

Ultrasound guided cannulation of dialysis access

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Abstract

Vascular access is the key part of haemodialysis (HD) treatment, as this is not possible without a functioning access. The use of the arteriovenous fistula (AVF) has fewer complications, lower mortality and fewer hospital admissions compared to central venous catheter (CVC). However, although guidelines recommend AVF as the access of choice, access-related cannulation complications may lead to greater morbidity. Most guidelines recommend using Doppler ultrasound (DU) to surveil the AVF for HD, but its use must not only be limited to surveillance as it can also be used for needling. Therefore, among those techniques at our disposal today, one of the best tools for AVF needling is Doppler ultrasound (DU). Despite the lack of evidence regarding ultrasound-guided needling of AVF, it is becoming part of our usual practice arsenal in many HD centres. Its use has allowed needling results to improve and the number of complications to be reduced versus traditional ‘blind’ needling. It should be remembered that even though it is very useful for the daily work of dialysis nurses, as in the case of other techniques, it requires adequate, specialised and long-term training to acquire competence in using it. For example, it is important to learn some concepts and terminology that should be known and, at the same time, be highly familiar with different techniques available. Two types of needling techniques are described using US assistance: US-guided needling, where DU is used to make a map of the vessels which can be utilised and to mark the best site to insert the needles once the mapping is done; and real-time US-guided needling, the simultaneous manipulation of the probe and the insertion of the puncture needle through the slice plane of the ultrasound device. Regarding the real-time technique, there are two approaches: out of plane (the probe takes a transversal image of the needle) and in plane (vessel axis aligned with the probe and the needle in the same plane) To ensure successful needling and to maximise reproducibility, especially with tight deadlines and staff resources, nursing staff need to follow some important recommendations that include safety and the use of the method, both for them and the patient. In this way, ultrasound-guided needling becomes a tool with enormous potential utility, but practical training is as important as knowing the technique.

Keywords

Cannulation, AV fistula, dialysis access, ultrasonography – Doppler evaluation, prosthetic grafts, techniques and procedures

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Vascular access (VA) is the key to effective haemodialysis (HD), as without functioning access, treatment is not possible. Vascular accesses for haemodialysis can be synthesised in two large groups: arteriovenous fistulas (AVF) and central venous catheters (CVC). At the same time, AVF can be native (nAVF) and prosthetic (pAVF). Fistula creation and maintenance have become more complicated in the last few years due to the increase in the age of the patients initiating HD and to the consequent increase in comorbidities, such as vascular as well as cardiac problems and diabetes, which have a well-known negative effect on the state of the patient’s vascular tree.

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Table 1. Created Vs Usable Arteriovenous Fistula.

Author	Technique (physical examination vs USS or angiography, etc.)	AVF creation rate (%)	Percentage of usable AVF
Allon et al. ¹⁰	USS	34/64	16/34
Fullerton et al. ⁹	USS + DOQI	23/39	79/71
Huber et al. ⁸	USS + angiography	90	71
Patel et al. ¹¹	USS + angiography	61/73	73/57

The table indicates in the first column the name of the author and the year of publication of the articles⁸⁻¹¹ the second column respectively indicates for each article the technique for preoperative mapping used; the third column indicates the percentage of fistulas made by comparing the methods used for pre-operative mapping; the fourth column indicates the percentage of usable fistulas compared to the percentage of fistulas made. It is evident in several articles how the percentage of fistulas that can be used does not correspond to the same percentage of fistulas made

In addition, the haemodialysis population is progressively changing. The last 2017 ERA EDTA Register Census data shows how EU haemodialysis patients, over the age of 65, comprise a total of 41% of patients with an incident percentage of 45%.¹

The use of AVF, whether native or prosthetic and both in HD centres and home HD (HHD), has more favourable associated results versus CVC use in terms of lower mortality, a lower percentage of technical failure in HHD cases and fewer hospital admissions.²⁻⁴ However, it is also known that these results may be limited by patient-related factors.⁵

There are studies showing that in the first 6 months of a fistula's life, there are many cannulation-related complications, such as needling failures, use of catheters and haemodialysis with a single needle.⁶

In a recent publication, Pisoni et al.⁷ relying on the study DOPPS data, has highlighted significant differences between the native vascular access site and the success in its use in the DOPPS participating countries. However, in Japan, there still remains a high percentage of native AVF (91%) and distal sites (95%), whereas in Europe 69% are native AVF and 66% distal AVF, and in the United States, following the implementation of the Fistula First programme, 68% are native AVF, with a proximal AVF prevalence (68% vs 32% distal).⁷

Bearing in mind the numerous studies based on the use of all the tools, native vascular access creation should be given maximum priority⁸⁻¹¹ at the percentage of created AVF, but often is not the same percentage of usable AVF (Table 1). All this leads to observe that AVF, often very hard to create and difficult to use, would not reduce the use of central venous catheters.

