

Infraclavicular access to the axillary vein — new possibilities for the catheterization of the central veins in the intensive care unit

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Abstract

Central vein cannulation is one of the most commonly performed procedures in intensive care. Traditionally, the jugular and subclavian vein are recommended as the first choice option. Nevertheless, these attempts are not always obtainable for critically ill patients. For this reason, the axillary vein seems to be a rational alternative approach. In this narrative review, we evaluate the usefulness of the infraclavicular access to the axillary vein. The existing evidence suggests that infraclavicular approach to the axillary vein is a reliable method of central vein catheterization, especially when performed with ultrasound guidance.

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Central vein catheterization is one of the most frequently performed procedures in the intensive care unit (ICU). Since 1962, it has become an integral part of treatment for almost every patient in the ICU [1]. The most frequently cannulated vessels are the jugular, subclavian, and femoral veins. Based on the latest evidence, the subclavian and jugular veins should be the first-choice options with respect to the risk of infection [2].

An additional route to the central vein is the axillary vein. Although this has been used incidentally since the end of the 1960s, it has never gained popularity. The implementation of ultrasonography in vessel catheterization has led to renewed attention on central venous access via the axillary vein [3]. The following paper discusses the current evidence regarding axillary vein cannulation via the infraclavicular route. It also describes practical aspects of the procedure, especially concerning the ultrasound-guided method of catheterization.

ANATOMY

An axillary vein is formed from the connection of the basilic and the brachial veins and runs from the lateral edge of the teres major muscle to the lateral edge of the first rib.

Traditionally, in the infraclavicular region, depending on the structure of the pectoralis minor muscle, an axillary vein is divided into three parts: proximal, posterior, and distal. Accompanying the vein is an axillary artery that is located slightly above and posterior to the vein and is most often parallel to it [4]. In the paracentral direction, the axillary artery can overlap with the vein, which has practical implications.

The average diameter of the axillary vein ranges from 0.84 to 1.23 cm, and its distance from the wall of the thorax ranges from 1.01 to 2.24 cm [5]. Mechanically ventilated patients have similar intrinsic diameters [6]. The dimensions and location of the vein are different in various segments of the vessel. In the peripheral segment, the internal diameter decreases, and the distance from the axillary artery and thoracic wall increases [5]. Some scientists emphasize the positive influence of the abduction of the arm on the value of the intrinsic diameter of the vein [7].

LANDMARK-BASED ACCESS

Although cannulation of the axillary vein from the axillary fossa access has been used since the end of the 1960s, it never gained widespread popularity [8]. Infraclavicular

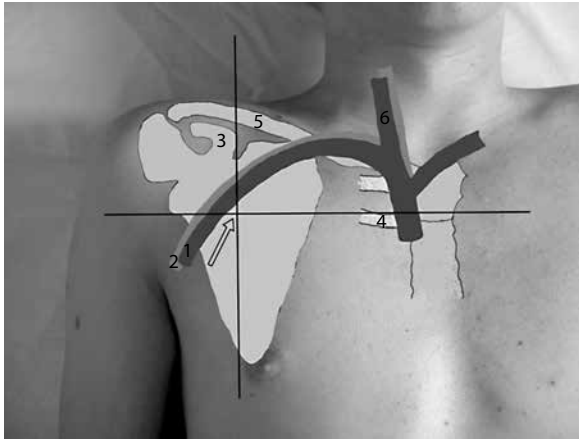


Figure 1. Main structures at the catheterization site. 1 — axillary vein; 2 — axillary artery; 3 — coracoid process of the scapula; 4 — second sternocostal cartilage; 5 — clavicle; 6 — internal jugular vein. Point of the needle insertion is at the intersection of tangents. Arrow indicates direction of the needle introduction. Reproduced with permission of WICHTIG EDITORE S.R.L. from [11]

