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Percutaneous ultrasound-guided central venous catheters: the lateral in-plane technique for internal jugular vein access

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ABSTRACT
Purpose: **To describe the possible ultrasound guidance techniques for the insertion of central venous catheters (CVCs), with emphasis particularly to the lateral short axis in-plane technique.**
Methods: **Numerous articles have shown significant benefits of using ultrasound guidance for venous access. Two main approaches to vein puncture are available, when considering visualization of the needle during its entry into the vein under the ultrasound beam: in-plane and out-of-plane, which can be combined with two types of vein visualization, placing the ultrasound probe on the vein long axis or short axis.**
Results: **Advantages and limitations in internal jugular vein (IJV) cannulation for long-term dialysis CVCs are described for the above-mentioned approaches and visualizations. The lateral short axis in-plane technique has virtually no limitations, ensuring most benefits.**
Conclusions: **The lateral short axis in-plane technique should be considered the first-line technique for IJV cannulation.**

Key words: **Catheterization, Central venous catheter, Internal jugular vein, Ultrasound-guided vascular access**

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INTRODUCTION

The remarkable increase in the use of central venous catheters (CVCs) has determined the need for a quick, safe and effective insertion procedure with no or minimal complications. Thus, the choice of the cannulation technique is crucial for the success of the procedure. The blind technique based on anatomic landmarks has been used for years in internal jugular vein (IJV) access, but in the last three decades (since 1984) percutaneous ultrasound-guided technique for IJV access has become the standard practice (1, 2). This real-time procedure, giving knowledge of the IJV position and size, has improved first pass success rate and has also reduced inadvertent injury of surrounding structures and consequently the number of complications, therefore increasing the safety and the efficacy of the procedure (2-6).

The IJV can be visualized either in short axis or in long axis, while the puncture can be performed "in-plane" (when the needle trajectory is included in the plane of the ultrasound beam) or "out-of-plane" (when the needle trajectory is not in that plane) (7). The aim of this paper is to describe the lateral in-plane/short axis technique with emphasis on its advantages versus the traditional out-of-plane technique for placing long-term dialysis CVCs.

ANATOMIC CONSIDERATION OF IJV CANNULATION

In the neck, the IJV most commonly is found anterolateral to the common carotid artery (8, 9). However, the vein may also lie anterior or very rarely medial to the carotid artery (10). In the upper neck the IJV lies superficial below the sternocleidomastoid muscle. Distally, the sternocleidomastoid muscle splits into the sternal (medially) and the clavicular (laterally) heads; this division of the muscle with the superior border of the median third of the clavicle crates a space called "Sedillot's triangle." This space might appear as the ideal entry site to puncture the IJV, because the vein is superficial (1-1.5 cm beneath the skin surface) and there is no muscle over it, representing a perfect ultrasound window to visualize the vein (8, 9).

The right IJV follows a straight (no angulations) course into the superior vena cava (SVC) via the right innominate vein (IV), and generally its diameter is larger than the left IJV (8). In addition, the left IJV has two angulations before arriving into the SVC: the first one is at the level of the junction between the IJV and the IV and the second one at the level of the junction between the IV and the SVC (2, 3, 8).

Remarkably, in patients with chronic kidney disease, the IJV access avoids potential subclavian vein stenosis/thrombosis, which can preclude the ipsilateral upper limb arteriovenous hemodialysis shunt (8). For all these reasons the IJV, in particular on the right side, is generally the first choice access site for CVC.

GENERAL CONSIDERATIONS

CVC complications

Complications associated with CVC insertion range from 5% to 19% (3, 11). They can be broadly divided as insertion and indwelling complications. The insertion complications are vascular injury (arterial puncture, pseudoaneurysm, arteriovenous fistula), hematoma, air embolism, pneumothorax and malposition. Generally, all these complications are limited to accidental arterial puncture when the ultrasound guidance is used (2, 4, 13, 14). Indwelling complications are infection, thrombosis, catheter pinching/kinking and fracture with possible embolization. When the anatomic landmark technique is still used, the number of complications and failure of vein access is still remarkable (12).

Ultrasound IJV evaluation

Preliminary ultrasound evaluation of the vein patency, size, location and possible anomalies is mandatory, thus avoiding futile attempts as in patients whose IJV is absent or thrombosed or who have congenital anomalies. Surrounding structures (subcutaneous tissue, carotid artery, thyroid and lymph nodes) must also be analyzed.

