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Ultrasound-guided venous cannulation in a critical care unit

Punção venosa guiada por ultra-som em unidade de terapia intensiva

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ABSTRACT

Use of ultrasound introduced as part of intensive care therapy makes viable bedside invasive procedures and diagnosis. Due to portability, combined with team training, its use guarantees less complications related to insertion, as well as patients' safety. It also reduces severe conditions related to the catheter, such as pneumothorax among others. Probably, in a near future, as purchase of ultrasound equipment becomes easier and team training more adequate, this tool will become essential in daily clinical practice.

Keywords: Ultrasonography; Echocardiography; Intensive care

INTRODUCTION

In the intensive care setting, ultrasound guided venous cannulation has now become an essential procedure for critically ill patients, however it has risks inherent to its insertion as well as permanence. To reduce risks related to insertion, the applicability of ultrasonography to aid insertion of a central and peripheral venous catheter will be discussed. This is a technology available in our daily clinical practice with some advantages in intensive care units, such as absence of exposure of patients to radioactivity, reproducibility, low cost, practicality and portability. Further, the method is not invasive and provides important bedside information, as well as support in invasive procedures.(1-4) Initially, its use was restricted to medical radiologists and echocardiographers. However, universalization of the method and standardizing of training by some societies such as the *American College of Emergency Physicians* (ACEP),(5) *European Federation of Societies for Ultrasound in Medidicine and Biology*(6) and *World Interactive Network Focused on Critical Ultrasound* (WINFOCUS,(7) furthered implementation in the developed countries while it is still incipient in developing countries such as Brazil. In the last decade, applicability of this method was not merely restricted to the intensive care setting, but also to the pre-hospital emergency system, intra-operative and during cardiac arrest (CA).(8-10) Another interesting point is the growing number of publications related to the method in indexed journals, stressing its importance as a complementary tool for care of the critically ill.(11)

BASIC PRINCIPLES OF ULTRASOUND

Sound waves are mechanical vibrations that induce alternate refractions and compressions in any physical medium they cross. Sound waves are defined by their amplitude and frequencies.

The classical image of general ultrasound or echography relies on echoes and is based upon the principles of reflection, refraction and dispersion of energy of ultrasound waves. The ultrasound equipment (US) generates an electronic wave and the piezoelectric transducers transform the electric wave into a mechanical wave. US is used in frequencies between 01 MHz and 50MHz. Attenuation of the echographic wave depends on the frequency of repetition of the wave peaks and valleys. Frequency of insonation also controls axial resolution of the echographic image. The greater the frequency the smaller the distance between peaks and valleys of the wave, which is called wave length that establishes the image axial resolution. Axial direction is based upon a model of lines to display tissue isonation. Depth of US wave penetration in the body is directly related to wave length - a short length wave has a lesser penetration into tissues when compared to longer waves. A linear transducer creates parallel beams that penetrate into the tissue perpendicular to the skin, which is why they are preferred for structures such as veins and arteries. The sectorial transducer creates divergent beams, creating an angular sector, that is why linear trasducers present greater axial resolution.

ULTRASOUND GUIDED VENOUS CANNULATION

Today, in the USA more than 5 million central venous catheters are introduced, associated with a complication rate of about 15%.[12] Main complications are arterial puncture, pneumothorax, hematoma and to a large degree , failure in catheter insertion of up to 35%. A series of factors are related to this percentage, among them operator experience and the patient's anatomical aspects (morbid obesity, coagulopathy, urgency of the procedure, etc.) Noteworthy about anatomy and position of the internal jugular vein in relation to the carotid artery, discloses that 50% of the times it (jugular vein) is positioned anterior to the carotid artery.[13-17] With use of US its location can be assessed, as well as the diameter and adverse conditions such as venous thrombosis, facilitating insertion and or choice of puncture site (Figures 1 and 2).