access was also not implemented in daily practice because of the too-complicated technique of the procedure and the high rate of unintended axillary artery puncture [9–11]. The infraclavicular access, originally described by Nickalls, was studied initially among a very small group of patients [12]. The technique was characterized by determination of a fixed distance of 5 cm (or ‘three fingers’) below the inferior aspect of the coracoid process. Moreover, the assessment of the medial border of the pectoralis minor, and the junction of the medial one-fourth and lateral three-fourths of the clavicle was necessary. The method also was used in the study conducted by Taylor and Yellowlees [13]. Contrary to the original technique, the approach proposed by Gawda *et al.* [14] is based only on the determination of two anatomical points of reference for puncture site identification. The needle is inserted in the point located at the intersection of the tangent to the medial part of the coracoid process in the sagittal plane, and the tangent to the superior edge of the second sterno-costal cartilage in the horizontal plane (Fig. 1). Then the needle is elevated 10–15° above the frontal plane and directed towards the middle of the clavicle.

The value of the anatomic orientation in the catheterization of the axillary vein has been diminished along with the implementation of ultrasonography in clinical practice. However, landmark-based access remains the only option when an ultrasound machine is inaccessible (i.e. a lack of equipment or insufficient skill of the physician) [12]. According to the results of surveys conducted in developed countries, catheterization of the central vein is still performed in a landmark-based manner [13, 14].

APPLICATION OF ULTRASONOGRAPHY

The lack of bony structures between the axillary vein and the surface of the body of the patient, as well as the relatively shallow location of the vein, enables catheterization in the infraclavicular area.

The first application of ultrasonography to the catheterization of the axillary vein assumed a static form. The technique relied on the establishment of the location of the vein and adjacent structures with subsequent cannulation of the vein without using an ultrasound machine [15]. Two reports of the real-time ultrasound-guided cannulation of the axillary vein were published 10 years later [3, 16]. Both studies were based on different techniques based on the mutual aspects of the ultrasound beam and the long axis of the needle, the short-axis technique, and the long-axis technique.

The advantages of ultrasound-based techniques over landmark-oriented techniques in terms of safety, and the rate of successful first passes have been proven in many randomized trials and meta-analyses [17–20]. For this reason, many experts and guidelines from professional societies recommend performing catheterization with ultrasound equipment [12, 21, 22].

REAL-TIME ULTRASOUND GUIDANCE

The cannulation of the vessels with ultrasonography can be performed statically in order to determine only the location of the vessel and adjacent structures. That approach has been superseded by real-time ultrasonography, which has been shown to be a superior technique in many studies [18, 23]. Real-time ultrasonography can be performed as a short-axis technique or a long-axis technique (Fig. 2).

The short-axis technique relies on setting the ultrasound beam perpendicular to the long axis of the vessel, which puts the cannulation needle a perpendicular position to the ultrasound beam as well. Configuring the ultrasound transducer toward the vein appears on the screen both in the cross-section of the vein and the adjacent structures (axillary artery, nerves of brachial plexus). The needle is visible in cross-section as a bright, highly echogenic point. A distinctive ramification of the short-axis technique is constant restricted visualization of the needle tip during execution of the procedure, and the screen can show both the needle tip and any part of the shaft of the needle [24].

In the long-axis technique, the ultrasound beam traverses the needle on its long axis, which yields an image of the needle in the longitudinal section on the screen with both the tip and the shaft of the needle visible. When correctly conducted, the real-time long-axis technique demands precise coordination of the placement of the very narrow beam

