

## DIALYSIS ARTERIOVENOUS FISTULAS: THE CRITICAL ROLE OF COLOR DOPPLER ULTRASOUND

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Despite being time-consuming and observer-dependent, CDUS is a method of choice for performing and controlling dialysis shunts. It contributes to increasing the number of native AVFs and enables early detection of lesions therefore allowing quick percutaneous or surgical therapy.

**Key-words:** Ultrasound (US), Doppler studies – Fistula, arteriovenous.

The aging of the population induces an increase of the occurrence of vascular and metabolic disorders with an impact on renal function, such as arterial hypertension or diabetes. In the USA, the prevalence of end-stage renal disease (glomerular filtration rate lower than 15 mL/min/1.73m<sup>2</sup>) doubled during the last decade of the twentieth century; in 1998, slightly more than one American per thousand was suffering from total renal failure. A third of these patients were treated by renal transplantation and two thirds by hemodialysis (1, 2). The amount of hemodialysis patients worldwide rose from 400,000 in 1990 to 1,100,000 in 2000 with a current estimation of more than 2,000,000 (3).

The type of treatment of end-stage renal disease depends on the patient's status, the etiology of the disease and the possible associated illnesses. Renal transplantation is of course the treatment of choice but it is not always feasible. When hemodialysis proves necessary, it is ideally performed after construction of a native radiocephalic arteriovenous fistula in the nondominant forearm, a method introduced by Brescia and Cimino in the USA in 1966 (Fig. 1A). Native brachiocephalic fistulas at elbow level develop more easily than their counterparts in the forearm but, beside the fact that they are shorter lived, they induce excessive blood flows more often, generate more distal ischemias and transform into aneurysms more frequently (4, 5). Peritoneal dialysis can be suggested as an alternative mode of therapy, namely for children or patients with a poor cardiac function, but its use is unfortunately limited in time (6). The polytetrafluoroethylene (PTFE) arte-

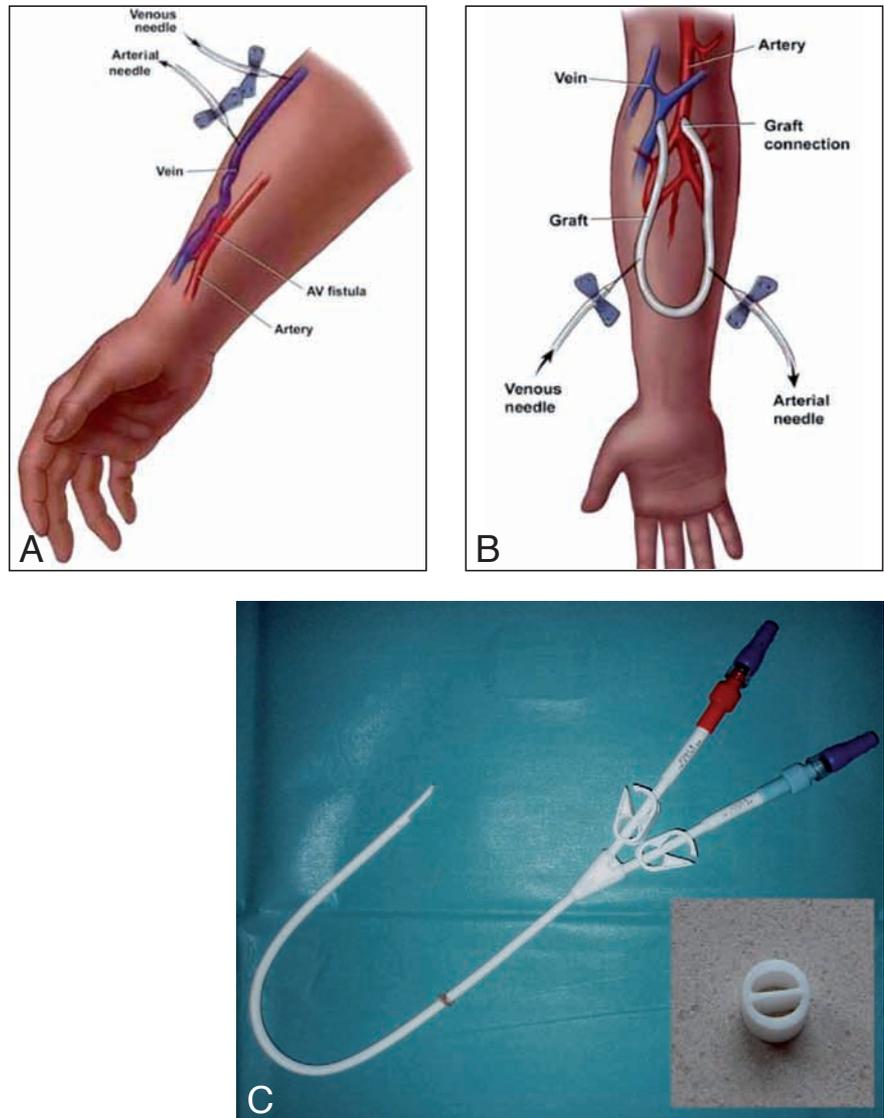


Fig. 1. — Diagram showing native radiocephalic fistula (A) and prosthetic shunt (B) with the dialysis needles in place (source: Mayo Foundation for Medical Education and Research). C. Photograph: Hickman double lumen catheter with cross section view.

riovenous graft introduced as early as 1976 (Fig. 1B) is a second choice since it implies a higher amount of pernicious thrombotic and infectious events (7, 8, 9). For reasons beyond the scope of our article, the arteriovenous graft has remained the most

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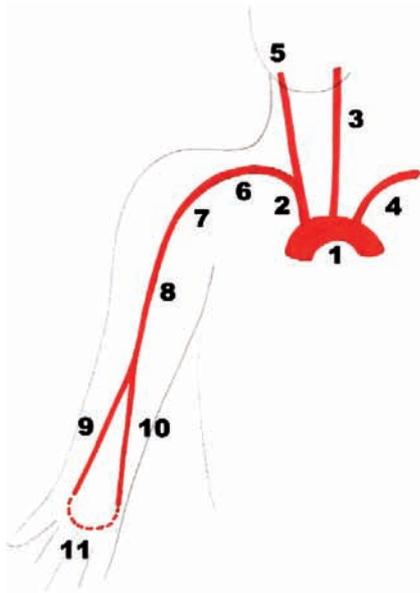


Diagram 2: upper limb arteries: 1. aortic arch, 2. brachiocephalic artery, 3. left common carotid artery, 4. left subclavian artery, 5. right common carotid artery, 6. innominate vein, 7. right axillary artery, 8. right brachial artery, 9. right radial artery, 10. right ulnar artery, 11. palmar arches.

