

Focus on:

II – Imaging in vascular access for haemodialysis

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■ ABSTRACT

A reliable vascular access is essential to effective haemodialysis. Imaging evaluation of vascular access for haemodialysis includes preoperative assessment of vascular anatomy and post-operative surveillance for access maturation, as well as diagnosis in vascular access dysfunction. This article reviews the current diagnostic imaging methods in haemodialysis fistulas. Ultrasound is the technique of first choice when imaging vascular accesses. Digital subtraction angiography is superior for the assessment of the central veins and makes diagnosis and treatment possible in the same session.

Key-Words: Computed tomography; digital subtraction angiography; magnetic resonance; ultrasound; vascular access for haemodialysis.

■ RESUMO

Um acesso vascular adequado é essencial para o tratamento dialítico eficaz. A avaliação imagiológica do acesso vascular para hemodiálise inclui avaliação pré-operatória da anatomia vascular e vigilância pós-operatória da maturação de acesso, bem como o diagnóstico de disfunção acesso vascular. Este artigo é uma revisão sobre os métodos de diagnóstico por imagem nas fístulas de hemodiálise. A ecografia é a técnica de primeira escolha no estudo imagiológico dos acessos vasculares. Angiografia é superior na avaliação das veias centrais e possibilita o diagnóstico e o tratamento na mesma sessão.

Palavras-Chave: Acesso vascular para hemodiálise; angiografia; ecografia; ressonância magnética; tomografia computadorizada.

■ INTRODUCTION

Portugal has been characterized by the highest incidence and prevalence of end-stage renal disease (ESRD) treated by dialysis or kidney transplantation in the European Union¹. A reliable vascular access is essential to effective haemodialysis (HD). The main goal of a vascular access team is to preserve arteriovenous fistulas long-term function and to avoid the use of dialysis catheters, which are associated with a higher mortality².

The most common complications in dysfunctional arteriovenous fistulas (AVF) are stenosis of the vascular access vessels, thrombosis and steal syndrome³. Vascular access thrombosis is generally related to stenosis and can occur as a segmental thrombosis or extensive thrombotic occlusion³. Dialysis patients can also develop central venous stenosis as a reaction to wall trauma associated with dialysis catheter and as a result of the arterialized flow conditions in the venous circulation⁴.

Imaging evaluation of vascular access for HD includes preoperative assessment of vascular anatomy and post-operative surveillance for access maturation as well as diagnosis in vascular access dysfunction.

In our centre, vascular accesses are managed in an interdisciplinary continuous cooperation between nephrologists, vascular surgeon and interventional radiologists.

This article reviews the current diagnostic imaging methods in haemodialysis fistulas.

■ ULTRASOUND

Ultrasound is widely available and non-invasive, and for these reasons is the most widely used vessel visualization method. As a cost-effective method, it allows assessment of vascular access maturity and diagnosis of complications^{5,6}. It is portable, and radiation and iodinated contrast media free. Doppler ultrasound is a direct technique for assessment of flow in vascular accesses. However, this method is operator dependent and subject to errors caused by variations in cross-sectional area and the angle of insonation.

Duplex ultrasound is the preferred method for pre-operative vascular mapping and it should be performed in all patients before placement of an access⁷. The ultrasound examination for dialysis access planning is designed to gather information about both the arterial system and the venous system⁸. A luminal diameter of 2.5mm or greater at the anastomosis point, absence of obstruction, a straight segment for cannulation, to be within 1 cm of the skin surface and to have continuity with the proximal central veins are venous requirements for AVF construction⁹. These criteria may differ for arteriovenous grafts (AVG) and among centres. In our institution we use a cut-off of 2mm for vein diameter.

