Upper limb anatomy and preoperative mapping

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Abstract

Vascular access is absolutely essential for haemodialysis due to its relationship with quality of dialysis and associated morbidity. Therefore, it must be monitored and continuously surveilled from the moment it is created to prevent failure in maturation and thrombosis. Multidisciplinary collaboration is necessary when the main aim is to achieve the adequate vascular access flow with the fewest possible complications. The starting point, and probably the main one, is vascular access planning. This planning requires both a deep understanding of the anatomy of the upper limb and enough skill to examine it by Doppler ultrasound. The aim of this article is to review the anatomical and haemodynamical concepts of the arterial and venous vascular tree and explain how to perform ultrasound mapping, optimising the technical resources provided by this tool. Likewise, adequate access creation criteria that minimise the risk of failure and associated complications will be discussed.

Introduction

Renal replacement therapy is currently the treatment used for patients with end-stage renal disease; hence, as most patients will require haemodialysis, clinical workup of vascular access (VA) is pivotal for the patient with chronic kidney disease. VA relevance is pivotal for two reasons: firstly, it is a key factor in receiving high-quality dialysis; secondly, an important part of the patient's morbidity and mortality depends on VA efficiency. Thus, it has become progressively more important to optimise all the steps related to VA survival and morbidity: VA creation, monitoring and surveillance to prevent thrombosis due to stenosis and early diagnosis of complications leading to significant morbidity.[1]

Multidisciplinary collaboration between all health professionals involved in presurgical mapping, implantation, follow-up and treatment of complications (nephrologists, vascular surgeons, interventional radiologists and nephrological nursing) is necessary. This collaboration must be close and fluid, and, of course, it must be adapted to each centre's policy, resources and organisation. However, the nephrologist depends highly on other specialist's skills – a dependence which often leads to delays in diagnosing and treating the pathology associated with VA morbidity. Therefore, the availability of a point-of-care of ultrasound or portable ultrasound scanner in Nephrology and Dialysis Units is mandatory to drastically increase diagnosis efficiency and treatment choice. Moreover, at the moment, there is a tendency to progressively use ultrasound more and more in clinical practice as the main tool both to plan the new VA and to detect and treat complications.

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When planning to create a new VA, the clinical workup must be based on correct history, arterial and venous physical examination. This offers a global vision of the venous and arterial network and allows for the diagnosis of any possible anomaly/pathology. Insonation, that is, the five pillars of the modern semiotic, must complete this clinical workup.[2]

This article reviews the upper limb's ultrasound vascular anatomy and the advantage of preoperative mapping in planning a new VA.

Clinical history

The patient should be asked about their medical history, such as Diabetes Mellitus, which may compromise the prognosis of the future VA. The medial calcinosis present in these patients usually prevents proper maturation due to lack of arterial dilation.[3] Antecedents that may have compromised the central veins must also be known, such as current or previous central venous catheters, pacemakers or any other devices that may have caused stenosis.[3] Finally, the physician must suspect the presence of arterial stenosis/occlusion in patients that present a history of clinically relevant vasculopathy in lower limbs and rule out atherosclerotic stenosis or occlusions of the VA feeding artery (risk of maturation failure) and the limb's distal arteries (risk of distal ischaemia/steal syndrome).[3]

Physical examination

Correct physical examination of the patient can be more helpful than medical history to detect the possible presence of significant vascular pathology. This examination should be performed in a warm environment with the patient's arm in decline, relaxed, before and after the placement of a proximal cuff to correctly fill the limb's veins.[3]

Adequate inspection can detect a collateral circulation in the shoulder and pectoral region, representing a sign of haemodynamically significant central venous pathology. The existence of morbid obesity will also condition VA prognosis, especially as it hinders needling. In these cases, vessel depth should be carefully evaluated with some image test to determine the draining vein's appropriateness for superficialisation/transposition procedures.

Arterial examination includes palpation of pulses at all levels (radial, ulnar and brachial), evaluating their width and detecting the presence of asymmetries. The physician should detect asymmetries in systolic blood pressure between upper extremities; an Allen test must be performed to determine the hand's arterial dominance and the palmar arch's functionality.