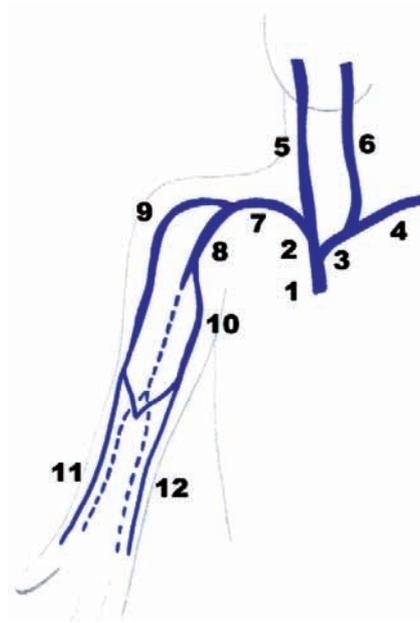


Fig. 3. — Upper limb veins: 1. superior vena cava, 2. brachiocephalic vein, 3. innominate vein, 4. left subclavian vein, 5. right internal jugular vein, 6. left internal jugular vein, 7. right subclavian vein, 8. right axillary vein, 9. right cephalic vein, 10. right basilic vein, 11. right superficial radial vein, 12. right superficial ulnar vein (dotted lines: deep veins of the forearm).

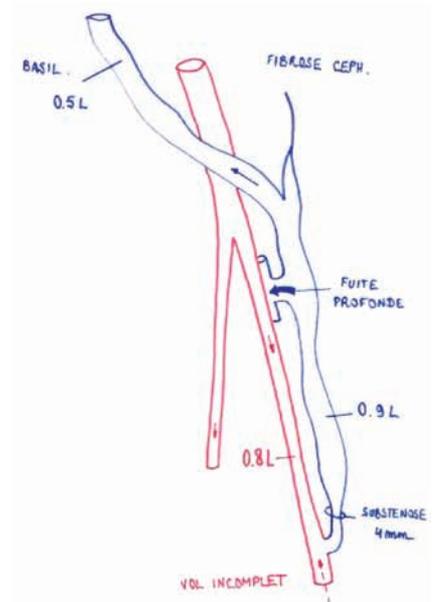


Fig. 4. — Diagram showing fistula drawing following CDUS.

widely used method of dialysis in the United States even though, thanks to the Kidney Disease Outcomes Quality Initiative (KDOQI), the tendency is presently reversing in favor of native fistulas (10). The double lumen dialysis catheter (Fig. 1C) devised by R.O.Hickman in 1979 already, should, apart from a limited use, only be considered as a very last solution. Its infectious and thrombotic complications are indeed extremely frequent (11).

Presently, a native shunt is the superior option. Japanese physicians have understood it correctly since they dialyze 90% of their patients via a Brescia-Cimino fistula. Their European counterparts follow close with 80% of their hemofiltrations via a native arteriovenous fistula (AVF) whereas their American colleagues are progressing: 25% of native AVFs in 2001 and the figure is steadily increasing (12). Let us stress here that, since the start of renal pathology and whatever the treatment selected, the patient's venous capital must by all means be pre-

served in order not to compromise the possible later construction of a hemodialysis access (11).

In this article, we will demonstrate the exceptional role of color Doppler ultrasound (CDUS) in preparing the site for dialysis AVFs and for their follow-up. The examination indications and the technical modalities for the use of CDUS have been kept separate for clarity of presentation.

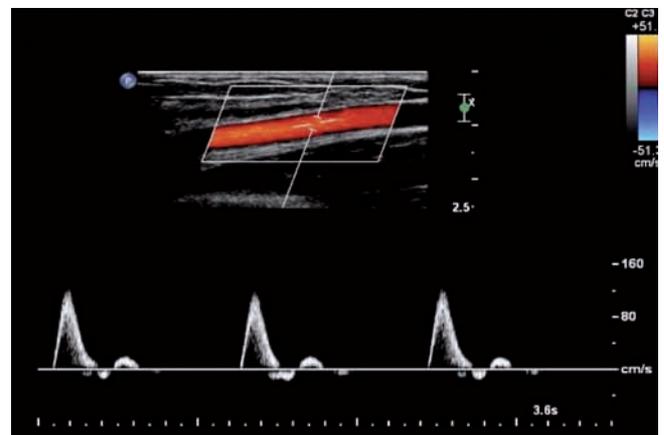
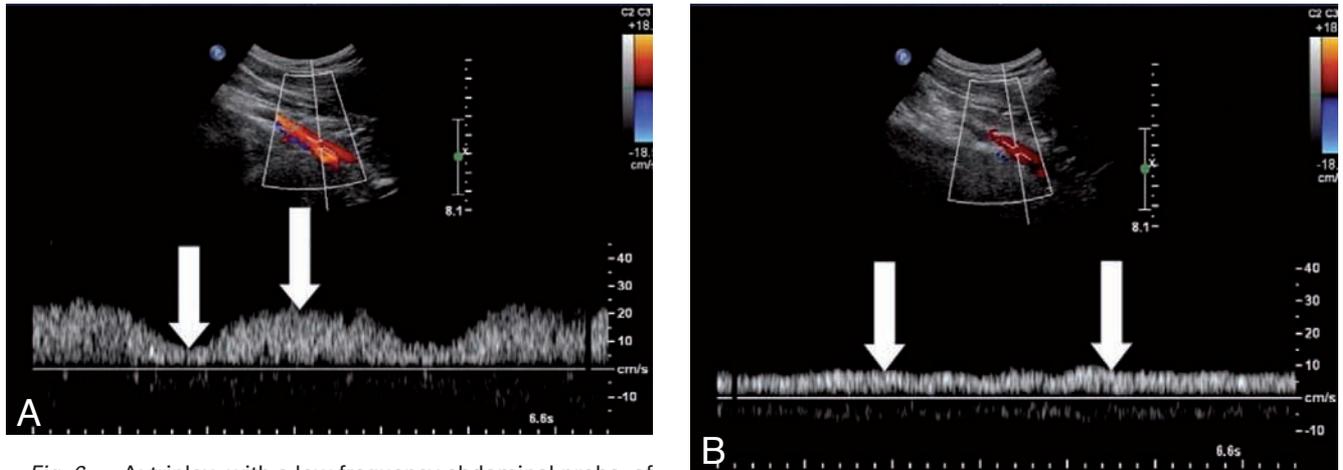


Fig. 5. — brachial artery triplex: optimal angle, gate size, PRF, focalization and gains.

