in a diverse patient population, including those that are critically ill. More recently, this technique has been used for more than simple cannulation, including placement of totally implantable venous access devices, venous access for permanent pacemakers and defibrillators and cannulation for renal replacement therapy.

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