Vein examination aims to find a palpable and compressible conduit without tortuosity, adequate calibre and length, which continues towards the deep venous system.[2] Limb inspection must be attempted before and after the

proximal cuff placement to identify the main drainage veins of the superficial venous system (cephalic and basilic vein) and their collateral tributaries up to the antecubital fossa. It is essential to determine diameter, continuity and vein compliance.[3]

Indications of presurgical ultrasound mapping

The widespread use of Doppler ultrasound in clinical practice has developed new protocols to evaluate vessel characteristics and optimise decision-making when creating new VA. In this respect, papers have been published documenting Doppler ultrasound's usefulness in vascular access planning in cases where the physical examination was inconclusive, such as in obese patients, with the absence of peripheral pulses or with previous surgeries.[4,5]

That is precisely why ultrasound has been included regularly in the preoperative check-up as an essential complement to physical examination. Despite this, there is no consensus when considering the use of ultrasound mapping as a routine examination in all patients who are candidates for VA implantation. Although different studies and a meta-analysis show the usefulness of ultrasound,[5,6] some studies suggest that overall benefit in patients with favourable anatomy is not evident.[7,8] There is still some controversy about it today. However, the main clinical practice guidelines published,[3,9,10] based on good clinical practice and existing evidence, recommend ultrasound mapping before surgery to obtain a global and accurate view of the patient's venous and arterial capital and mainly in cases in which the physical examination is not conclusive.

Ultrasound examination: General considerations

Ultrasound mapping of the upper limb vessels before VA implantation is based on three different applications[11]:

1. B-mode ultrasound, which provides a two-dimensional greyscale image to study vessel morphology and anomalies.
2. Pulse wave Doppler (PWD), which records the velocity over time curve in veins and arteries, analysing red blood cells (RBCs) velocities.
3. Colour Doppler (CD) sampling reproduces real-time mean velocities of RBCs over time in a colour box.

The examination should be carried out with abundant gel to avoid losing information on the sides of the probe in the forearm's curved fields, and excessive pressure avoided on the skin, given the marked tendency of the superficial veins to collapse.
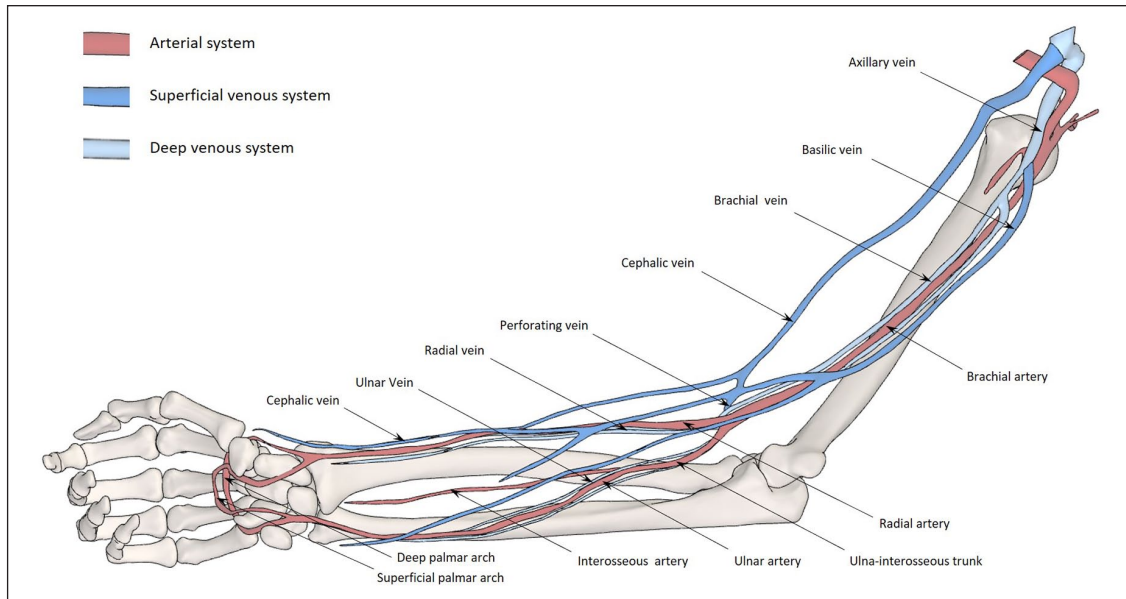
Figure 1. Atlas of the arterial and venous vascular bed.