**Indications for CDUS before the creation of a native shunt**

Since a native dialysis AVF requires maturation over several weeks before it can be punctured, when the renal disease reaches stage 4 (glomerular filtration rate between 15 and 29 mL/min/1.73m<sup>2</sup>) and even earlier if the disease develops more rapidly, the patient is



*Fig. 6.* — A: triplex, with a low frequency abdominal probe, of a normal right subclavian vein: cardio-respiratory modulation of the flux (arrows).

B: left side: occlusion of the innominate trunk with demodulation of the subclavian flux (arrows).

C: angiographic proof of the occlusion (arrow), due to a dialysis catheter. The stars indicate the collateral network.

referred to the vascular surgeon for a clinical examination of their upper limb vessels (11). If arteries and veins appear suitable for the construction of an AVF, the shunt is created without any further examination (13). Should the vascular structures seem suboptimal, the patient must be referred to a radiologist for CDUS assessment. Obese, female, elderly, diabetic patients as well as those suffering from cardio-vascular disorders will derive the greatest benefit from CDUS assessments (11, 14). Patients with Raynaud's syndromes, thoracic outlet syndromes and those with a history of previous central vein catheter should also benefit from CDUS assessments (15) even more as this noninvasive and widely available imaging is not expensive (16). It remains, nevertheless, time-consuming and observer-dependent (17).

Preoperative CDUS not only helps to increase postoperative and primary patencies in native fistulas (18, 19), it also increases the number of native shunts versus PTFE grafts (20).

#### Indications for CDUS in the surveillance of AVFs

Surveillance of dialysis shunts aims principally at lowering the frequency of fistulous thromboses whose consequences on the patients' morbidity and mortality are well-known and which entail important additional costs (2).

A clinical inspection of the fistula at each dialysis session is a first stage in the surveillance program. Venous collapse, decreased thrill, edema in the limb are some warning signs.

The second stage of surveillance is the control of dialysis physico-chemical parameters. Any disturbance in the arterial or venous pressures in function of the flow, of the urea reduction rate and of the recirculation rate must be noticed (2). Some dialysis centers are equipped with validated instruments linked directly to the hemodialysis network to measure the access blood flow by dilution technique. Any abnormal value should be noted (21, 22).

CDUS is the third stage of surveillance. It is recommended when the fistula reveals a clinical problem or when the dialysis parameters are altered (2). Some authors also advise to perform routine CDUS on the pretext of allowing the detection

of stenoses that do not appear at clinical examination or that do not infer a significant decrease in the dialysis outflow (8, 23, 24). The fact that the fistula outflow, as well as the coronary arteries flow, only starts dropping when the shunt diameter is considerably reduced (25), also advocates for a systematic control. Therefore, in our institution, we perform an annual CDUS for each dialysis patient even if no abnormality is assessed during their dialysis sessions. Other authors think that such examination is not relevant since the detected lesions are not meaningful (26). KDOQI does not recommend any time limit and advises to proceed on a case by case basis (2). We do not think, however, that the cost of a yearly CDUS is unacceptable considering the total annual cost of dialysis or that of a fistulous thrombosis.

Even if some authors consider angiography as the gold standard in

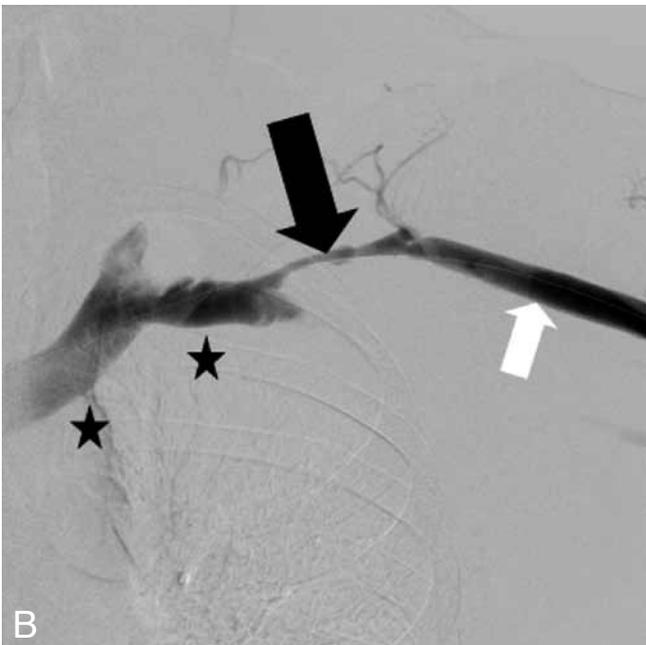
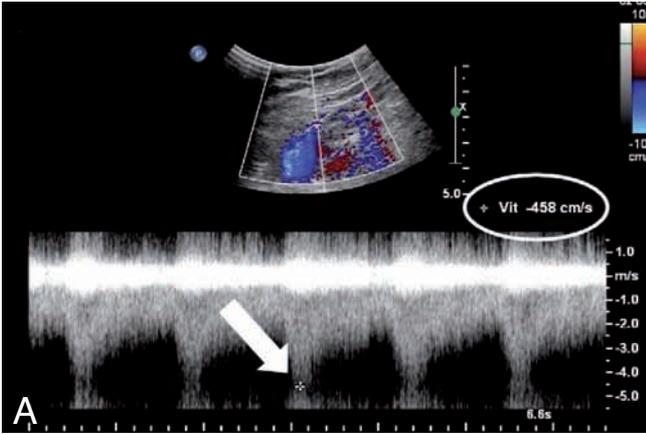


Fig. 7 — A: triplex at the level of an ostial cephalic vein stenosis: obvious acceleration, without aliasing thanks to the 5 MHz probe, at 4.5 m/s.