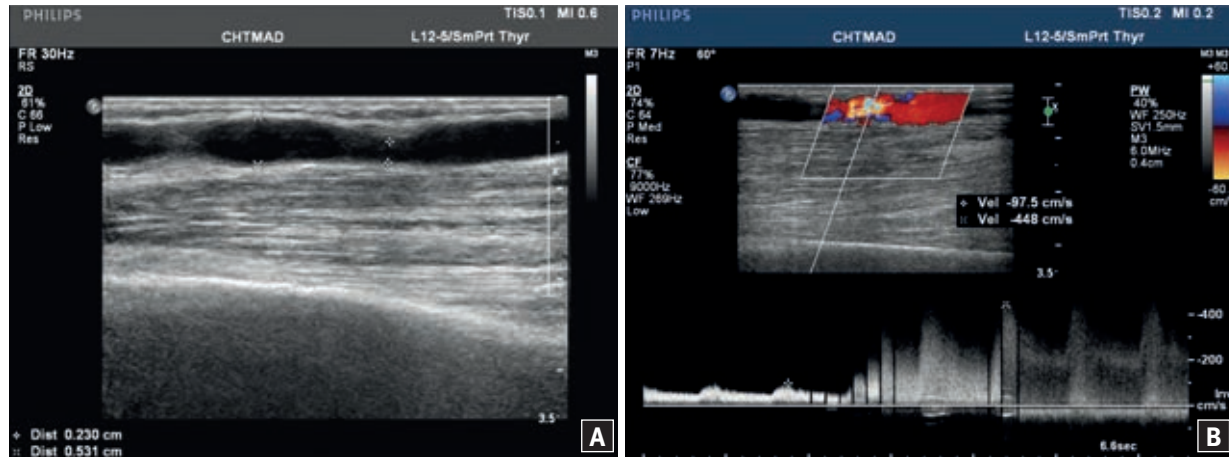
In patients with persistent post-operative swelling, ultrasound may confirm extravasations and haematomas or purulent infiltrations, as well as stenosis of the venous outflow tract, in the latter case with known limitations for assessment of central veins.

Failure to mature should be evaluated by physical examination and, if needed, ultrasound^{5,7}. If an adequate AVF is not clinically identified in the first 4 to 8 weeks after surgical access creation, an ultrasound examination can be performed to detect a correctable anatomical problem¹⁰. If no stenosis is identified, thresholds for venous diameter and blood flow may suggest whether the AVF is mature for haemodialysis. Fistulas are more likely to be useable when they meet the rule of 6s characteristics: flow greater than 600mL/min, diameter at least 0.6cm, no more than 0.6cm deep, and discernible margins⁷. Ultrasound also allows the identification of large draining venous branches (competing veins), which may be surgically ligated to increase flow throughout the main draining vein to allow AVF maturation¹¹.

Ultrasound has become the primary imaging method in the case of vascular access dysfunction. Doppler ultrasound can provide anatomical assessment and direct evidence for the presence, location, and severity of access stenosis. Any visible narrowing of the draining vein on B-mode ultrasound or colour aliasing of flow within the vein should be further assessed with velocity measurements by spectral Doppler imaging¹⁰. Anastomosis luminal diameter inferior to 2mm or a Peak systolic velocity (PSV) ratio (anastomosis/artery 2cm upstream) greater than 3:1 has been suggested to represent a stenosis at anastomosis with diameter reduction greater than 50%¹². A draining vein PSV ratio superior to 2:1 suggests stenosis superior to 50%¹³ (Fig. 1).

Figure 1

On B-mode ultrasound, vein lumen measures 2.3mm at stenosis and 5.3mm in non-diseased segment (A). Doppler colour flow imaging demonstrates turbulence at stenosis (B), where a four-time elevation in PSV is found, which represents stenosis superior to 50%.



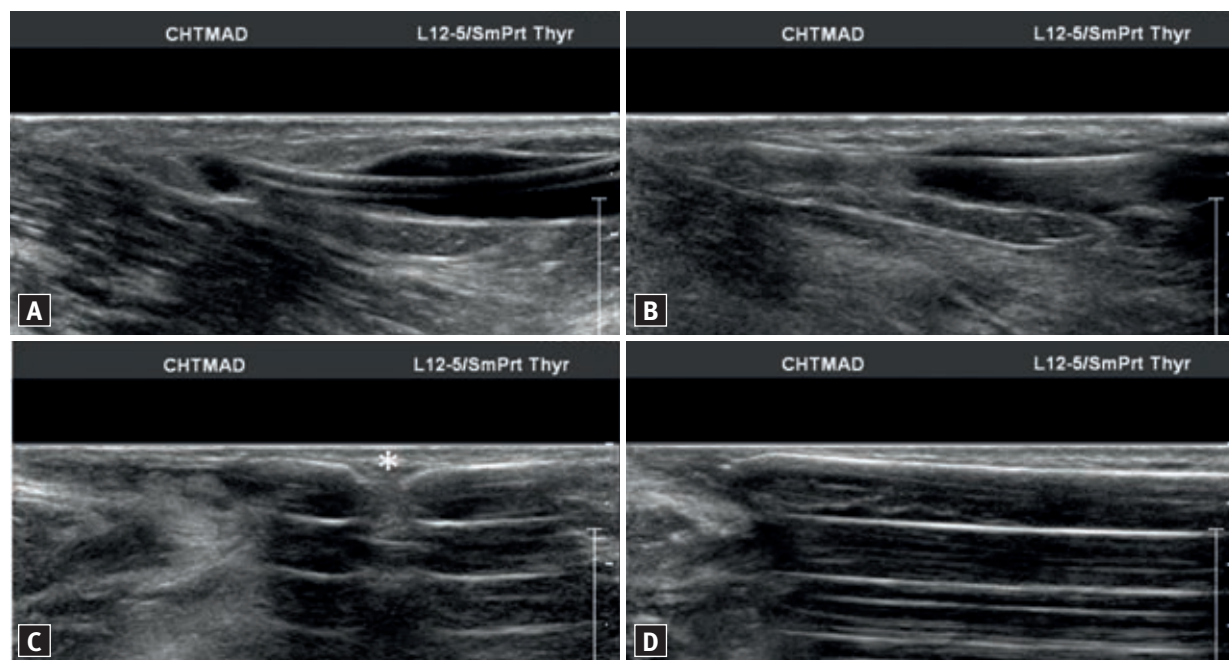
Ultrasound also allows the diagnosis of thrombotic occlusion. In any suspicion of steal syndrome clinical examination is mandatory, followed by ultrasound, as necessary. Central veins may be evaluated indirectly by using Doppler ultrasound¹⁴. However,