Patient position

The patient's ideal position is supine decubitus, without bending the elbow, when examining the arterial system, and evaluating the subclavian and axillary veins. However, to assess the arm's veins, it is advisable to raise the head of the bed to 45°, with the arm in a relaxed position and study them before and after proximal tourniquet placement to achieve maximum vein dilation. Alternatively, the patient can be placed in a sitting position by extending the upper limbs alternately on the examination table, at 45° to the vertical axis. It is important to maintain a warm environment during the test to prevent venous vasospasm. The leg should be placed in a slight external rotation to assess the lower limbs. Correct ultrasound mapping requires knowledge of the limb anatomy, especially regarding arterial vessels and the deep and superficial venous system.[12]

Probe and scans

Vessel examination should be carried out with high-resolution small-part transducers (7.5–20 MHz), with a 4 cm, or smaller, head. The deepest central veins can be also insonated with microconvex transducers. The use of a linear probe requires steering activation, that is, the activation of a 20° electronic angular deviation of the colour box and Doppler line in a centrifugal direction. In this way, the vessels are non-orthogonally insonated because, from a technical point of view, this is the most unfavourable condition for the Doppler effect recording since a cosine of 90° is equal to 0. This technical rule applies both to colour-power Doppler sampling and spectral analysis. There are two helpful scans for superficial vessels: (1) longitudinal scans

in anteroposterior or latero-lateral direction, parallel to the transducer long axis; (2) axial-transverse scan on the vessel short axis. Such scans are helpful even with '*on-plane*' or '*out of plane*' needle guidance.

The vessel spectral curve must be clean, regular and without great artefacts. Doppler parameters must be measured on the frozen image, after the angle adjustment at 60°. This value enables proper vessel sampling and introduces a constant error, which does not invalidate the quantitative analysis. In this way, quantitative and semiquantitative data from different operators and devices can be compared.

High intensity and low-frequency spectral frequencies, originating from the vibrations of the vessel wall and adjacent structures, should be eliminated by a 100–200 kHz high-pass filter. In existing platforms, the wall noise filter self-adjusts with the Doppler transmission frequency.

Arterial ultrasound examination

Arterial anatomy of the upper limb

Arterial vascularisation of the arm depends on the subclavian artery, which is a branch of the aorta on the left side, while on the right, it is one of the terminal branches where the brachiocephalic trunk bifurcates (Figure 1).[13]

Subclavian artery

Anatomically, this is not a long artery and is shorter on the right side, as mentioned above. It is also located deep in the tissue known as the thoracic outlet until it passes immediately below the clavicle. Both its deep trajectory

and the acoustic shadow of the clavicle make it a difficult artery to scan using ultrasound and it is extremely difficult to visualise it entirely. That is why it is usually impossible to evaluate the whole trajectory directly, except in very thin patients.

Axillary artery

This trunk is the continuation of the subclavian artery, from the first rib's lateral edge to the pectoralis major muscle's inferior border. As the subclavian artery, it is a short artery. Its location allows for better insonation. It can be visualised with ultrasound from the lower edge of the clavicle anteriorly below both pectoral muscles and through the axillary cavity, with the arm in abduction.

Brachial artery

Greater in length, it continues to the axillary artery and paves a route along the whole arm's inner face. It can be located in an ultrasound-accessible position – with the arm at 45° – between the arm's biceps and triceps muscles (bicipital groove). It bifurcates in the antecubital fossa, giving two terminal branches: radial and ulnar artery. In up to 15% of cases, it can present an anomaly consisting of a proximal bifurcation, which will cause the existence of a double artery in the arm.