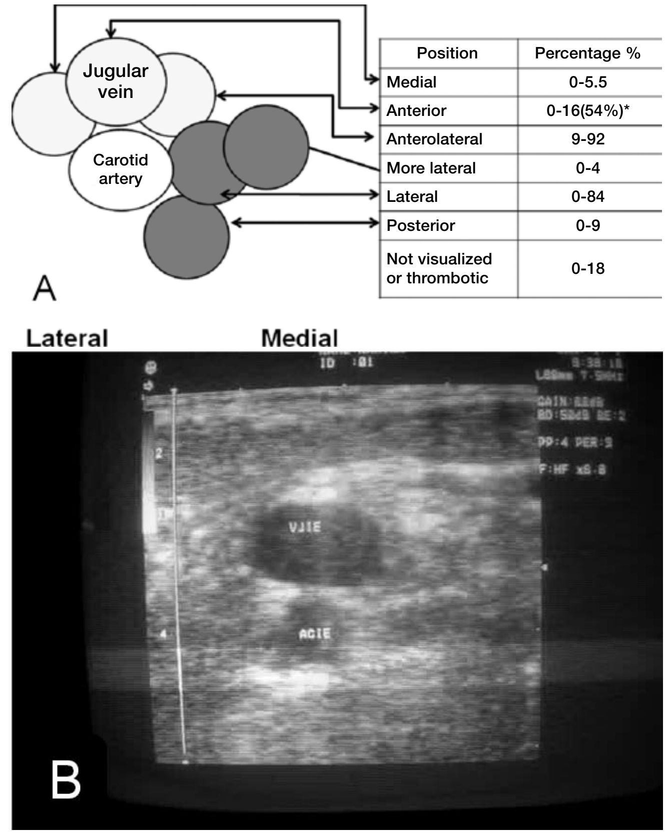

Figure 1 – A - Anatomical variation of the jugular vein[13-16]; (*) 54% are located anterior to the carotid artery; B - Ultrasound image site of the internal jugular vein.

Based on two meta analyses,[18-19] the American Agency for Healthcare Research and Quality) published in 2001 a recommendation for use US guided cannulation. It is one of the 10 main practices of safety ands improves patients' care.[20] US guided venous cannulation prevents one puncture accident for every seven central accesses (number needed to treat (NNT=7) and prevents one case of failure in the insertion for every five trials (NNT= 5). Similar to recommendations of the North American agency, the British National Institute for Clinical Excellence included in 2004, these recommendations in its guidelines.[21] Another factor related with this procedure would be the cost/effectiveness analysis of implementing training of a team and acquisition of the equipment, Reviewing literature, we found the work of Calvert and Hind,[22] who by an analytical model of cost/effectiveness for each thousand catheters inserted, saved 2 thousand sterling pounds, when compared to usual insertion. Development of new equipment and cost reduction in a near future will foster utilization of US as a routine practice in the intensive care setting.

To aid cannulation the probe must preferably be the straight linear (Vascular probe 5-10 MHz), as they have

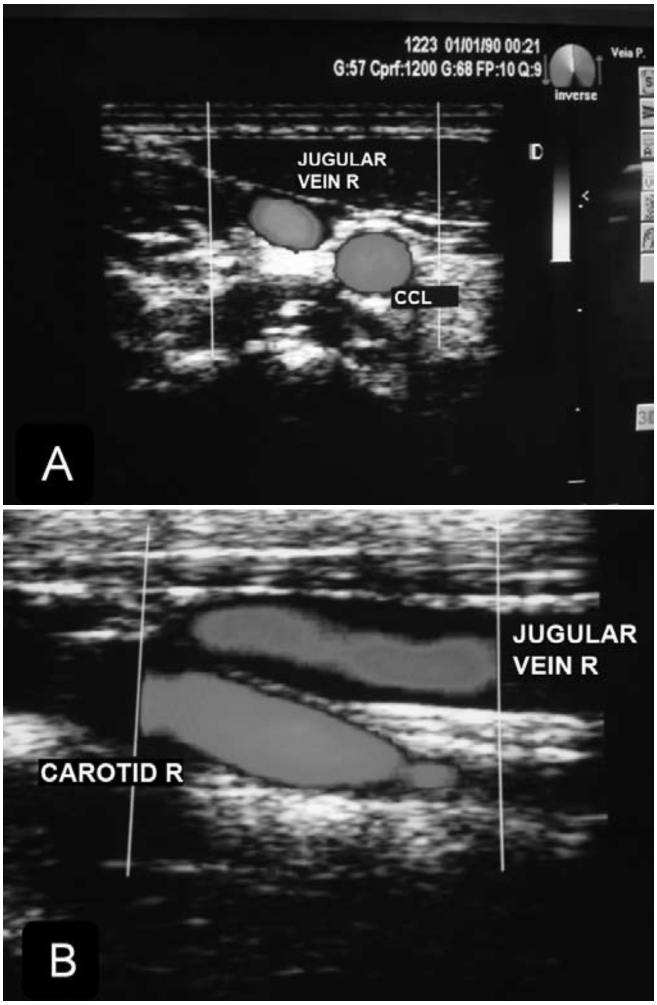

Figure 2 – A - Cross sectional incidence with color doppler (short axis); B - Longitudinal incidence with color doppler (long axis).