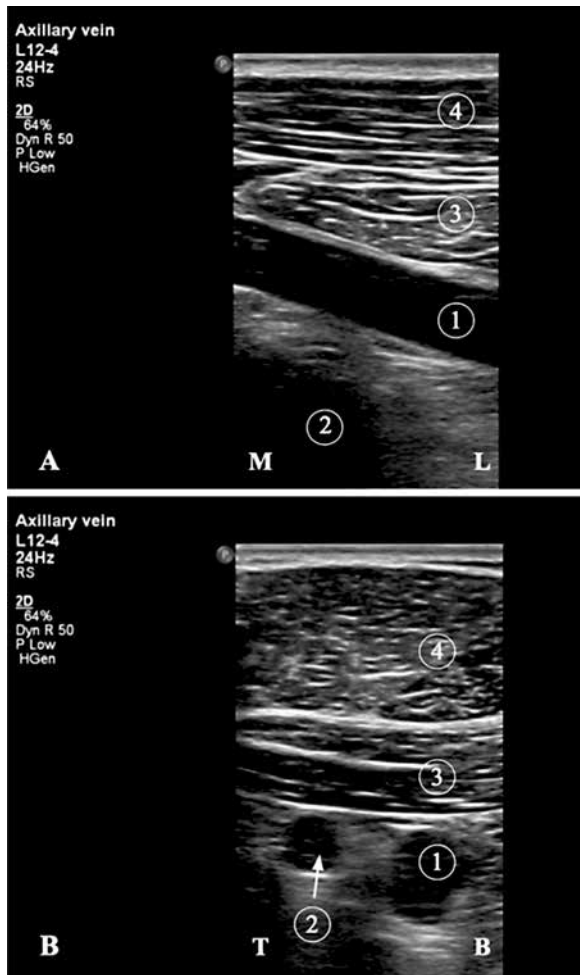


Figure 2. Visualization of the right axillary vein. **A** — long-axis view of the right axillary vein: M — medial part of the right infraclavicular area; L — lateral part of the right infraclavicular area; 1 — lumen of the axillary vein; 2 — shadow of the second rib; 3 — pectoralis minor muscle; 4 — pectoralis major muscle. **B** — short axis view of the right axillary vessels: T — top part of the right infraclavicular area; B — bottom part of the right infraclavicular area; 1 — lumen of the axillary vein; 2 — lumen of the axillary artery; 3 — pectoralis minor muscle; 4 — pectoralis major muscle

and the long axis of the needle. Nonparallel alignment of the ultrasound beam and the needle precludes constant observation of the needle tip on the screen [24]. In the long-axis technique, the visibility of the adjacent structures of the vein is very limited [25].

A meta-analysis of different accesses to the vessels did not unequivocally confirm the advantage of one technique over another [26]. The experiments conducted on the simulation models indicate better visualization of the tip of the needle in the long-axis technique [27]. Sommerkamp *et al.* [28] conducted a comparative evaluation of both catheterization techniques and showed the long-axis technique was more effective and secure than the short-axis technique. Distinct from other types of vascular access, there is a lack

of studies comparing both techniques in the cannulation of the axillary vein under clinical conditions.

Since 2004, some large prospective studies of the ultrasound-guided infraclavicular catheterization of the axillary vein have been published. Sharma *et al.* [16] performed a survey on the short-axis technique among 200 patients subjected to implantation of a tunnelled catheter and obtained an efficacy of 96%. Improper location of the catheter occurred for 15% of patients. Glen *et al.* [29] in a group of 119 mechanically ventilated patients conducted cannulations using the short-axis technique with an effectiveness of 94% and with a low rate of complications. Ahn *et al.* [30] performed a randomized clinical trial of mechanically ventilated patients and compared the influence of abduction of the arm on the efficacy of catheterization of the axillary vein. A survey that preceded the sample-size calculation demonstrated an efficacy of 97.1% versus 98.8%, and did not show differences in the rates of complications. In the sub-group of patients cannulated with abduction of the arm there was a considerably smaller rate of improper placement of the tip of the catheter [30]. Buzancais *et al.* [31] used the long-axis technique for infraclavicular access and compared the cannulation of the axillary vein in proximal and distal parts of the vein. They did not claim differences in the efficiency of the procedure, which was stated to be 96.5% and 98.4%, respectively. The study was conducted on mechanically ventilated patients in the ICU or in the operating theatre. Czarnik *et al.* [6] conducted a study of mechanically ventilated, critically ill patients, and analyzed the efficiency of catheterization and the rate of complications in a group of 202 patients. They achieved a success rate of 95.1%. Malposition of the tip of the catheter occurred in 13.4% of cases.

Despite the growing number of studies, the literature still presents the axillary vein and the subclavian vein as interchangeable, a fact which has been noted by some experts [32–34]. Some significant large studies are not free of such imprecision [35]. The misuse of the appropriate anatomical nomenclature hinders the comparison of different techniques of cannulation and the creation of guidelines [20, 21]. Despite growing evidence, the recommendations of experts still do not include access via the axillary vein in their guidelines.