Valsalva maneuver and Trendelenburg position

In all patients the Valsalva maneuver or the Trendelenburg position should be used for increasing the size of the vein, reducing the risk of air embolism during IJV cannulation and consequently improving the success of CVC insertion (13). In patients with fluid overload who present with enlarged IJV diameter, these precautions may not be necessary, especially when the patient has dyspnea.

Ultrasound guidance is mandatory for CVC insertion

Ultrasound guidance can now be considered a mandatory tool for CVC insertion, as indicated by most guidelines (2, 13-15). Surprisingly, this indication was not clearly confirmed by the recent American Society of Clinical Oncology guidelines (16), which rather underscored the necessity of CVC placement by well-trained providers. The surprise came from the fact that ultrasound-guided placement of central venous access has been extensively evaluated in randomized controlled trials, which have been pooled in three meta-analyses (17-19) demonstrating that for IJV puncture it clearly reduces the number of complications, failures and time required for insertion. The anatomic landmark method remains important for emergencies when ultrasound equipment and/or expertise might not be immediately available. Legal issues should also be considered when choosing not to use ultrasound guidance when this technology is available to the physicians performing the procedure (20).

IN-PLANE AND OUT-OF-PLANE APPROACH TO VEIN PUNCTURE

As previously stated, when visualizing the IJV the ultrasound probe can be placed either in the short axis or in the long axis of the vein. Additionally, the needle introduction can follow an "in-plane" (when included in the plane of the ultrasound beam) or an "out-of-plane" (when only a very limited part of the needle can be visualized by the ultrasound beam) approach (7). Therefore, we need to keep in mind the various combinations of short and/or long axis vein visualization and of in-plane and/or out-of-plane needle visualization.

The long axis view of the IJV can be obtained by positioning the ultrasound probe in longitudinal orientation on the patient's neck (the ultrasound probe is parallel to the course of the IJV) with its caudal edge in contact with the clavicle. This view shows the whole course of the IJV and with this probe positioning the needle is inserted "in-plane" at the level of the cranial edge of the ultrasound probe; this allows the operator to visualize the entire length of the needle through the soft tissue and into the IJV (4). However, with this type of technique all the information of the surrounding structures (carotid artery, lymph nodes, thyroid) may be lost. In addition, the IJV access will be at least 3 cm cranial from the upper margin of the clavicle, for the limitation imposed by the ultrasound probe length. This will limit the possibility to transform a short-term into a long-term venous access in dialysis patients. Thus, a lower approach is preferable in dialysis CVC placement.

The short axis view of the vein can be obtained by positioning the ultrasound probe in a transverse orientation (90° rotation from the long axis) on the patient's neck (the ultrasound probe is perpendicular to the course of the IJV). This view allows the visualization of the lateral surrounding structures (carotid artery, lymph nodes, thyroid). With this position of the ultrasound probe, the needle is usually inserted vertically (vertical out-of-plane technique) above the middle part of the ultrasound probe in a position 1-1.5 cm cranial from the upper margin of the clavicle. This allows

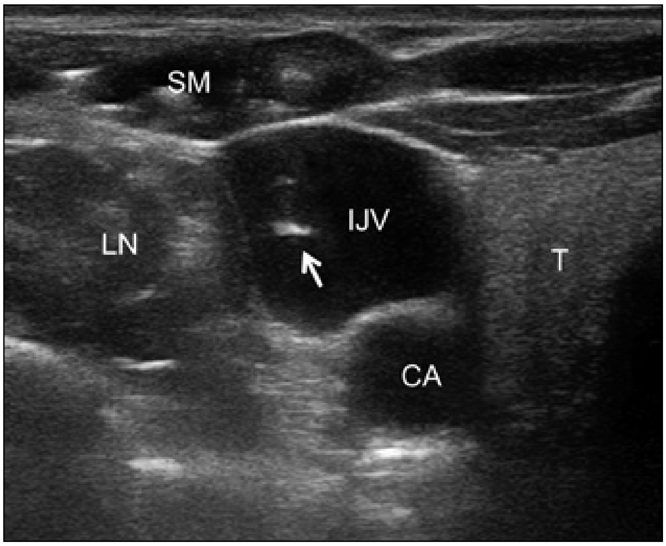

Fig. 1 - *Short axis vertical out-of-plane technique ultrasound image of the right neck area showing the internal jugular vein (IJV), carotid artery (CA), lymph nodes (LN), sternocleidomastoid muscle (SM) and the thyroid (T). The needle is visible in a limited fashion into the internal jugular vein as a bright dot (arrow).*