B: angiographic counterpart: cephalic vein (white arrow) stenosis (black arrow), stars indicate the subclavian and innominate veins.

assessing dysfunctioning dialysis fistulas (2, 22, 27), we think that CDUS, possibly linked with magnetic resonance (MR) angiography (cf infra), remains largely sufficient and we keep iodinated contrast enhanced controls for cases requiring percutaneous therapy.

**Indications for CDUS in case of immature AVFs**

If a prosthetic arteriovenous graft can be used soon after its creation, it is advisable to allow native AVFs to mature over a period of about six

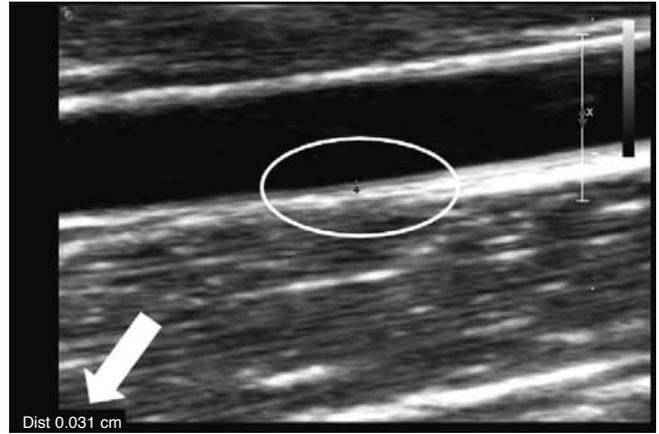


Fig. 8. — B-mode of a normal intima-media thickness: measurement between the "inner surface" and the first anechoic line.

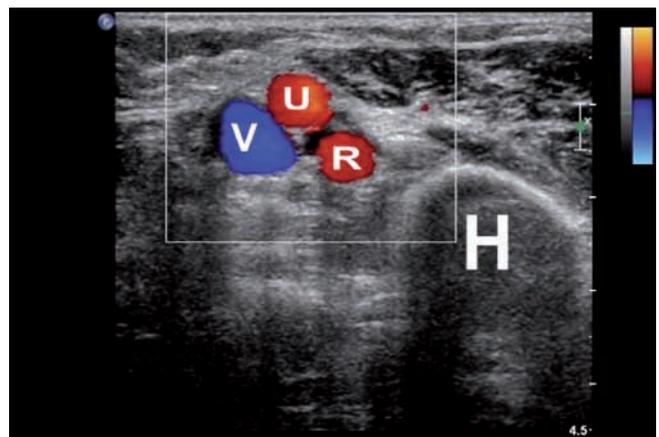


Fig. 9. — Color Doppler of an upper brachial branching at the level of the mid-humerus (H): the ulnar (U) and radial (R) arteries, the brachial vein (V).

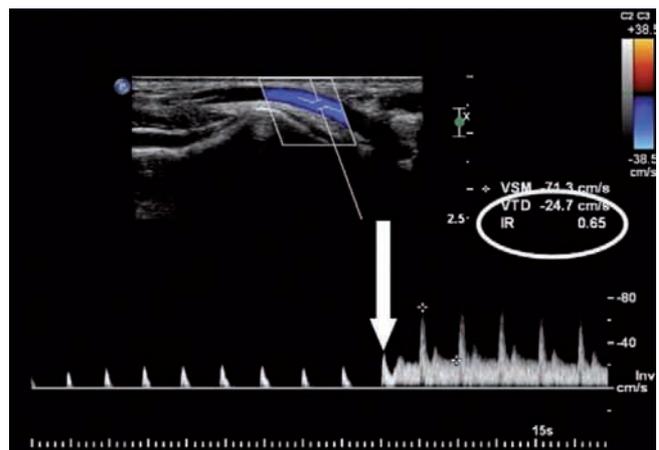


Fig. 10. — Triplex showing the effect of the releasing (arrow) of a brachial tourniquet on the radial arterial spectrum: the resistive index drops to 0.65 (white circle), a good predictive factor before AVF creation.

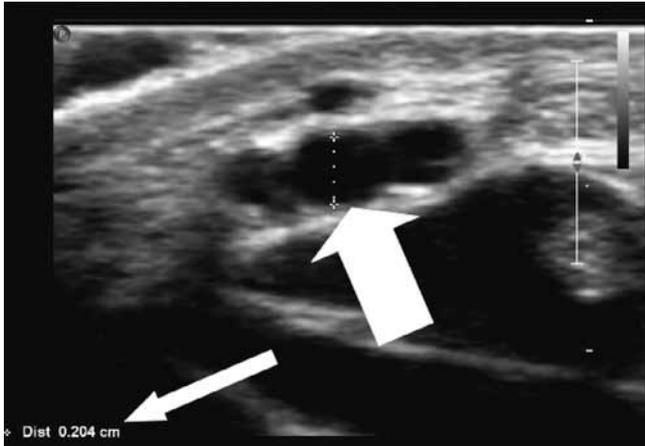


Fig. 11. — B-mode of the internal lumen of a radial artery (thick arrow). The measurement (2 mm, thin arrow) indicates that the prognosis of the shunt is good.

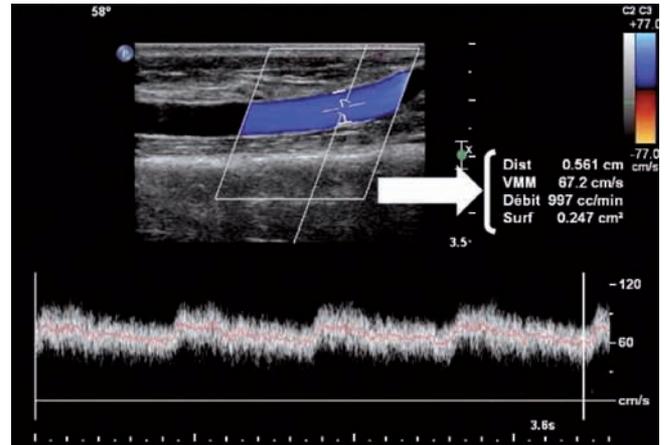


Fig. 13. — Triplex of a cephalic vein with a flow measurement (arrow): appropriate setting of angle, PRF and vessel diameter; 4 cardiac cycles are taken into account.