Radial artery

The brachial artery's terminal branch, which presents a relatively deep first segment, is placed in a more superficial position. It approaches the hand and follows the radial edge of the forearm (pulse channel). It is easily visible throughout its trajectory using ultrasound. The radial artery can be identified from its origin because it is the most superficial artery after the brachial artery's bifurcation. As previously mentioned, it can sometimes originate directly from the brachial artery in the proximal third of the arm, in which case it travels the entire arm to the wrist.

Ulnar artery

This is the other terminal branch of the brachial artery, which, like the radial, follows a relatively deep path at the beginning but is located superficially in the wrist. Typically, it branches into a collateral at a short distance from its origin, the *interosseous artery*. As its name indicates, the latter follows the forearm's deepest trajectory close to the interosseous membrane, between the radius and ulna bones. However, it is a non-constant artery that may sometimes dominate the forearm, to the detriment of the radial and ulnar arteries. The common initial trunk of the ulnar and interosseous arteries is often called the ulna-interosseous trunk.
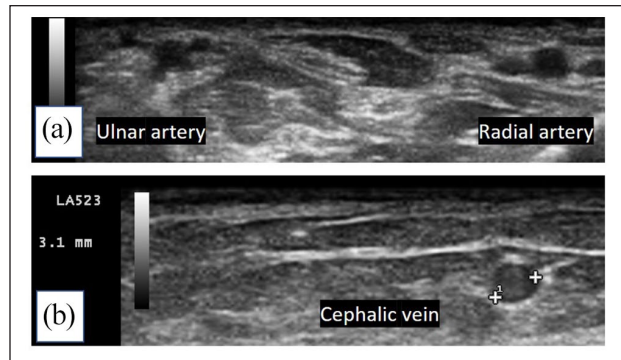

Figure 2. B mode. (a) Arterial examination. Radial and ulnar arteries with their respective satellite veins. (b) Venous examination. Diameter measurement.

Palmar arch

This represents the terminal anastomoses between the radial and ulnar arteries. The palmar arch shows great variability. Usually, it consists of two arches: the deep palmar arch, mainly dependent on the radial artery, which anastomoses with the ulnar artery; and the superficial palmar arch, tributary to the ulnar, which anastomoses with the radial artery. Its morphology and patency can be explored using high-frequency ultrasound and the Allen Test. Palmar arch patency is crucial for hand perfusion when a distal arteriovenous fistula is implanted. In fact, after VA implantation, the hand's entire vascularisation depends on the palmar arch.

Arterial mapping

The arteries are examined morphologically, placing the probe first in a transverse plane, with the probe's directional mark towards the right site. The short axis helps achieve correct assessment of the arterial diameters and explore in an ascending or descending direction. The operator will note the diameters of the radial and brachial arteries, calcifications and anomalies, such as the radial artery's proximal bifurcation (Figure 2(a)).

Subsequently, the arterial tree is studied dynamically on the vessel's long axis. Firstly, colour Doppler is used to identify the areas with aliasing, where the flow velocity rate increases. This acceleration is quantified with the spectral Doppler, which allows the determination of the peak systolic velocity (PSV) to assess the degree of existing stenosis. The longitudinal study should be carried out ideally at an angle of 60° between the vessel's major axis and the Doppler beam's direction to avoid errors in the velocity measurement.[14]