However, although the guidelines¹²⁻¹⁴ recommend AVF as the access of choice, access-related cannulation complications may lead to greater morbidity.⁶ In many cases these complications may lead to hospital admission, the need for complementary examinations of the access and even to access loss. It must be remembered that when needling of the vascular access for HD is described, three techniques to do it are detailed: area technique, rope ladder and buttonhole. The first of these, area technique, is the least recommended as it causes a greater number of complications

and its use is not recommended in clinical guidelines. These recommend rope-ladder as the technique of choice if there is a good vascular access with a good needling segment. Regarding buttonhole technique, it is recommended for vascular accesses with specific characteristics (short needling segment, presence of pathology that delimits the needling area, internal devices to guide needling, etc). Furthermore, most guidelines recommend using Doppler ultrasound (DU) to surveillance the VA for HD, but its use in vascular access must not only be limited to surveillance but also to needling the access.

Therefore, one of the best tools for AVF cannulation among those at our disposal today is Doppler ultrasound (DU).¹⁵ Despite the lack of evidence regarding ultrasound-guided needling of arteriovenous fistulae, DU is becoming an usual practice in many HD centres. Its use has allowed needling results to improve and the number of complications to be reduced versus traditional 'blind' needling.¹⁶ Some studies have been conducted on different cannulation techniques, such as those by Marticorena et al.,¹⁷ where needling is performed under US control by trained nurses in order to compare metallic versus plastic cannulae. In another article, Marticorena et al.¹⁸ themselves describe the development of competencies that must be acquired by nursing staff to use ultrasound to assess and cannulate the vascular access for HD. They describe three levels of competence: basic, intermediate and advanced. Competences are acquired through theoretical and practical sessions, as well as through training with simulation models before using it with patients. The authors comment that people new to the use of this tool should be aware that it takes daily use of ultrasound at the patient's bedside to acquire these competencies, and that around 500 ultrasound-guided needling's are required to reach the maximum competence described in the article.

Thanks to the expansion of the technique and its increasing use as a tool by nephrology nursing staff, publications have begun to appear dealing with cases in which this technique has been used by nurses in complex fistulae.¹⁹ With reference to patient perception, one of the main reasons why the patient rejects the creation of a fistula is fear of cannulation failure, pain and the appearance

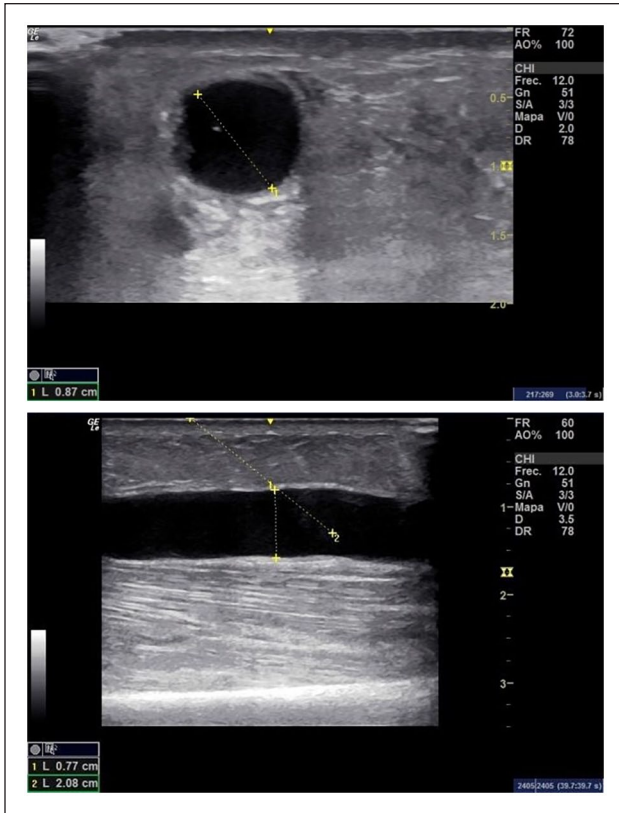


Figure 1. Diameter, depth and flow assessment.