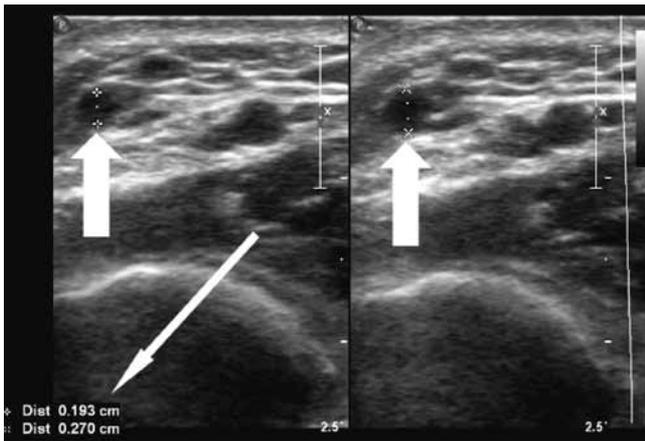


Fig. 12. — B-mode of a favorable distensibility test: increase of the venous diameter (thick arrows) by 50% (thin arrow) after brachial tourniquet.

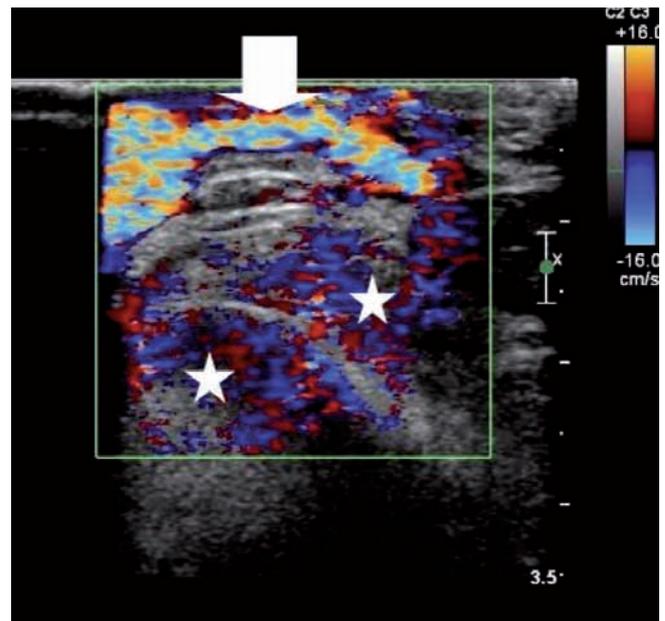


Fig. 14. — Color Doppler of an AVF anastomosis (arrow): the stardust artifact (stars).

weeks before initiation of hemodialysis (28). Successful fistula maturation, which translates into a fitting increase of the vein caliber, results from a clear increase of its flow (29). It is easier for brachiocephalic AVFs than for radiocephalic anastomoses but the latter remain preferable mainly because of their greater longevity (5). Since radiocephalic AVFs tend to reach their maximum flow at 4 weeks (30), a clinical inspection of the shunt is recommended one month after its construction. If the draining vein is badly or not palpable, an assessment CDUS should be carried out to define the reason of its lack of maturation (cf infra) (8, 10).

Once it has been treated, the vein must be closely monitored due to

quick and frequent phenomena of restenosis (4, 31). Later on the fistula will 'calm down' and ensure its durability (5).

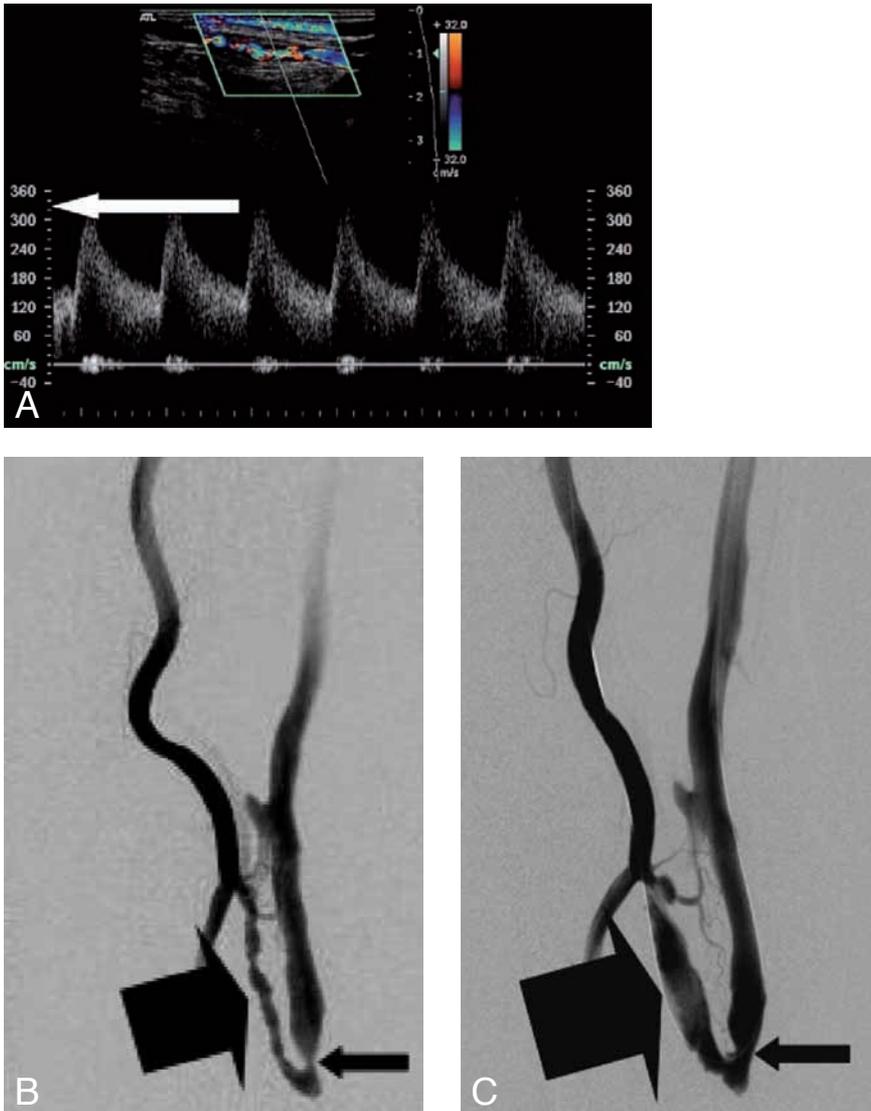
#### Indications for CDUS prior to therapy

It is up to the radiologist or to the surgeon to decide whether or not to have CDUS performed before treating a dialysis fistula. Individual practices vary, however advantages of pre-intervention CDUS include optimizing the selection of the punc-

ture site, limiting the number of punctures and, more generally, reducing the duration of the intervention (16).