Under normal conditions and in the absence of pathology, the Doppler wave's morphology will typically be triphasic, with a positive initial peak followed by a negative wave and a positive end-diastolic wave. This waveform,
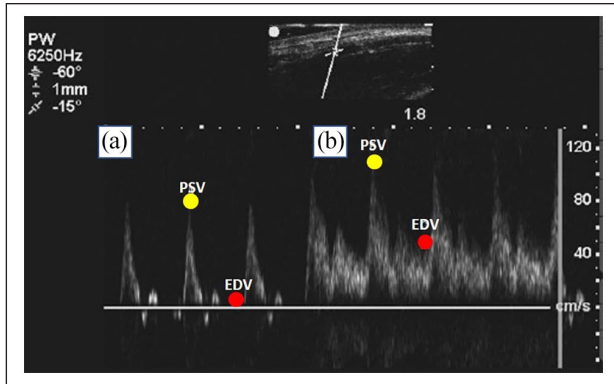
Figure 3. Doppler mode in arterial examination: (a) triphasic morphology with high resistance flow and (b) reactive hyperaemia.
PSV: peak systolic velocity; EDV: end diastolic velocity.

which corresponds to a high resistance flow, does not vary along the arterial tree and has the same morphology in the proximal arteries (axillary and brachial) as in the distal arteries (radial and ulnar), with only small variations in width (Figure 3(a)).

Venous ultrasound examination

It is well known that the prognosis of the new VA depends on the condition of the patient's venous drainage system. That is why it is the most important part of mapping and will probably take up the most exploration time (Figure 1).

Venous anatomy of the upper limb

In upper limbs, venous drainage occurs in two main systems: superficial and deep venous systems.[12]

The *deep venous system's* veins are located alongside the main trunk arteries and bear the same corresponding names (radial, ulnar, brachial, axillary and subclavian veins), usually in even numbers, so that two veins accompany each artery. They are usually less developed in upper limbs than in lower limbs, so they are seldom used to create an arteriovenous fistula since they are also at a deeper level; however, it is necessary to ensure their patency. In many cases, proximal veins (subclavian, brachiocephalic vein), as the accompanying artery, cannot be seen directly using ultrasound.

The *superficial venous system* is usually well developed and is therefore preferred in vascular access creation. It differs from the deep one because it follows an epifascial path, collects the venous drainage from superficial tissues and drains into the deep venous system. It consists of two drainage systems: the cephalic vein and the basilic vein.

Cephalic vein. This vein is responsible for superficial venous drainage and follows a path along the forearm's radial edge, external arm face and deltopectoral groove. It is the longest vein in the upper limb because it originates at the base of the thumb and empties into the axillary vein at the height of the lower edge of the clavicle. Its trajectory follows the most superficial path of all the trunk veins, so it is the first-choice vein to try to create vascular access. It often presents a dorsal branch at wrist level and may be appropriate for access creation.

Basilic vein. This follows a trajectory in the ulnar portion in the forearm, while in the arm, it is located in the inner face, close to the brachial vascular sheath package. Despite being an epifascial vein, it is located in a deeper position than the cephalic vein throughout its entire length. Besides, it perforates the brachial fascia from the distal third of the arm, goes deep into this and drains into the brachial vein in the arm's proximal third, close to the axilla; it is shorter than the previous one. Although its deeper location often preserves it from injuries due to iatrogenic puncture, it is the second-choice vein for VA after the cephalic vein.

Communicating veins of antecubital fossa. This is a network of superficial veins that connect the cephalic vein system with that of the basilic. They are also very important in the development of the arteriovenous fistula since, on the one hand, they determine the venous drainage of the forearm towards the arm's veins and, on the other hand, the forearm's perforating vein is located in their midst. The perforating vein as well as the median cubital vein are of great surgical importance since are the veins used for the Gracz fistula and, in general, of all elbow fistulas with open drainage towards the cephalic and basilic veins in the arm. They present great anatomical variability and are most frequently laid out in the so-called 'Y' (with the prominence of the median vein) and 'M' position (with the dominance of the cephalic median and the basilic median veins).

Venous mapping. Both the superficial and the deep venous system should be explored, from the wrist to the central veins (axillary or subclavian), paying special attention to the superficial veins.

The study must be carried out with the probe placed in a transverse direction, which allows the precise morphological assessment of the wall's diameter, compressibility and characteristics (Figure 2(b)).