angiography remains the standard for evaluating the central veins.

The benefit of duplex Doppler ultrasound on surveillance is controversial. The highest ultrasound surveillance

Figure 2

Ultrasound-guided angioplasty. B-mode ultrasound shows diagnostic catheter (A) and support guide wire (B) through stenosis. When angioplasty balloon is partly inflated it is possible to observe the waist (*) at the level of stenosis (C), which disappears after full inflation (D).



benefit could be expected in AVGs and accesses with chronically lower flow¹⁵. Long-term follow-up via three-month duplex ultrasound can significantly extend the patency rate of dialysis vascular accesses¹⁶.

In our practice, we also use ultrasound during intervention, to select the adequate location to insert the introducer, to guide the puncture, particularly in immature AV fistulas or thrombosed vascular accesses, and to assist vessel angioplasty in patients not yet on haemodialysis (Fig. 2).

■ ANGIOGRAPHY

Digital subtraction angiography (DSA) is the gold standard for the evaluation of dialysis vascular access, and allows complete vessel visualization. A further advantage of this method is the possibility of treatment on the same session. However, DSA depends on ionizing radiation and contrast agents. Patients with renal disease or contrast allergy pose limitations on the use of iodinated contrast material (ICM). Alternative contrast media may be used in those patients. Current alternatives are dilute ICM, carbon dioxide (CO₂), and gadolinium¹⁷. Diluted ICM with a contrast volume of 10ml is safe and usually sufficient for diagnostic visualization¹⁸. In any suspicion of rupture during angioplasty in patients not yet on dialysis, under ultrasound guidance or CO₂ angiography, we generally

use a small amount (up to 10ml) of ICM to check AVF integrity. Carbon dioxide is a highly soluble, invisible gas. When injected into vessels, it briefly displaces the blood before it is rapidly dissolved and eliminated through exhalation¹⁹. CO₂ is non-allergenic and non-nephrotoxic, making it safe for use in patients with either contrast allergy or kidney disease²⁰. Although there is a known risk of neurotoxicity, central venography above the diaphragm is still permissible with CO₂²¹. If residual gas is seen between injections, the patient's position should briefly be changed to move the CO₂ bolus into a different vessel to allow dissolution²². In our Institution, we use a system of three-way stopcock and a flow switch system. Special attention must be given to purging syringes of air and, once filled with CO₂, not allowing valves to be left open.

CO₂ angiography represents an alternative to conventional DSA and is useful for the diagnosis and intervention of dysfunctional dialysis vascular access²³ (Fig. 3).

The CO₂ venography has a sensitivity of 97% and a specificity of 85% in the assessment of upper-limb and central vein patency and stenosis, compared to conventional venography²⁴.

Gadolinium-enhanced DSA is also a further effective method for angiographic vessel visualization. Since its association with nephrogenic systemic fibrosis (NSF) in 2006, its use as an angiographic agent in patients with CKD has appropriately declined

Figure 3

A. CO₂ retrograde DSA in a patient with immature AVF, with just anastomotic sub-occlusive stenosis, with no evidence of CO₂ filling the vein; B. CO₂ angiography after angioplasty with a 4x40mm balloon angioplasty, with evidence of CO₂ on venous segment.