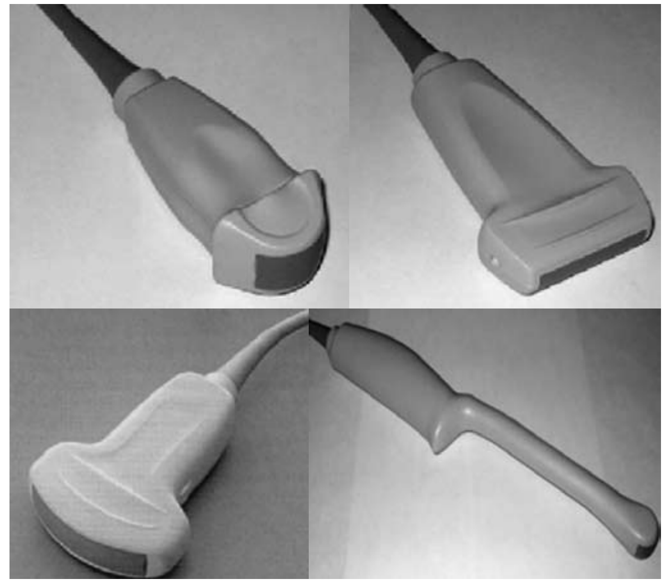

Figure 3 – Types of probes, respectively: microconvex (2.5 MHz), linear (5-10MHz), convex (3.5-5.0MHz), transvaginal.

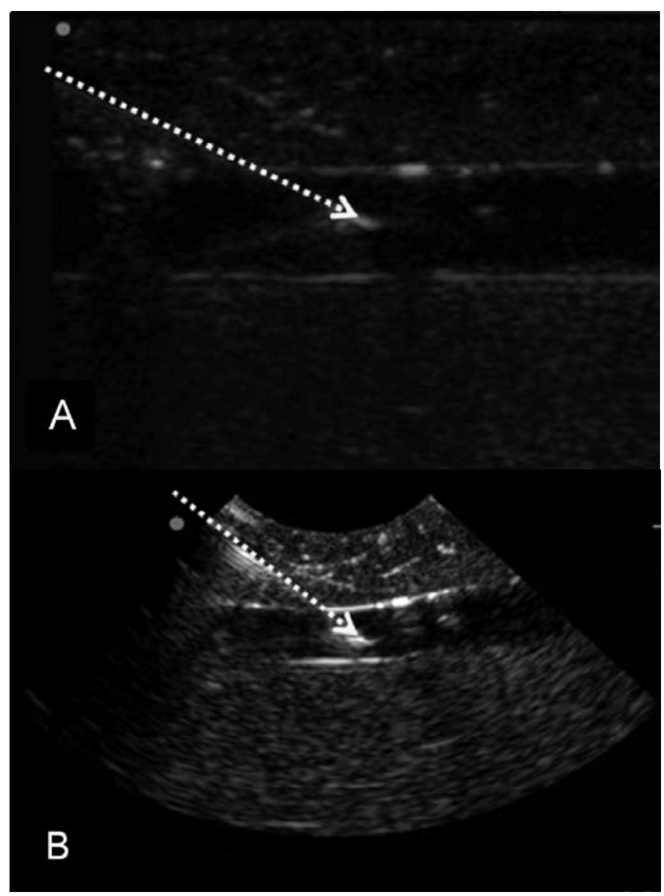

Figure 4 – A - Longitudinal incidence (experimental puncture model) using linear probe (vascular); B - micro-convex probe (sectorial echocardiograph.

high resolution and good penetration in tissue. However, as described in literature any type of probe may be used including the transvaginal (Figures 3 and 4).[23-25] Differences between probes are based upon positioning of the quartz crystals and emission of US waves at different frequencies (Hertz) and distance between them. The higher the probe's frequency, the greater the resolution, however lesser the depth. The lower the frequency, the greater the depth, the lesser the resolution. The possibility to change frequency and distance of the waves in the same equipment must be highlighted.

