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Review

Application of ultrasonography in central venous catheterization; access sites and procedure techniques☆

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ABSTRACT

Central venous catheterization is commonly performed in clinical practice. Traditional procedural technique is based on anatomical landmarks, but is associated with a high risk of failure and complications. To decrease their incidence European and American societies recommend application of ultrasonography. Preliminary ultrasonographic examination allows for assessment of local anatomical relations as well as vessel morphology (diameter, patency), while real-time ultrasonography increases chances of successful needle insertion.

This paper presents the most common venous access sites and procedure techniques.

Aplicación de la ecografía en la cateterización venosa central; lugares de acceso y técnicas del procedimiento

Palabras clave:
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Cateterización
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RESUMEN

La cateterización venosa central se realiza de manera común en la práctica clínica. La técnica tradicional del procedimiento se basa en referencias anatómicas, aunque ello está asociado a un elevado riesgo de fallos y complicaciones. Para disminuir su incidencia, las sociedades europeas y americanas recomiendan la aplicación de la ecografía. El examen ecográfico preliminar permite la evaluación de las relaciones anatómicas locales, así como la morfología de los vasos (diámetro, permeabilidad), mientras que la ecografía a tiempo real incrementa las opciones de una inserción exitosa de la aguja.

Este documento presenta los lugares de acceso venoso más comunes y las técnicas del procedimiento.

Introduction

Central venous catheterization (CVC) is a commonly performed clinical procedure. It is essential for administration of hyperosmotic fluids, catecholamines, cytostatics, for monitoring hemodynamic state and renal replacement therapy. Traditionally, venous access is obtained by the Seldinger method using anatomical landmarks. However, CVC is associated with risks which include procedure failure and serious mechanical consequences, such as pneumothorax, air emoblisms, cardiac tamponade, or hemorrhage. Pneumothorax[1] or retroperitoneal hemorrhage,[2] although rare complications, may arise during the procedure and possibly result in patient death. It is estimated that the incidence of procedure failure and complications related to traditional anatomical landmark-based technique range from 5% to 40% and 5% to 19%, respectively.[3] These statistics depend on many factors such as the experience of the physician performing the procedure, physical and hemodynamic state of the patient, as well as anatomical vascular variations. Many European and American societies (the American Society of Anesthesiologists, the American Society of Echocardiography, the Society of Cardiovascular Anesthesiologists, the Centers for Disease Control and

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Prevention (CDC)) recommend the usage of ultrasonography (US) in the catheterization of central veins due to the possible risk of serious medical complications.[4–7]

Ullman and Stoelting, as early as the 1970s, used Doppler US to map out the course of the internal jugular vein before catheterization.[8] In 1986 Yonei et al. described central venous catheterization aided by real-time ultrasound (RTUS).[9]

Ultrasonography assisted catheterization is rising in popularity along with technological advancements as well as more common access to US equipment. The usage of US allows not only for preliminary assessment of the catheterized vessel, but also real-time guidance of catheter insertion. Risk of procedure failure at first attempt as well as arterial punctures and hematomas are significantly reduced in comparison with cannulations relying only on anatomical landmarks. RTUS also decreases the total number of procedure attempts and significantly shortens procedure duration.[5,7]

Additionally, RTUS is time-efficient and cost-effective, even when including investment in US devices and instructional courses for personnel.[10,11]

Study technique

An ultrasonographic scanner with a broadband ≥5 MHz transducer (the standard usually being 7.5 MHz), a sterile sleeve for the probe, and sterile gel are necessary in order to performed central venous catheterization.[12]

A preliminary US examination should be performed before antiseptic preparation of the skin surface, to assess the vessel size, its position in relation to anatomical landmarks and arteries, depth under the skin and exclude intraluminal pathologies such as stenosis, septations, or thrombotic material. The procedure may be attempted if the above mentioned contraindications have been ruled out while maintaining a sterile environment. US-assisted cannulation can be performed by one person: the probe should be operated by the non-dominant hand, while the dominant hand is used for the venipuncture. The vessel as well as the needle may be visualized cross-sectionally (*out-of-plane)* or longitudinally (*in-plane*). The majority of veins are accessed with an *out-of-plane* approach, meaning the vessel is visualized on its short axis. The needle in this approach is positioned at a 45° angle relative to the skin surface, at a distance from the probe equal to that of the vessel depth under the skin.[13] This technique does not allow for the visualization of the entire needle, but only its tip appears as a hyperechogenic (white) dot (Fig. 1). The advantage of an *out-of-plane* approach include the possibility to perform the procedure in a limited space (near boney structures or dressings) as well as a stable picture fairly easily obtainable even by an inexperienced ultrasonographer.

An *in-plane* approach requires the needle to be positioned by the lateral edge of the probe at an angle of 30° relative to the skin. This technique allows for visualization of the entire needle's length and precise monitoring of its path through the tissues (Fig. 2). However, acquiring a stable image may be difficult for unexperienced operators. Furthermore, positioning the US probe longitudinally along the vessel requires more space than a cross-sectional placement. Regardless of the chosen approach, aspiration of blood is always required to confirm the presence of the needle in the vessel lumen. Subsequent steps are similar to those in classical venous access. The position of the catheter in the vein as well as any potential mechanical complications may be evaluated by US after the procedure.

However, application of US in CVC may be limited by physical conditions such as subcutaneous emphysema or massive injuries. Therefore, physicians (especially residents) should be familiar with traditional catheterization techniques based on anatomical landmarks.[14]

Fig. 1. An *out-of-plane* approach. The needle's tip appears as a hyperechogenic dot.

Fig. 2. An *in-plane* approach. The needle is visualized in its long axis.

Puncture site characteristics

Typical central venous access sites include the internal jugular, subclavian, and femoral veins. Peripheral veins such as the basilic or cephalic veins are less common. The access site is chosen based on various factors, such as: coagulation state, patient's physique, physical injuries, post-thrombotic changes. The purpose of cannulation and the estimated duration of venous access should also be taken into account.

Internal jugular vein

The internal jugular vein (IJV) is the most commonly chosen vessel for catheterization. It is a continuation of the sigmoid sinus. The vein exits the skull through the jugular foramen following a path near the internal carotid artery, posteriorly at the beginning and lateral to the common carotid artery in the caudal section of the neck (Fig. 3). It is usually located superficially, 2–3 cm under the skin surface, which makes it easy for US evaluation. An important advantage of this vein is its fairly straight extension to the superior vena cava, which decreases the risk of bending or looping of the catheter. The size of the IJV may vary greatly between patients and the cross-sectional area between the right and left veins in the same patient may differ even up to 850%.[15]