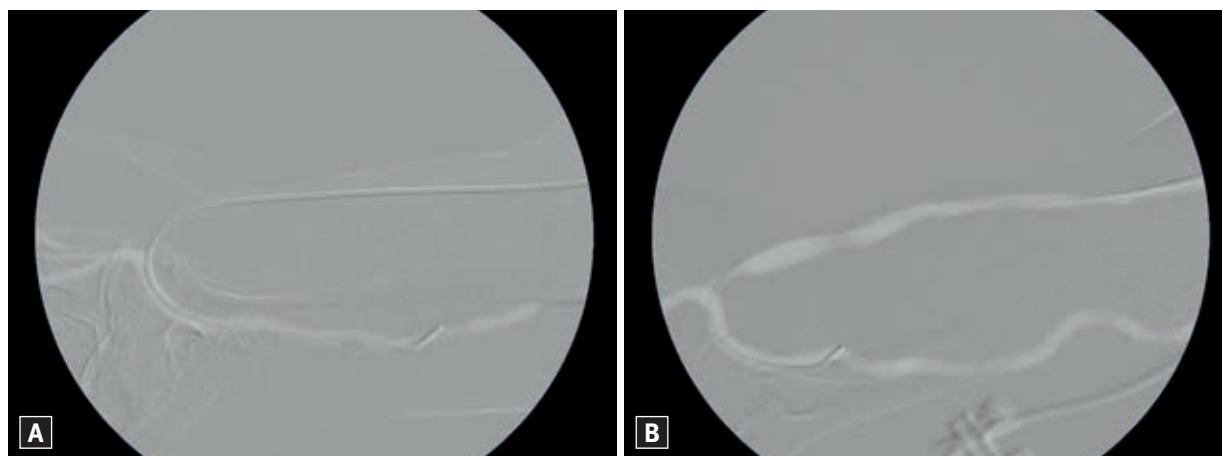


Figure 4

Digital subtraction angiography demonstrates post azigos superior vena cava occlusion, with drainage through hypertrophied hemiazigos system in one patient (A) and double superior vena cava in another patient without central stenosis (B,C).



rapidly (25-27). The application of gadolinium as an ICM alternative for angiography is essentially limited to patients with normal renal function who have anaphylactic reaction to ICM.

Diagnostic DSA, without therapeutic intention, is not recommended, for reasons of radiation and invasiveness²⁸.

Digital subtraction angiography is the gold standard imaging method for the study of central veins (Fig. 4).

Preoperative imaging of the central veins should be performed in patients with a history of previous central venous catheters²⁹.

Digital subtraction angiography is considered the gold standard for evaluating poor maturation of the fistula if the patient is already on dialysis therapy⁷, and allows evaluation of both arterial and venous segments of a dialysis vascular access.

Complete angiographic evaluation can be performed via retrograde arterial puncture of the brachial artery, near the elbow. It can also be done after antegrade puncture of the access vein, and in this case AV anastomosis can be visualized after proper compression of the draining vein with contrast medium reflux. Finally, when looking for a more proximal arterial stenosis, it is possible to introduce the catheter through the anastomosis into the native portion of the arterial vessel after retrograde puncture of the access vein.

■ COMPUTED TOMOGRAPHY

Computed tomography angiography (CTA) requires radiation exposure and iodine contrast administration. It is suitable for visualizing central veins and complete vascular tree in the case of an inconsistent sonographic finding. The CTA should only be used to clarify vascular access dysfunction if ultrasound and angiography yielded inconclusive findings (Fig. 5).

In particular, central venous thrombosis and para-vascular soft tissues can be effectively detected with CT.

Computed tomography angiography is a non-invasive technique and may have economical benefits compared with purely diagnostic DSA³⁰.