Insertion through the US may be guided by two wave modes: the B mode (Bright) or through the Doppler mode, transformation of US waves reflected from a moving object, for instance, blood into an audio or color signal. Due to lack of availability of US with Doppler mode in all equipment, a longer learning curve and a longer time of insertion, our review is restricted to the two-dimensional mode.

The technique must follow the same steps of conventional cannulation of the central venous access: operator and patient asepsis and antisepsis, placement of sterile drapes, use of sterile devices protecting the probe (sterile glove or specific device for probe, placement of sterile gel between interface of the probe of patient body surface, between probe and sterile device to ease wave propagation and reduce artifacts). The technique may be carried out with two operators, that is to say, one positioning the probe and the other doing the puncture or one operator performing the entire procedure.

The static puncture technique,[26] that is to say, the anatomical assessment of the vein in which the catheter will be inserted and outline of the puncture point are carried out. Once the puncture point is outlined, puncture is performed. Another way to perform puncture is the dynamic technique, as it permits real time visualization of the catheter with immediate assessment of complications. In both techniques, orientation of the probe in relation to the anatomic structures may be with a cross-sectional axis (short axis) (Figure 4) or longitudinal axis (long axis) (Figure 5A). The differentiation of the anatomical structures in this case, the visualization of the jugular vein and carotid artery are made through compression movements, using the probe (compressibility sign of the venous system) (Figure 5B).

Differentiation between both structures must not rely only on pulsatility, because not everything that pulsates is an artery. Other form to differentiate these vessels is compression of the liver (hepatojugular reflux) and by observing engorgement of the venous system. This method (US) permits to assess thrombosis of the potential puncture segments, thereby avoiding complications. Some bedside maneuvers facilitate puncture: Trendelemburg position, Valsalva maneuver (increase of intrathoracic pressure), among others.

The vein must be positioned in the center of the monitor and needle insertion at a 45 degrees angle in relation to the probe and equidistant from this with the vein must be carried out, similar to the Pythagorean Theorem (Figure 6).

Once skin is overcome in the cross-sectional direction with the needle, it must progress towards the anterior wall of the vein, with its movement as a reference. Non-visualization of the needle or non-visualization of the movement of structures on the monitor, probably points to non-alignment of the probe in relation to needle insertion. In this case, the needle should be pulled back and a new angulation and insertion must be made. After assuring that the needle is inside the vein, by blood aspiration with the plunger, the later is withdrawn and the line is introduced by the usual technique (Seldinger). Advantage of the cross- sectional axis (short axis) technique is lesser time of the learning curve and possibility to visualize smaller veins. Nevertheless, ACEP[5] recommends the longitudinal axis due to better visualization of the guide-line (Figure 7), when maybe, there is a lesser a perforation of the vein's posterior wall. Some equipment, currently make both axes simultaneously available. After central venous cannulation and its due securing, control X-rays of the chest are carried out also a complementary lung ultrasound to discard pneumothorax.[27-28]