PROCEDURE SAFETY

The rate of early complications for ultrasound-guided axillary vein access is low. In the majority of studies, an unintended axillary artery puncture occurred in less than 3% of cases and was associated only with a local perivascular hematoma. Pneumothorax is a very rare complication. Only Buzancais *et al.* [31] reported incidents of pneumothorax in 3.3% patients who had received cannulation in the proximal

Table 1. Studies of the real-time ultrasound-guided infraclavicular cannulation of the axillary vein

Study	n	Effectiveness (%)	Malposition (%)	Artery puncture (%)	Pneumothorax (%)
Sharma <i>et al.</i> [16]	200	96	15	1.5	0
Glen <i>et al.</i> [29]	125	94	1	3	0
Buzancais <i>et al.</i> [31]					
distal access	62	98.4	11.3	6.5	0
proximal access	60	96.5	0	0	3.3
Ahn <i>et al.</i> [30]					
neutral position	240	97.1	3.9	1.7	0
abducted position	241	98.8	0.4	0	0
Czarnik <i>et al.</i> [6]	202	95.1	13.4	2.5	0.5

n — number of patients; proximal access — patients with proximal access to the axillary vein; distal access — patients with distal access to the axillary vein; neutral position — patients with neutral position of the arm during cannulation; abducted position — patients with the arm abducted during cannulation

segment of the axillary vein (on the border with the subclavian vein). The majority of prospective experiments were performed in mechanically ventilated patients. It is noteworthy that the applied values of positive end-expiratory pressure (from 0 to 15 cm H₂O) did not impact the incidence of pneumothorax associated with catheterization (Table 1).

The rate of catheter malposition can reach up to 15% and usually consists of inserting the catheter into the internal jugular vein on the cannulated side. Interestingly, abduction of the arm and catheterization of the axillary vein in its proximal segment reduces the rate of this complication [30, 31]. It should be noted that intravenous location of the tip of the catheter outside the superior vena cava is not a dangerous complication. The execution of the cannulation under ultrasound guidance enables the proper diagnosis of the problem during the procedure with the implementation an efficient correction [35–37].

Thus far, there have been no randomized controlled trials directly comparing ultrasound-guided catheterization of the axillary and the other central veins. The cannulation of the subclavian vein among 200 critically ill patients with ultrasound guidance in Fragou's study showed mostly the improper position of the tip of the catheter (9.5%). Other early mechanical complications were incidental [35]. In the ultrasound-guided cannulation of the internal jugular vein in a group of 450 patients studied by Karakitsos *et al.* [19], the rate of artery puncture reached 1.1%. There were no data regarding the number of catheter malpositions. In both studies, the procedures were performed only by experienced intensivists with over five years of practice in vascular cannulations.

There is currently a lack of studies analyzing the late complications of infraclavicular cannulation of the axillary vein, such as colonization of the catheter, catheter-related blood stream infection, and intravascular thrombosis.

PRACTICAL ASPECTS

Regardless of the chosen method for cannulation, the ultrasound-guided scrutiny of both axillary veins is mandatory for choosing the most convenient vessel to perform cannulation. One should choose the vein that is wider and more shallowly located. The presence of an echogenic intraluminal clot should be excluded by application of the pressure test [12]. The exclusion of axillary vein thrombosis is of utmost importance for patients after previous cannulations, dialyzed inpatients and patients subjected to chemotherapy. Disturbances in flow are diagnosed with a colour Doppler [12, 21].

Pre-scanning is also performed to distinguish the vein and the artery due to their proximity and similar intravascular diameter. Except for pressure tests, a pulsed-wave Doppler is often used to differentiate the axillary vessels, which is especially useful in patients with hemodynamic decompensation (Fig. 3).

The effectiveness of the Trendelenburg position is questionable with respect to the data confirming the low impact of the manoeuvre on the size of the cross-section of the vein [38].