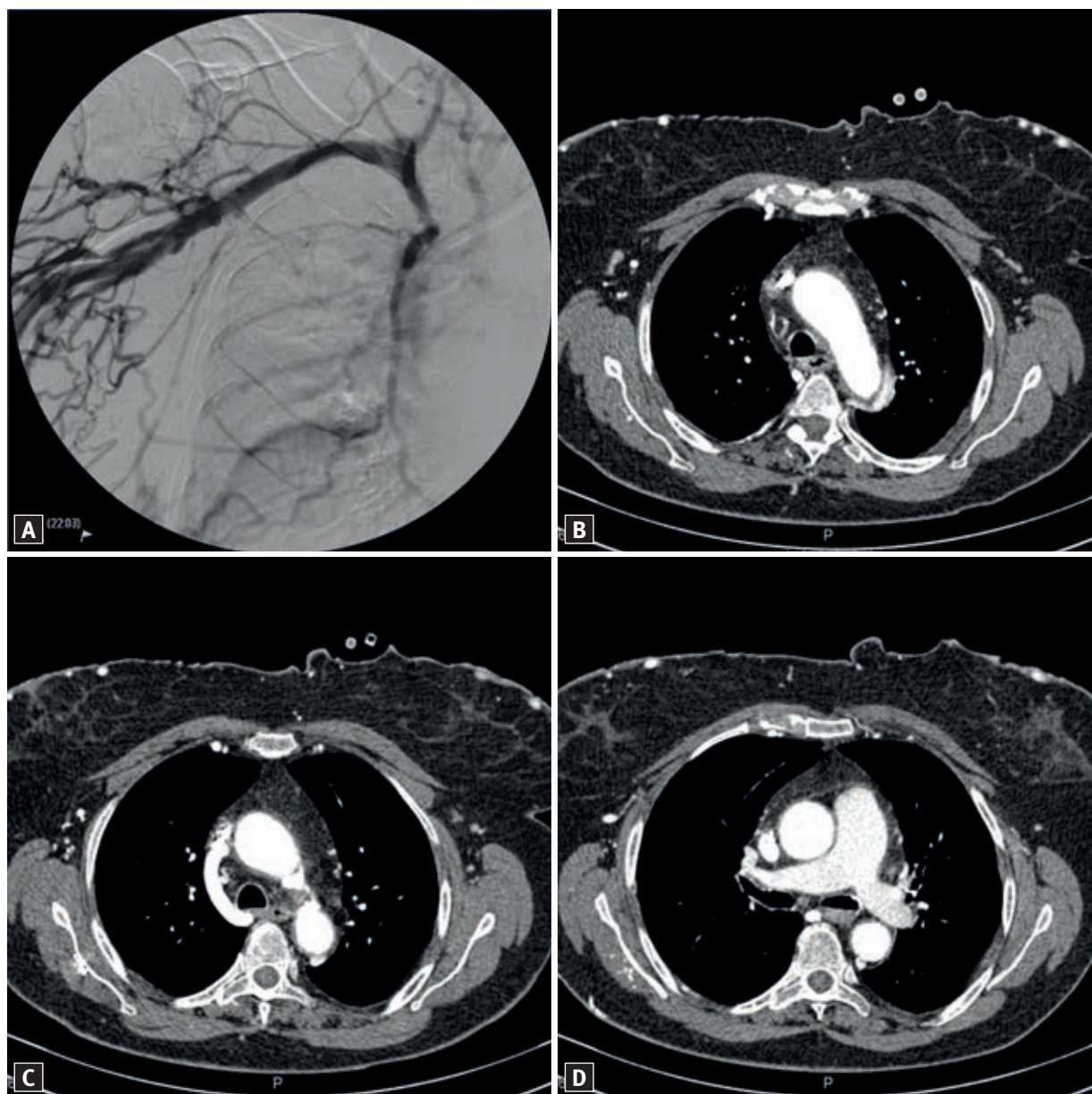
The CTA allows diagnosis of dysfunctional vascular access, as well as simultaneous visualization of the entire vascular tree^{31,32}.

■ MAGNETIC RESONANCE

Magnetic resonance (MR) is radiation and ICM free. The presence of claustrophobia, pacemaker, and magnetized metal in patients are limitations in MR scanner. This is costly comparing to other imaging methods, particularly ultrasound.

Figure 5

The DSA reveals imaging compatible with post azigos superior vena cava occlusion with reversed flow on azigos vein (A). CT shows occlusion of pre azigos vein occlusion with normal permeability of azigos vein and post azigos superior vena cava (B, C, D).



Magnetic resonance angiography (MRA) provides anatomic assessment and direct evidence for the presence, location, and severity of access stenosis, and is particularly useful in central veins evaluation³³. Similarly to CTA, MRA is a valid alternative to purely DSA in the assessment of central veins.

However, for the reasons stated before about gadolinium, contrast enhanced MRA is no longer recommended in patients with CKD²⁵⁻²⁷.

There is promising data for the preoperative visualization of arterial and venous vascular structure by

non-contrast MR angiography (MRA), but those techniques are not yet used in the clinical routine³⁴.

CONCLUSION

Ultrasound is the technique of first choice when imaging vascular accesses. Digital subtraction angiography is superior for the assessment of the central veins and makes diagnosis and treatment possible in the same session. Computed tomography angiography should be reserved for patients with inconclusive ultrasound and DSA. Gadolinium-enhanced magnetic resonance imaging is no longer recommended in ESRD patients, because it may trigger nephrogenic systemic fibrosis, but there are promising results on non-contrast MR angiography.

Conflict of interest statement: None declared.

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