The main qualities that must be determined in venous mapping are:

- *Vessel patency.* This characteristic checks vein compressibility after squeezing with the probe and venous modulation, which appear on the spectral Doppler trace after distal compression. A subcutaneous vein is

easily compressible when applying external pressure with the transducer. Non-compressibility is a sign of endoluminal material, that is – thrombosis and supposes manual compression is performed in the distal territory. In that case, flow in the proximal veins must increase, causing a 'surge' that is easily detectable by CD.

- *Distensibility.* The vein's ability to dilate as endoluminal pressure increases can be assessed using B-mode to measure vein diameter through a transverse section before and after proximal cuff placement. The vessel should be measured without compression as a superficial vein easily collapses with the probe's external pressure.

In general, it is important to explore the entire path of the vein. Attention should be paid to wall thickening due to past phlebitis and significant changes in the vessel's calibre. The value of the minimum diameter of the vein should also be determined, and attention paid to anomalies and tortuosity, which may hinder needling in the future.

The sonographer must follow a series of recommendations in the vein evaluation.

- Should be looked for venous stenosis (usually segmental thrombosis/thrombophlebitis after peripheral indwelling catheters), for side branches (if many, the flow could be dissipated) and for the depth of the peripheral vein (as deep veins will cause problems with punctures).
- The basilic vein depth will have to be specifically noted throughout its path, helping us plan future needling areas. This must be emphasised throughout the path in the case of deep veins to assess their possible superficialisation and/or transposition.
- It is important to determine vein position in the antecubital fossa since it will give us information on where the flow will go after the fistula is created.
- The operator can report the location and the calibre of the antecubital perforating vein.
- Stenosis in the proximal segment of subclavian and brachiocephalic veins may not be directly visible using ultrasound modalities. Their patency and functionality depend on the so-called indirect signs of patency. First of all, *respiratory phasicity* must be checked: this is generated by negative pressure in the thorax during inspiration, which causes a 'sucking' effect in the proximal veins of the arm, in the form of an increase in flow with deep stimulation if the drainage system has correct patency and functionality (Figure 4). Secondly, the closure of the heart valves causes a pressure wave which, in the absence of central venous pathology, spreads retrogradely through the blood column and is seen in the form of *transmitted heart pulsatility*. Small
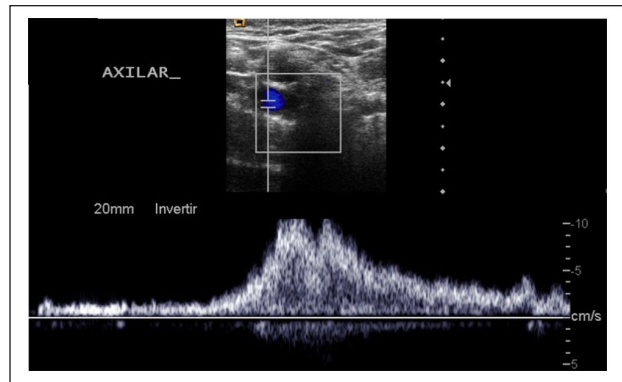

Figure 4. Doppler mode in venous examination. Respiratory phasicity.
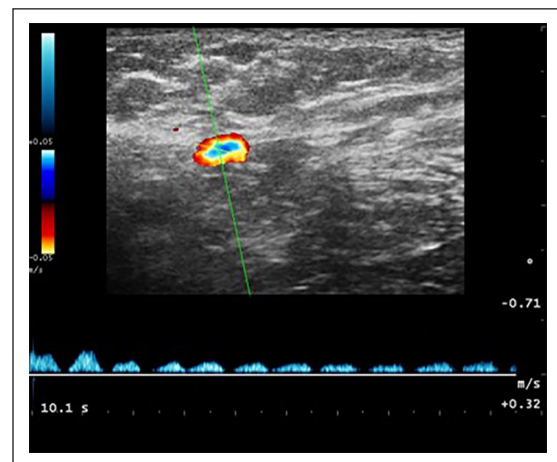

Figure 5. Doppler mode in venous examination. Transmitted heart pulsatility.