Figure 2. Site marking.

of haematoma.²⁰ Other complications apart from haematoma, like multiple needling attempts, or extravasations, increase patient dissatisfaction and evidently also increase treatment costs.²¹

All the above mentioned can be improved or avoided with the use of US.

Needling types with US assistance

US-guided needling

This is the use of ultrasound to make a map of the vessels which can be utilised by the access. Once the mapping has been done, the best site to insert the needles can be marked. In this technique, ultrasound is not really used during cannulation. To sum up, the steps taken in this technique are:

Before proceeding with cannulation, it is necessary to:

1. Establish the vein segment;
2. Assess diameter, depth and flow (Figure 1);
3. Choose the site, marking it with a dermatographic marker (Figure 2);
4. Choose the needling technique: rope ladder (preferably), or buttonhole technique. It is advisable to avoid area needling technique²²⁻²⁴;
5. For prosthetic AVF, it is mandatory to use the rope-ladder technique, as no strong scientific evidence supporting the use of buttonhole for this type of AVF has been generated yet.

Real-time US-guided needling

Real-time US-guided needling consists of the simultaneous manipulation of the probe and the insertion of the puncture needle through the slice plane of the ultrasound device. The insertion is controlled in real-time, enabling the needle to be re-directed. One hand is used to insert the needle from one of the sides of the probe, while the other hand controls the needle trajectory with the probe. Both tools are handled with care to maintain the needle trajectory in the slice plane and direct it to the objective.

This technique allows for greater freedom when choosing the entry path and enables the nurse to adjust the trajectory during cannulation. However, before beginning any procedure, it is essential to define and locate the vessel precisely. For this, the area where it is located must be carefully examined using ultrasound.

The greatest difficulty that nurses encounter when putting this technique into practice is hand-eye coordination, therefore it is beneficial to create a visual map of the access anatomy.

Three elements must be interrelated when performing real-time cannulation with ultrasound: the ultrasound plane, the vein and the needle. The relationship between the plane and the vessel can be transversal or longitudinal,^{15,16} while the relationship between plane and needle can be out of plane or in plane.^{25,26} The combination of the plane-vein-needle relationship defines the approach.



Figure 3. Vessel placement (simulation model).

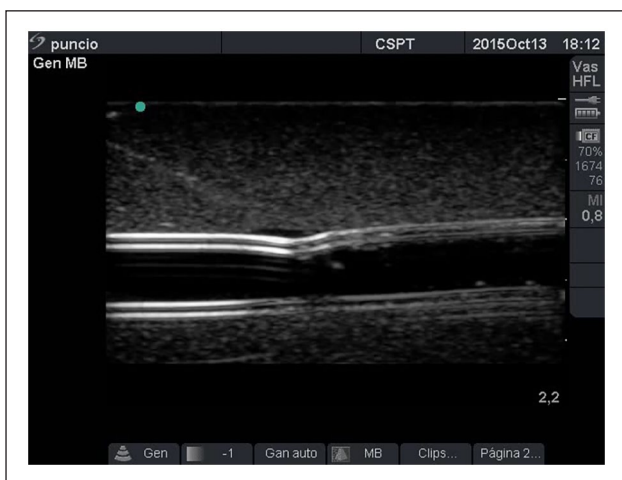


Figure 4. Longitudinal image of the vessel (simulation model).

Relationship between ultrasound plane and vein

-Transversal or short axis: the beam of ultrasounds cuts the vessel perpendicular to the long axis of the vessel, thereby obtaining a circular section in the image. When a vessel is examined transversally, it must be placed in the centre of the circular section of the vessel located in the centre of the image (Figure 3). The main advantage of this plane is that allows a broad panoramic view of the vein and adjacent structures to be obtained. This approach allows operators to avoid undesired needling of risk structures like arteries and nerves.