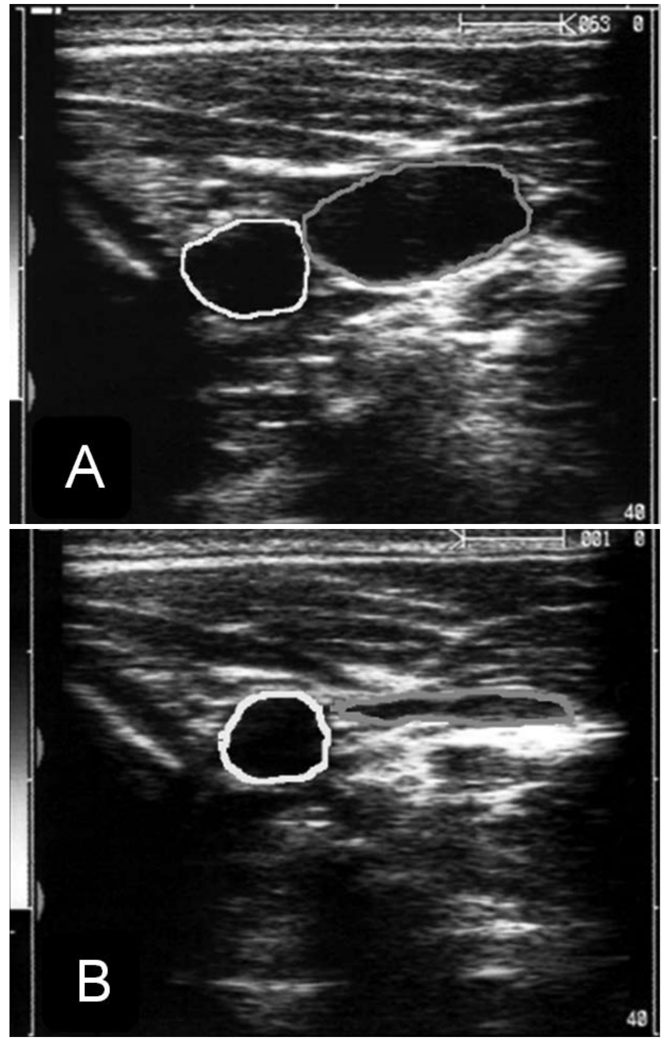

Figure 5 – A - Cross sectional axis (short axis) showing the right carotid artery in yellow and the internal jugular vein in green; B - Signs of collapse of the internal jugular vein upon performance of probe compression (compressibility sign).

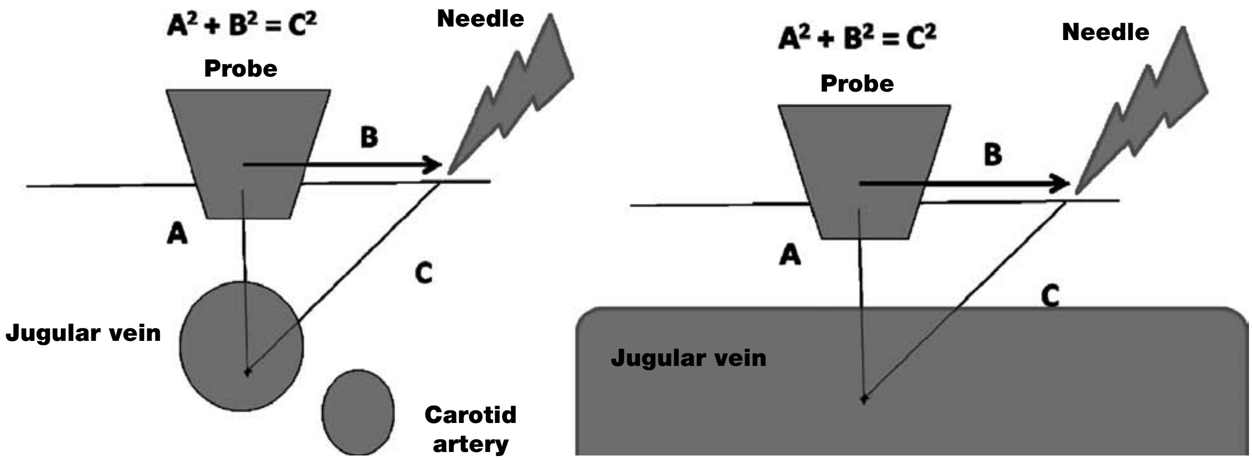

Figure 6 – A - Needle positioning and insertion, cross-sectional axis; B - Longitudinal axis.

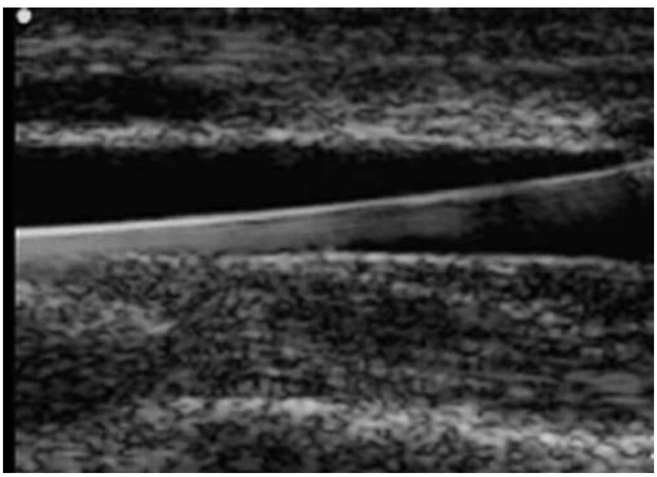

Figure 7 – Guide-line insertion longitudinal axis.