#### Indications for CDUS per- and post-surgical or percutaneous treatment

When the immature AVF of a patient preparing for dialysis with impaired renal function must be treated, it is to be advised to limit the exposure to nephrotoxic iodinated contrast material. Iodine dilution is a first solution; a smart alternative



*Fig. 15.* — A: triplex of arterial stenoses: color aliasing and obvious acceleration at more than 3 m/s (arrow).  
 B: angiographic correlation: post-ostial radial artery stenoses (thick arrow) and post-anastomotic venous stenosis (thin arrow).  
 C: the fistula after percutaneous treatment.

consists in partially or totally assessing the therapy (dilatation, thrombolysis...) by CDUS without any vascular opacification.

Besides, CDUS can prove useful in the operating room when the surgeon performs a banding of an excessively high flow fistula. The radiologist can then measure the flow repeatedly in order to guide the extent of vein caliber reduction.

Finally, CDUS cannot be ignored for the post treatment check-up and for the long term surveillance of the treated fistulas that prove potentially frail.

#### General CDUS technique for upper limb vessels

CDUS examination can be performed on a seated patient (8, 15) but we prefer, like J.M. Corpataux (29), to perform the study in the supine position, as much for the patient's comfort as for the radiologist's. The bare-breasted patient will be installed in a room with a minimum temperature of 20°C (15) and the ultrasound gel should be slightly warmed and spread liberally (10). Most authors admit that a high-frequency

probe, around 10 MHz, should be used (7).

The US unit must be used at full capacity, i.e. in the triplex mode, associating the brilliance mode (B), the color Doppler mode and the pulsed Doppler mode with an angle of insonation between 30 and 60° in order to avoid an alteration of the velocity measurements (32).

The study in B-mode is carried out, after an appropriate gain adjustment, on both planes of the vessels, particularly for veins whose diameter is often ellipsoidal. Venous elements should moreover be examined by using a gentle transducer pressure. Let us not forget that the upper limb is arterially fed by the brachial artery via the subclavian artery then the axillary artery. The brachial artery most often divides, at elbow level, into a radial artery and an ulnar artery, which anastomose at the hand (Fig. 2). Venous draining of the upper limb rests on a deep network and a superficial one, linked by perforating vessels. The deep network borders the arterial system with, generally, two veins for each artery. The superficial structure consists, though there exist many anatomical variations, of a radial vein and an ulnar vein that anastomose at the elbow joint to give a cephalic vein and a basilic vein drained respectively by the subclavian and the axillary systems. The central return pathway occurs along the superior vena cava, via the innominate trunk on the left (Fig. 3).

Pulsed Doppler spectral analysis is performed with an optimal adjustment of the gain, of the repetition frequency and of the gate size, ideally two thirds of the examined vessel (Fig. 5).

The study of central veins remains a problem for sonographers. If the superior vena cava and the innominate trunk are completely out of reach because of aeric and osseous interpositions, their permeability can be checked indirectly. Indeed, in the case of an important stenosis or thrombosis, the cardio-respiratory modulations of the subclavian veins disappear (Fig. 6). In obese patients, a direct study of subclavian veins will prove complicated if a high-frequency transducer is used. Some advocate then to resort to MR or CO<sub>2</sub> angiography to spot stenoses (11, 15, 27). In our experience, we almost never resort to MR imaging. Whenever confronted with difficult cases, we use low-frequency abdominal transducers. If their spatial resolution is lower than that of

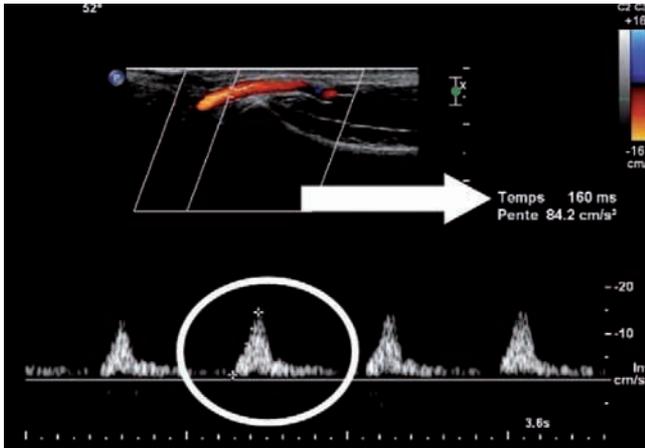


Fig. 16. — Arterial stenosis triplex: downstream SUT increase at 160 ms (arrow).

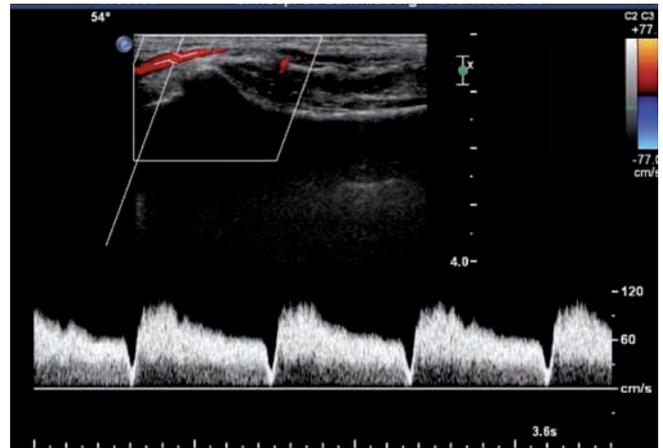


Fig. 17. — Radial steal triplex, the wrist being at left, the elbow at right: blood flow is in the direction of the probe, via the palmar arches.

high-frequency probes, the drawback is balanced by a reduced sensitivity to absorption and, mainly, by a lower susceptibility to phenomena of frequency ambiguity, so much so that the accelerated specters of stenosed veins can be optimally studied (32) (Fig. 7).