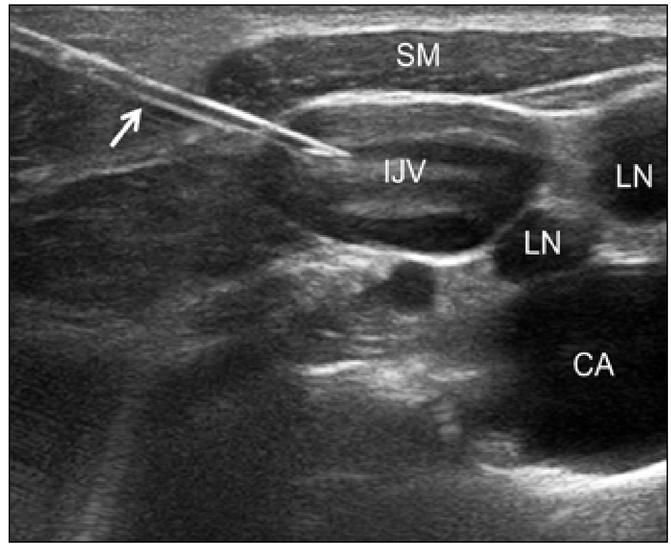

Fig. 2 - *Short axis, lateral in-plane technique ultrasound image of the right neck area showing the internal jugular vein (IJV), carotid artery (CA), lymph nodes (LN) and the sternocleidomastoid muscle (SM). The needle is visible in its entire length with the full tip into the internal jugular vein (arrow).*

the operator to visualize the IJV and simultaneously all surrounding structures and ensuring a caudal vein access (optimal for long-term CVCs with subcutaneous tunneling) (4, 20). However, with this type of technique the operator has a very limited view of the needle (Fig. 1) and continuous adjustments of the probe are necessary to maintain the needle tip within the ultrasound beam, with perfect coordination of needle and ultrasound probe movement.

So, for a "perfect" ultrasound-guided technique, the IJV, its surrounding structures (in particular the carotid artery) and the entire length of the needle have to be visualized simultaneously. But, this is not possible with the two traditional ultrasound techniques previously described.

LATERAL SHORT AXIS IN-PLANE TECHNIQUE

In the nondialysis setting, in particular in the intensive care field, real-time ultrasound needle guidance with an in-plane/long-axis technique has been recommended for optimizing the probability of needle placement (2).

The lateral short axis in-plane technique is a combination of the advantages of both previously mentioned classical techniques, without their limitations. The probe is positioned in a transverse orientation (short axis), with a good view of the IJV and its surrounding structures. The needle is inserted at the level of the lateral edge of the ultrasound probe. This guarantees the visualization of the entire length of the needle during vein access (Fig. 2), keeping the vein entry site 0.5 cm from the upper margin of the clavicle, an optimal position for long-term CVCs. No movements of the ultrasound probe are required during the needle insertion.

ENTRY SITE AND FINAL SUBCUTANEOUS COURSE OF LONG-TERM CATHETER: SHORT AXIS LATERAL (IN-PLANE) *VERSUS* VERTICAL (OUT-OF-PLANE) TECHNIQUE

Lateral and vertical short axis approaches are the preferred techniques for long-term catheters because they allow a very caudal IJV access, generally 0.5-1.5 cm from the upper margin of the clavicle.

The vertical technique is named after its vertical percutaneous approach. Often, the entry site is in the middle part of the sternal head of the sternocleidomastoid muscle, the needle is angled 75°-85° to the skin with an almost perpendicular trajectory and advanced slowly until it reaches the superior wall of the IJV, partially collapsing the lumen and allowing the transluminal passage of the needle tip. With this access not only subcutaneous tissues but in some cases also the sternocleidomastoid muscle (sternal head) may be crossed by the needle.

The lateral technique is named after its lateral percutaneous approach. The entry site can be at the level of the Sedillot's triangle or laterally to the lateral border of the sternocleidomastoid muscle; the needle is angled 30° with a lateral trajectory and then advanced slowly until it reaches the superior-lateral wall of the IJV, collapsing partially the lumen and allowing the transluminal passage of the needle tip. With this access only subcutaneous tissues are crossed by the needle, avoiding the sternocleidomastoid muscle and possible laterocervical lymph nodes.