During an encounter of the needle with the wall of the vein, the so-called 'tenting effect' could occur. In hypovolemic patients this could lead to the closure of the lumen of the vein and could preclude a puncture. It is important to note that the tenting effect by itself does not guarantee that the needle is situated directly over the axillary vein. For this reason, visualization of the axillary artery to exclude the presence of the needle over the artery is recommended. After the puncture, one should confirm the presence of the needle in the vein and exclude in the artery for both techniques [39]. The in-plane technique demands a change in the angle of the ultrasound transducer. The proper localization of the guidewire should be confirmed by ultrasonog-

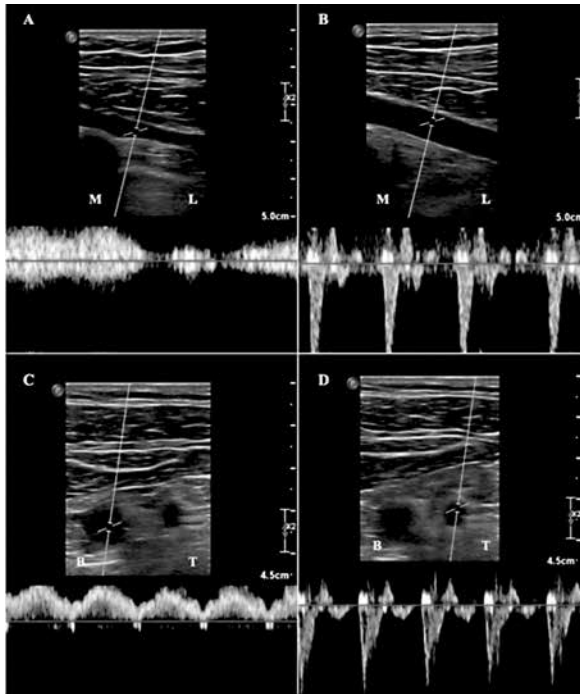


Figure 3. Character of the blood flow in the axillary vessels. **A** — long-axis view of the left axillary vein; **B** — long-axis view of the left axillary artery; **C** — short-axis view of the left axillary vessels with pulsed-waved Doppler focused at the axillary vein; **D** — short-axis view of the left axillary vessels with pulsed-waved Doppler focused at the axillary artery; M — medial part of the left infraclavicular area; L — lateral part of the left infraclavicular area; T — top part of the left infraclavicular area; B — bottom part of the infraclavicular area

raphy and by excluding the guidewire in the axillary artery [39]. After insertion of the guidewire, the immediate control of the internal jugular vein on the cannulated side is recommended in order to exclude the presence of the guidewire in the jugular vein [40]. The same check of the jugular vein is necessary directly after insertion of the catheter into the axillary vein. The crucial steps in real-time ultrasound-guided cannulation of the axillary vein are included in Figure 4.

The tip of the catheter near the upper aperture of the thorax should be positioned in the lower 1/3 of the superior vena cava or at the junction of superior vena cava and the right atrium [22, 41]. The catheter should also be aligned parallel to the long axis of the superior vena cava to minimize the risk of its perforation and the occurrence of cardiac tamponade. There is growing evidence that suggests that this complication is extremely rare [12, 41]. The parallel alignment of the catheter towards the course of the vein also prevents thrombotic complications. Practically, the catheter should be inserted on the right side at a minimum depth of 20 cm instead of on the left side at approximately 25 cm [22].