-Longitudinal: the ultrasound beam cuts the vessels parallel to the long axis of the vessel, thereby obtaining a longitudinal image of the vessel (Figure 4). When a vessel is examined longitudinally, the plane must be placed exactly in the middle of the vessel, to

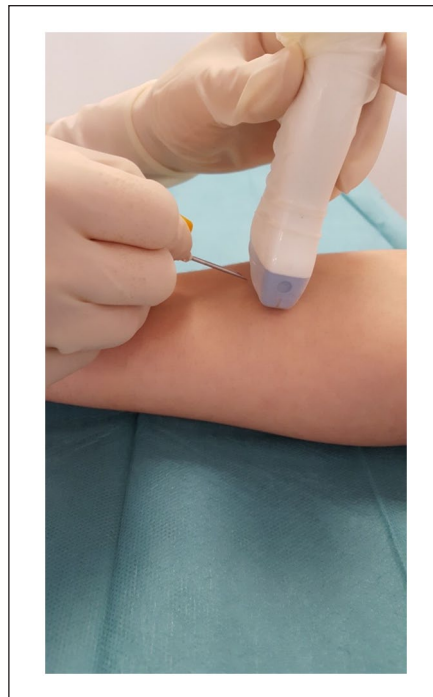


Figure 5. Out of plane approach.

ensure the widest area, just as in any circumference. The advantage of this view is that it allows cannulation in plane and gives a view of the needle throughout the segment.

Relationship between the orientation of the probe with respect to the needle

-Out of plane: the probe takes a transversal image of the needle, the vessel is circular as it is transversal to the probe (Figure 5), and the needle appears as a bright point. The main disadvantage is that it is not possible to determine exactly which segment of the needle is being seen. Consequently, in order to locate the needle tip, a series of search manoeuvres must be performed, such as the sliding manoeuvre and the inclination or tilting of the probe.

-In-plane: with the vessel axis aligned with the probe, and the needle in the same plane (Figure 6), it is possible to obtain a complete image of the needle, thereby allowing the needle tip to be seen throughout its trajectory as it progresses through the tissue. This kind of approach is generally considered to be the approach of choice for US-guided techniques.

Out of plane insertion technique. When the transversal out of plane approach is used, the needling site in the skin can be calculated with the triangulation principle (Figure 7). If an entry angle into the skin of 45° is used, the distance

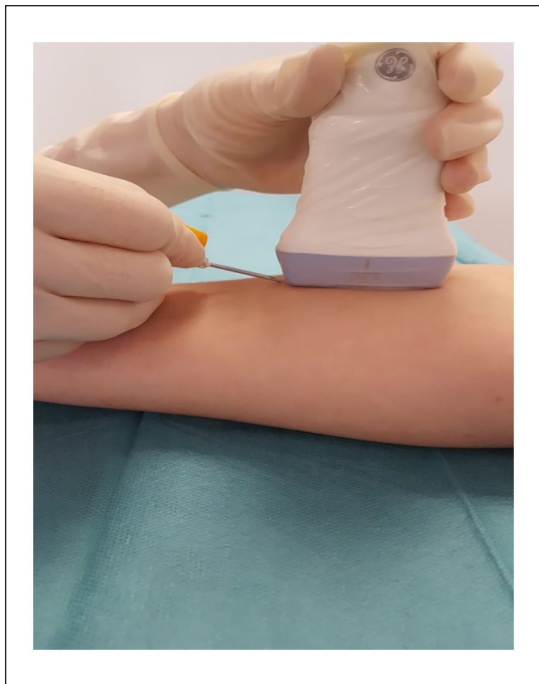


Figure 6. In plane approach.

between the probe and needle insertion point will be approximately the same as the depth at which the vessel is to be found.²⁷ By using this simple principle, the vessel can be needled successfully although the needle trajectory cannot be controlled. The disadvantage is that if the angle calculation and the depth are not exact, the adequate trajectory of the needle can be wrong and undesired structures can be needled.