#### CDUS technique before AVF creation

As it has been explained above, a pre-AVF CDUS must be performed when clinical examination of the upper-limb vessels is inconclusive. It starts with a study of the arterial network where it must exclude any stenosis that would be revealed in B-mode by a reduction in vessel diameter and in Doppler mode by a maximum local velocity increase of more than twice the median systolic velocity of the artery. The intima-media thickness, which must be under 0.6 mm, is measured at the far wall of the vessel and possible calcifications are spotted (Fig. 8). In the instance of elbow fistulas mainly the absence of upper brachial bifurcation must be checked since it is a source of future dysfunctioning (Fig. 9). A hyperemia test must be carried out and allows checking the adequate reactivity of the arterial system: after releasing a brachial tourniquet fastened during two minutes, the resistive index (S-D/S, automatic calculation) must be lower than 0.7 (14) (Fig. 10). Finally, in the case of wrist fistulas, the minimum luminal diameter of the radial or ulnar artery must ideally be equal to or higher than 2 mm (11) (Fig. 11).

The exploration of the venous system starts with a thorough

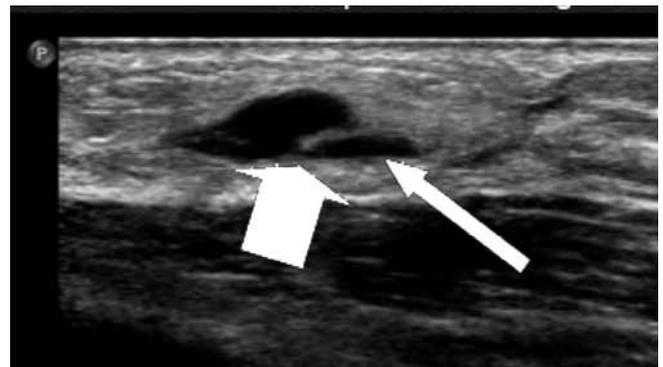


Fig. 18. — B-mode of an ulnar artery (thin arrow) with an anastomotic stenosis (thick arrow).

mapping, examining very closely the permeability of the central veins, which may be confirmed by MR angiography assessment. The thickness of the walls is recorded and the examiner will verify that, for native wrist AVFs, the draining vein has a diameter of at least 2 mm. Venous distensibility is measured by the tourniquet test: ideally, the diameter of the vein must have increased by 50% after a two-minute application (11, 14) (Fig. 12).

The examination report is usefully accompanied by a diagram, even by skin marking (15). We acknowledge this practice may not be practically feasible in all cases but we aim to perform the examination in the presence of the vascular surgeon who will construct the anastomosis.

#### CDUS technique and criteria for normal AVFs

Except when an extensive thrombosis is suspected, the examination should not be carried out right after dialysis. Indeed, flow calculations can be wrong owing to reduced blood volume (2). Moreover, if the examination is performed immediately following hemodialysis, important vascular segments may be hidden under the dressing and it will prove challenging for the echo Doppler to make a distinction between post-puncture spasms and actual stenoses.

The absolute criterion for a well functioning dialysis fistula is that it is able to undergo at least six dialysis sessions a month and sustain a



Fig. 19. — A: Triplex of a cephalic vein stenosis: color aliasing and spectral acceleration up to 6 m/s (arrow).

B: angiographic confirmation of the stenosis (arrow).  
C: the same vein after percutaneous dilatation.

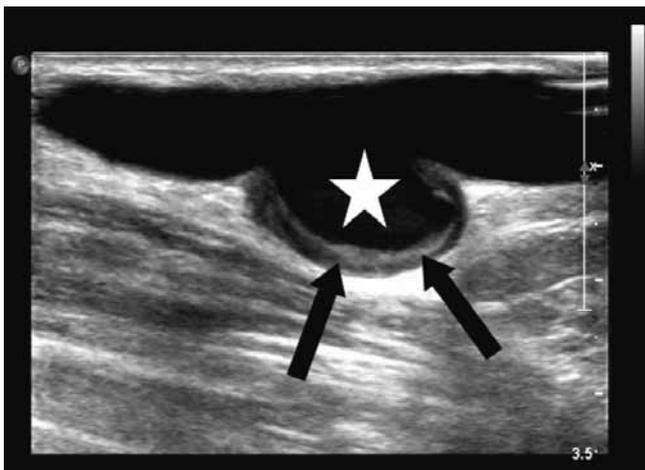
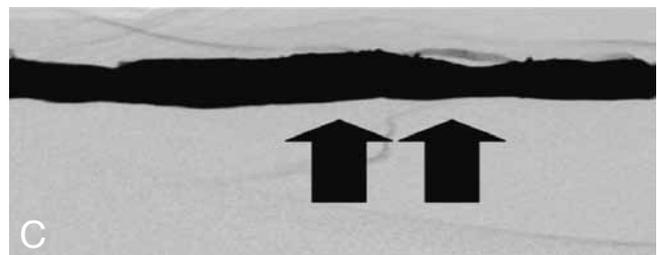
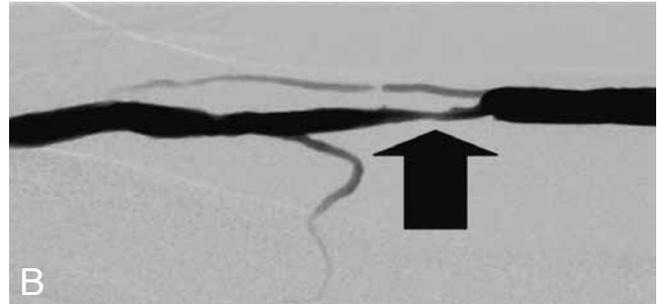


Fig. 20. — B-mode of a venous aneurysm (star) with partial parietal echogenic clotting (arrows).

blood flow rate of 350 mL/min (8) or – more prosaically – that it ensures a sufficient flow for hemodialysis (11), which can perfectly be confirmed by CDUS. The AVF CDUS must examine the whole shunt in triplex mode. We follow Franco and the KDOQI guidelines and use easy echo Doppler criteria, based on figure 6, that indicate a healthy shunt: 6 weeks after surgery, the fistula flow volume must be at least 600 mL/min and the diameter of the draining vein, at a maximal depth of 6 mm, must be greater than 6 mm. Another criterion of adequacy must be added to this list of basic criteria: the length of the venous segment that is punctured must equal 10 cm or twofold 4 cm (33).