heartbeat modulations are detectable in the Doppler curve of central veins, and they are an indirect sign of patency (Figure 5). In the presence of stenosis or central venous occlusions, the flow in these veins becomes slow and continuous without any deflection. Even so, it will lack variations with respiratory and cardiac movements, which will result in a flat flow curve.[11]

Predictive maturation factors

Undoubtedly, ultrasound mapping places a large amount of anatomical and functional information on the limb's vascularisation at our disposal and offers us multiple criteria to help create a new VA. However, it adds uncertainty when deciding on which type of fistula is the most convenient for each patient at all times. Multiple ultrasound variables associated, to a greater or lesser extent, with good access prognosis have been described in the literature. This does not prevent the most convenient access for each patient

from sometimes being a complex decision. Thus, all the specialists should take the decision as a multidisciplinary team, based on the patient's personal preferences.[3,15]

Vein diameter

There is agreement among different authors that vein diameter after proximal tourniquet placement is the ultrasound parameter of greatest importance in access prognosis.[16,17] On the other hand, although the differences are small, there is no consensus on the minimum diameter that can be considered a good prognosis.[5,18–20] On the one hand, there is a risk of either discarding viable veins at the limit in diameter, or of creating accesses that may not function. Since most studies coincide that prognosis is poor in veins of diameter <1.5 mm, this diameter can be considered the minimum from which the fistula is deemed to be viable. Most authors agree on a good prognosis for fistulas made in veins >2.0 mm, so it is reasonable to consider it a good prognosis factor in daily practice.[3] Diameters between 1.5 and 2.0 mm can be considered suitable for creating the access but have uncertain prognosis, so the decision must be taken based on other factors.

Arterial diameter

The artery should be measured by determining the internal arterial diameter, which is the vessel's adequate calibre. However, this parameter is difficult to obtain in most peripheral arteries with 7.5–10 MHz probes. This value has been shown to have important predictive value in access success.[3] There is no agreement regarding the minimum diameter that can be used in practice.[5] However, the opinion between authors and experts is that the larger the artery diameter, the better the prognosis. So, in this practice, it is advisable to use the same values as with the vein, considering a minimum diameter of 2.0 mm to have good access prognosis,[19,20] and below a minimum diameter of 1.5 mm considered to be a non-viable access.[20–22]

Increase in the diameter of the vein

For the access to mature correctly, the fistula's drain veins must be larger after surgery to drive the entire volume of flow to the central veins and to cannulate properly. This capability is known as distensibility and is defined as the vein's ability to dilate as intraluminal pressure increases. This venous distensibility can be assessed directly by measuring vein diameter prior to and within 2 min of placing a proximal tourniquet on the limb, and measuring the percentage increase in the vessel's diameter. Although an increase of above 48% is considered a good prognosis,[23] there is no minimum value required for creating access, but the prognosis is better when there is a greater increase in the vein diameter.

It is important to remember the need for a warm environment to prevent vessel spasm during exploration. Vein diameter is measured through transverse scans with the probe placed in a perpendicular plane to the skin, and the inner diameter is always taken as the measurement.

Analysis of the arterial Doppler curve: Peak systolic velocity (PSV)

The arterial Doppler waveform of upper limbs has a triphasic morphology at rest. A sudden systolic peak is followed by a rapid fall in the flow and a reverse inflexion (reverse wave) due to the arterial wall's elastic recoil in peripheral arteries. Small anterograde modulation appears at the end of diastole. This pattern corresponds to a high-resistance vascular bed. In segmental stenosis, once the >50% diameter narrowing is detected, the PSV increases doubles at the stenosis point in comparison to the upstream vascular tract. The spectral trace acquires a monophasic morphology with high-speed diastolic velocities. This pattern is difficult to verify in presurgical mapping since limb distal circulation is anastomotic. A post-stenotic pattern appears downstream of the stenosis, with a flattened morphology, losing the triphasic component and acquiring a biphasic or even monophasic form. These signs indicate poor arterial inflow and poor access prognosis.[20] Some authors suggest that a PSV value <50 cm/s in the radial artery is a sign of poor prognosis. But, as other factors, such as the stiffness and arterial calcification, can influence PSV, the absolute value of PSV in the radial artery cannot be considered a reliable factor for fistula prognosis.[24,25] Therefore, arterial Doppler curve assessment should be aimed at assessing a correct wave or a post stenotic pattern indicative of segmentary stenosis.