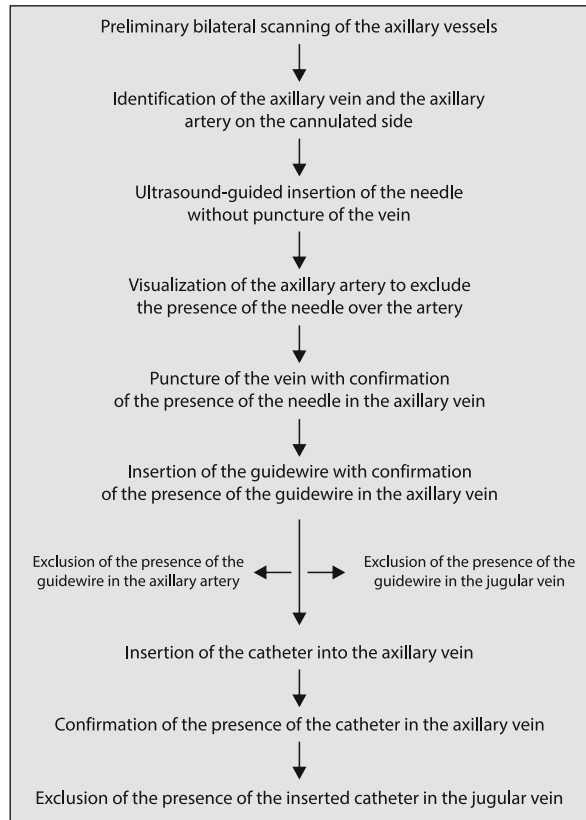


Figure 4. Steps in the real-time ultrasound-guided infraclavicular cannulation of the axillary vein

SPECIFIC INDICATIONS FOR AXILLARY VEIN CANNULATIONS

The majority of cannulations of the axillary vein are performed because of traditional reasons for insertion of a vascular catheter into the large vein, including measurement of central venous pressure, a lack of peripheral access, and administration of catecholamines. Although the internal jugular vein is the most popular route of central venous access, many patients simultaneously require various vascular access points in order to perform haemodialysis, temporary heart pacing or pulmonary artery catheterization. Moreover, the accessibility of particular central veins through anatomical deformations, post-traumatic distortions, thrombosis appearance and local infections is often limited. The potential benefits of the infraclavicular approach to the axillary vein are presented in Table 2.

EMERGENCY INDICATIONS

The usefulness of ultrasonography in central vein catheterization performed under emergency conditions has

Table 2. Main features of the infraclavicular access to the axillary vein

Possibility of having the head of the patient in the neutral position
Possibility of cannulation for patients with neck and cervical spine injuries
Minimal risk of pneumothorax
Easy care of the cannula and comfort of the patient
The possibility of cannulation during resuscitation
Minimized risk of infection in patients with tracheostomy and with unhealed wounds after sternotomy

been demonstrated in many studies [42–45]. Previous reports relating to the catheterization of the axillary vein under the emergency conditions mainly concerned descriptions of individual cases. To date, there has been a lack of cohort studies concerning the efficiency of catheterizations executed in the axillary vein under emergency conditions, albeit some surveys were partially based on the procedures performed under emergency settings [6, 46].

DIALYSIS CATHETERS

Although the subclavian vein is not the best place for the insertion of a dialysis catheter, it has been shown in the literature that practical usage of the axillary vein for its use is very efficient [46, 47]. It should be noted that in patients who may experience an arterio-venous fistula, access via an axillary vein is contraindicated [48].

IMPLANTABLE DEVICES

Ultrasound guidance is used for central vein punctures to insert a guidewire before pacemaker implantation [49]. Although the procedure is not routinely executed in the ICU, utilization of ultrasonography for infraclavicular access to the axillary vein, both static and real-time, are effective approaches [50, 51].

CONTRAINDICATIONS

There is a lack of specific contraindications to catheterization of the axillary vein in the infraclavicular area. The existing contraindications do not differ from those of other access points. A particularly sensible approach would be to perform catheterizations with thick catheters because the intravascular diameter of the axillary vein does not often exceed 1 cm. The insertion of dialysis catheters on the side where the arterio-venous fistula could occur, similarly to cannulation of the subclavian vein, is not recommended [47].

Caution is also necessary for cannulation of the axillary vein in patients with obesity because the visibility of the vein on the screen might not be sufficient for proper cannulation. For this reason, cannulation based on the anatomic landmarks among this population is not indicated [11].

CONCLUSIONS

Many reasons exist for the widespread usage of axillary vein catheterization in the ICU. Large venous vessels located near the upper aperture of the thorax are used for the introduction of multi-lumen catheters, endocavitary guidewires, dialysis catheters, and pulmonary artery catheters. These interventions often focused on one particular patient, whose situation steers clinicians towards catheterization of many central veins. The skill of the application of various accesses to the central veins raises the safety of the patient, especially in the treatment of those with limited possibilities regarding central vein cannulations.

It seems that with the implementation of ultrasonography, infraclavicular axillary vein cannulation has become an equivalent alternative to catheterization of the jugular vein and could be often the first-choice option for vascular access.

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