In plane insertion techniques. By using the longitudinal, in-plane approach, the needle can be directly and continuously controlled but the operator must have extremely good manual skills. The most closely centred longitudinal plane of the vein is obtained in the vessel. The needle is introduced laterally to the probe right next to the edge. In this case there is no recommended distance for the probe when needling, as this will vary depending on the longitude of the probe and the depth of the vessel. What is fundamental is to keep it in the centre and keep the hand holding the probe still while inserting the needle. The only hand that must be moved is the one holding the needle, which must be inserted into the skin in complete alignment with the centre of the probe. If the needle cannot be seen during insertion, it is highly likely that the probe or the needle insertion plane has been altered. In this case, the needle must never be introduced further: it must be withdrawn, and the plane and needle repositioned before reinserting the needle. A fundamental

factor that is sometimes forgotten when inserting in plane is that the needle will be seen better if the ultrasound indices more tangentially on the needle.

However, any randomised and controlled study can define the superiority of one of these approaches. So it seems correct to affirm that the best approach is the one the operator has more experience and is more familiar with.

Recommendations

First of all it should be remembered that even though ultrasound guided cannulation is very useful for daily work of dialysis nurses, as other techniques requires adequate, specialized and long time training to get the competences to use it.¹⁸

To ensure successful needling and to maximise reproducibility, especially with tight deadlines and staff resources, it is necessary to follow some important recommendations that include safety and the use of the method, both for the patient and nursing staff.

1. Make sure that:
 - a. The patient feels comfortable and placed in a similar position to that of the haemodialysis session.
 - b. The operator feels comfortable with the bed at the right height, the probe and its controls are easily accessible and there will be sufficient space and some adequate ambient lighting.
2. Identify the course and the depth of the vein.
3. Choose the skin entry site and orient the probe as you prefer.
4. Disinfect the cannulation area and put on the tourniquet.
5. Use anaesthetic, if/where necessary.
6. Use a probe cover or clean the probe with sterile wipes.
7. Put on a sterilised gel.
8. Place the probe on the skin gently, avoiding unnecessary pressure, to not modify distances between the probe, the skin and the vein.
9. Make sure the probe is oriented correctly.
10. Insert the needle in the skin with a safe movement, possibly putting two fingers on the tube, close to the needle wings, to have more freedom of movement.
11. Direct the probe to frame the needle perfectly and make sure you follow it during its trajectory in the vein.
12. If the needle is not perfectly framed, stop: do not continue. Withdraw it progressively backwards and re-direct the probe to frame it perfectly. This is really important to avoid possible complications.

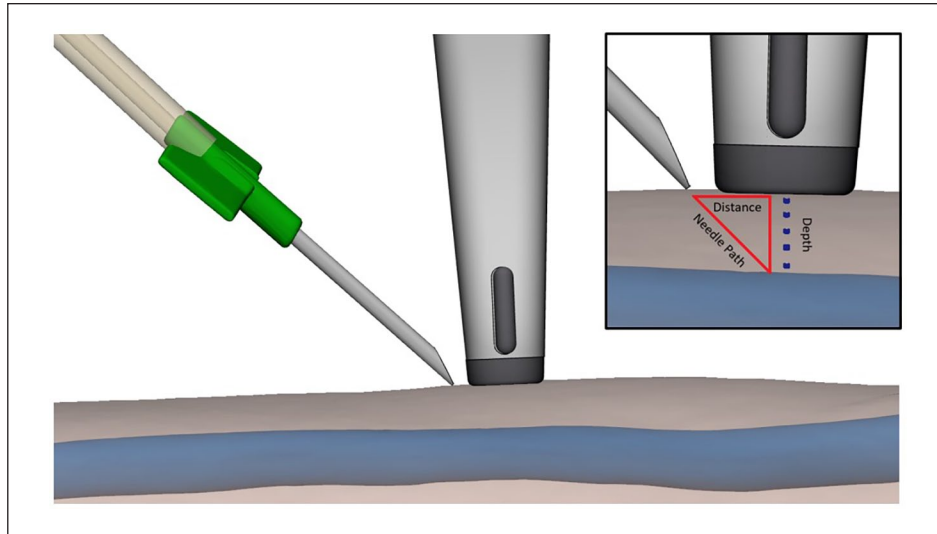


Figure 7. Triangulation principle.

13. Make sure the tip of the needle is in the middle of the vein. The blood in the tube will confirm it has been inserted correctly.
14. Gently clean the gel from the skin, avoiding sudden movements that can move the needle and safely anchor it to the skin

Technology provides us with different tools to use with ultrasound and in US-guided cannulation, including a portable probe as big as a smartphone which has a high-frequency probe with excellent resolution and even a highly manageable wireless probe.

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