The internal jugular vein is the preferred access way for ultrasound-guided venous cannulation, however the subclavian vein has some peculiarities. Visualization of the subclavian vein by infraclavicular projection is made difficult by the clavicular acoustic shadow, thereby the dynamic puncture technique is unviable. The static technique should be used, outlining the puncture site. An alternative would be puncture by the supraclavicular pathway at the emergence of the subclavian vein with the jugular vein. However, it is not often used today, due to needle orientation towards the pleura and elevated chances of puncture accidents. An approach described in literature is puncture of the axillary vein as alternative to the subclavian vein, since it is easily visualized with US, more laterally located, associated with a longer distance between the probe and clavicula make dynamic insertion easier, with lower complication rates than the traditional method.[29-31]

Peripheral veins should be used as first option in an emergency setting, however, some clinical situations, for instance, edematous patient, obesity, among others, make the insertion difficult. US, preferentially the linear ones (high resolution and discernment of structures with less than 1mm) make possible catheterization, using cross- sectional or longitudinal axes of basilica, cephalic and or axillary veins. Care must be given to the pressure applied on the probe to avoid collapse of the structure to be visualized (Figure 8).

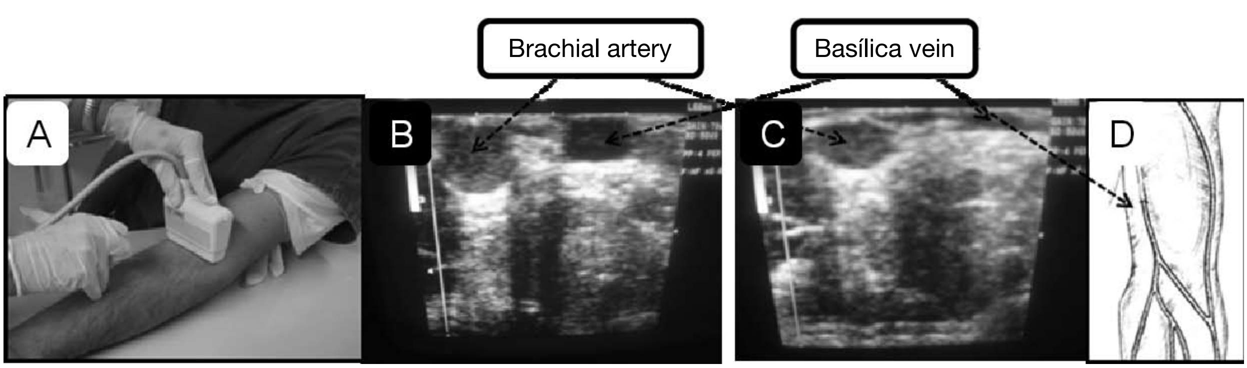

Figure 8 – A - Performance of the procedure by the nursing team; B - Anatomic location cross sectional axis; C - Compressibility maneuver of the venous system; D - Portrait of the venous system.

CONCLUSION

Utilization of ultrasound warrants precise visualization of the target, direct visualization of the needle and guide-line's progression, reduces puncture attempts, improves success rates of insertion, minimizes catheter related complications and reduces insertion time, mainly in patients with a difficult vascular access. Therefore, the disadvantages of equipment cost, team training time and interpersonal barriers represent obstacles to be overcome in view of the method's benefits.

RESUMO

A utilização da ultrassonografia inserida no contexto de terapia intensiva possibilita a realização de procedimentos invasivos e diagnósticos beira-leito. Através da portabilidade dos equipamentos atuais, associado ao treinamento da equipe, sua implementação assegura diminuição das complicações relacionada á inserção assim como segurança aos pacientes. Sua implementação reduz complicações graves relacionada ao cateter, como pneumotórax e lesão vascular, entre outras. Provavelmente, em um futuro próximo, com a facilitação de aquisição de equipamentos de ultra-som e treinamento adequado da equipe, esta ferramenta se tornará indispensável na prática clinica diária.

Descritores: Ultra-sonografia; Ecocardiografia; Cuidados intensivos

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