The anatomic relationship of the IJV with the carotid artery, as demonstrated by Turba et al (9), was at 30° in 73% and at 90° in 5% of the cases, with a superficial anatomical course through the Sedillot's triangle in 97% of the cases (8). Therefore, a lateral, 30° access at the Sedillot's triangle should be considered the safest and most effective percutaneous technique to reach the IJV.

One of the possible CVC complications is pinching/kinking in the subcutaneous tract. This mechanical force on the catheter can lead, over time, to occlusion and fracture of the catheter with possible embolization. This complication has been reported in 1% of the patients in the nondialysis setting (11). To prevent this rare but clinically significant complication, the subcutaneous course of the catheter has to be straighter and less acutely angled as possible. In a previous study we demonstrated that the angle at the level of the IJV access and the initial subcutaneous course of the catheter was different between the two techniques (vertical vs. lateral short axis) (22). In the vertical short axis out-of-plane method, the angle of the catheter in its subcutaneous course was very acute (range 20°-45°), with malfunction due to catheter pinching in 1.1% of the patients. On the contrary, in the lateral short axis in-plane method, the catheter angle was less acute (range 45°-85°), with no cases of malfunction due to catheter pinching.

Such difference in the subcutaneous catheter course and angle between the two methods is due to the entry site. In the vertical approach the catheter from the anterior vein access is laterally diverted in the subcutaneous tissue, determining an acute angle of the catheter (Fig. 3). In the lateral approach the catheter comes out of the vein laterally, without changes in its direction and consequently no acute angle (Fig. 4).

For large bore dialysis CVCs, the possibility of kinking in the vertical out-of-plane approach can be reduced by blunt dissection of the subcutaneous tissues at the vein entry site and by designing a subcutaneous tunnel with a lateral exit site.

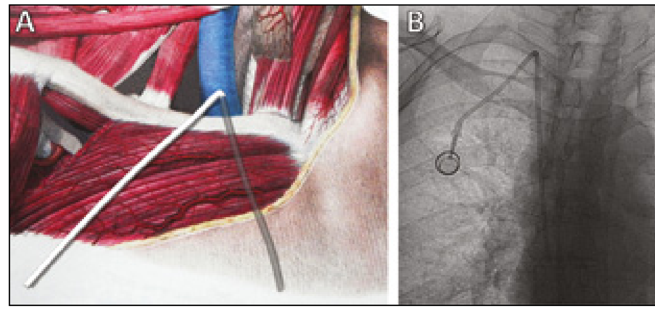

Fig. 3 - ***A)*** *Anatomical drawing and* ***B)*** *chest x-ray illustrating a catheter inserted with the vertical out-of-plane technique with an acute angle.*

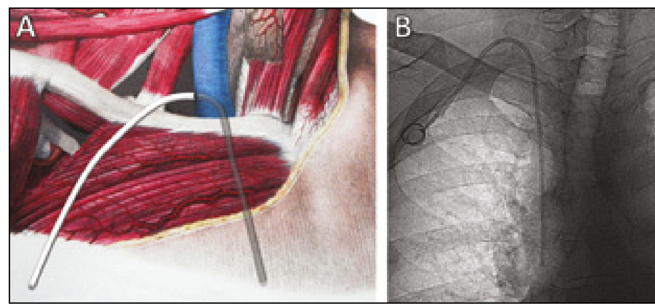

Fig. 4 - ***A)*** *Anatomical drawing and* ***B)*** *chest x-ray illustrating a catheter inserted with the lateral in-plane technique with a smoother angle, reducing the possibility of catheter kinking.*

CONCLUSIONS

Ultrasound-guided central vein cannulation has many advantages, giving the operator the possibility of choosing the most appropriate and safest venous access on the basis of ultrasound assessment, performing a 100% safe insertion, ruling out malpositions or pleuropulmonary damages, during and after the procedure. The ultrasound-guided lateral, short axis in-plane technique for percutaneous IJV cannulation of long-term CVCs should be considered the first-line technique, because it allows a simultaneous view of the IJV, its surrounding structures and the entire length of the needle. In addition, the subcutaneous tract of the catheter has a straighter course with a less acute angle and lower possibilities of catheter kinking.

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