Response to reactive hyperaemia

For the access to mature correctly, an increase in the feeding artery's flow of 10–20 times versus the baseline value is necessary. This haemodynamic variation is achieved thanks to an adaptative response to wall shear stress, which permits vessel dilation. The arterial dilation process can be compromised if there are highly calcified arteries, as is the case of patients with multiple cardiovascular risk factors and diabetes. Therefore, it is essential to distinguish patients in which there is insufficient dilation capacity in the vascular bed and a high risk of maturation failure. The absolute values of resting PSV have not demonstrated prognostic utility in this regard.[20] *A hyperaemia test* has been proposed for this purpose – hand ischaemia is induced by making a fist for 2 min. Opening the hand allows the operator to evaluate reperfusion time and resistance variation to hyperaemia using PWD. Normally, Doppler curve at the radial artery shows sudden vasodilation of vascular bed in response to ischaemia. We can evaluate haemodynamic

response by calculating the increase in PSV[26,27] and the decrease in Resistive Index (RI),[3] obtained with the formula: $RI = [PSV - EDV]/PSV$, where EDV (end diastolic velocity) is the lowest velocity value in the Doppler curve. RI variations are the parameter most widely used in practice: an RI value <0.7 after the hyperaemia test and is a sign of good VA prognosis.[3] RI determination is subject to significant variability in measurement. Some studies have not found a relationship between RI and fistula prognosis,[22] so it is relatively helpful in deciding about the access to be created (Figure 3).

Arterial wall thickness

Arterial wall thickness, evaluated with the high-resolution probe (10–20 MHz) by measuring the thickness of intima-media layers (IMT), is a well-known marker of cardiovascular risk factors in the general population. A clear relationship between carotid artery IMT and cardiovascular events has been suggested.[28,29] Thus, IMT determination in the access-feeding artery can be used as a prognostic factor of VA patency.[30] Despite this, its true role in the decision taken on the vascular access to be created is not described, so IMT determination is not usually part of routine presurgical mapping.

Central venous patency

The presence of central venous pathology is a known factor of poor prognosis for creating the new vascular access.[3] Therefore, when clinical suspicion of central vein stenosis derives from clinical history, a careful analysis of the central vein's spectral wave should be performed. A multiphasic flow detected from respiratory movements and heart pulsatility at the subclavian or jugular vein level is a sign of venous patency[11,25] (Figures 4 and 5).

Prognostic ultrasound criteria in presurgical mapping

Major factors	
Vein diameter. Recommended >2.0 mm	
Arterial diameter. Recommended >2.0 mm	
Venous distensibility	
Central venous patency	
Minor factors	
PSV	
Hyperaemia test	
IMT	

Conclusion

The ultrasound devices available in daily practice have proven to be a tool of capital importance in assessing the patient before surgery, as well as the portable ones available in the haemodialysis units. They do not delay decision-making, and allow greater agility and quality of care. High-resolution check-ups can be performed. The vascularisation of the limb and venous capital can be examined accurately. Which access is most appropriate can be decided according to the circumstances without having to do invasive radiological tests. But for this improvement in diagnostic capacity to be turned into better patient care, greater and improved collaboration between the professionals involved is necessary, especially the nephrologist-vascular surgeon relationship.[31] Joint check-ups between both specialities are desirable to offer the vascular access candidate an immediate and adequate proposal for individual treatment needs, without the need for delays that may affect their morbidity and mortality.

That is why ultrasound should play a leading role in decision-making regarding vascular access. However, at no time should incorporating such technology replace an adequate individual assessment of each patient, which must be performed jointly between the medical team, nephrologist and vascular surgeon and the patient himself.

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