Flow measurements are said to be taken on the feeding artery (2, 34) but we actually check arterial and venous flows, with necessarily an angle of insonation between 30 and 60°. Three to four cardiac cycles are taken into account and turbulence areas are avoided (8). The blood flow is calculated automatically by recent machines by using the classical formula: outflow (in mL/min) = average blood velocity  $\times (\pi D^2/4) \times 60$ , where D represents the vessel diameter in cm (Fig. 13). Let us insist on the fact that, even if they are done by an experienced examiner, Doppler measurements of the blood flow have a margin of error of 5% (35). The minimum blood flow rate in a wrist AVF must ideally be 500 mL/min, i.e.

350 mL/min for the dialysis device and 150 mL/min to keep the fistula patent during hemodialysis sessions. The minimum blood flow in a graft is 650 mL/min and we agree to say that it must be at least 750 mL/min in a native arm fistula (2). The fistula blood flow should always be recorded in the report and will be the standard for all further CDUS as, whatever the cause of AVF dysfunction, any drop of more than 20% in the fistula blood flow by comparison with a former normal examination must be considered suspicious and lead to a more thorough study of the fistula, even to a closer surveillance (11).

Let us note that findings of colored tissular signals in the region of the anastomosis are quite normal and are called stardust artifact. They appear on all AVFs and are a result of vibration phenomena (Fig. 14).

#### CDUS criteria of AVF disorders

Lesion therapy modalities are mentioned because we consider they are significant for AVF follow-up, even if the radiologist is not interventional.

#### Cardiac pump problem

It is quite evident that a left cardiac failure or an aortic valve stenosis may induce a flow drop in the dialysis AVF. Such very central lesions will be diagnosed thanks to the concomitant demonstration of a systolic upstroke time (SUT) increase in both the fistula and the arterial sectors that are not included in the shunt (36). The treatment of

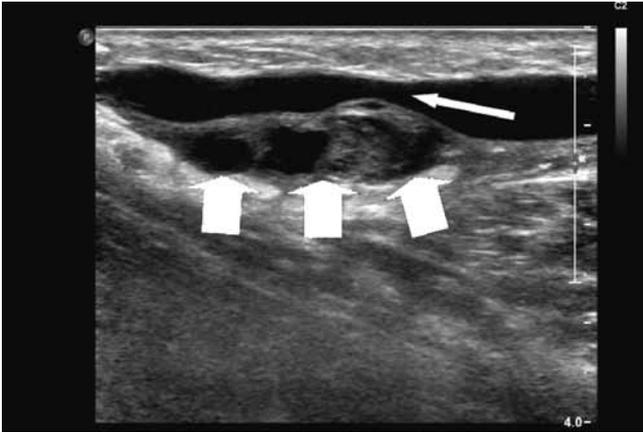


Fig. 21. — B-mode of a variable echogenicity perivenous hematoma (red arrows) entailing a venous stenosis (white arrow).

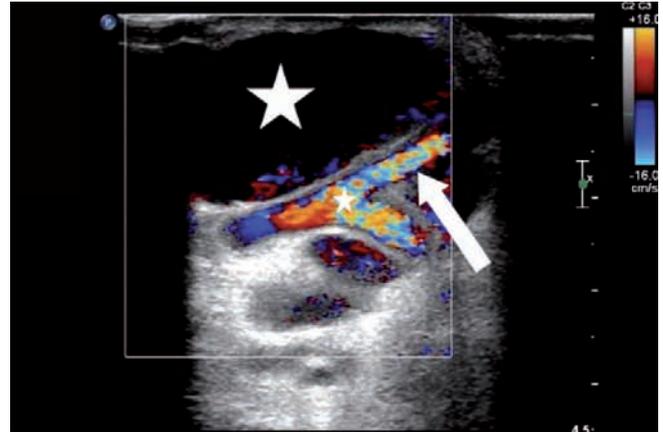


Fig. 22. — Color Doppler of an anechoic seroma (star) generating a post-anastomotic venous stenosis (arrow).

these pump problems is medical, even cardio-surgical.

#### Stenosis of the subclavian artery

In most cases, Doppler echographers cannot reach the ostium of the subclavian artery. A diagnosis of stenosis is then based on the SUT of the subclavian artery at the level of the clavicle. The problem is that the arteriovenous anastomosis itself implies a SUT increase. A correct measurement of this value can be obtained by a simple gesture that consists in shutting the post-anastomotic vein manually during some seconds.

A lower than 70 millisecond SUT must be rated as normal (extrapolated from 36). There is no pathological threshold, as far as we know, above this value but a subclavian ostial stenosis must be suspected if the SUT is noticeably higher than the mean SUT in the arteries of the neck, the contralateral upper limb and the lower limbs.

#### Arterial stenosis

The indirect Doppler criterion for a significant arterial stenosis is a flow drop.

Direct criteria, in B-mode, consist in a higher than 50% decrease of the endoluminal arterial diameter and, in pulsed-wave mode, in a twofold increase of the mean systolic velocity (Fig. 15) together with an increase of the downstream SUT (Fig. 16) (16).

In case of tight stenosis, percutaneous transluminal angioplasty, possibly together with a metallic endoprosthesis fixed on a balloon, is the therapeutic treatment of choice (37).

#### Arterial steal

The steal syndrome is due to a diversion of the arterial flow intended for the limb towards the draining vein of the fistula. Due to an excessive flow rate or to a stenosis of the feeding artery, the flow of the post-anastomotic artery is reversed, fed by the palmar arches in the forearm AVFs and by deep lying collaterals in the case of brachial shunts (Fig.17).

The intensity of the reversal may vary, similarly to the subclavian steals (32, 38), and the phenomenon rarely has a clinical impact (2-6%) (7). If it causes distal ischemic symptoms, a surgical or interventional radiologic treatment can be suggested (9).

#### Anastomotic stenoses

B-mode sonography displays the narrowing directly whereas the Doppler mode pinpoints an increase of the systolic velocity with local turbulence, a flow drop and, in the color mode, an enhanced stardust artifact (Fig. 18).

Anastomotic stenoses are generally viewed as the result of a technical error when they are detected soon after AVF construction and must be managed surgically (37).

#### Venous stenosis

Repeated punctures as well as vibrations and turbulences caused by the shunt contribute to the development of venous stenoses. They are the result either of a fibrosis or of an endothelial hyperplasia that can affect valvular zones (9, 16). Their diagnosis rests on the direct visuali-

zation of a more than 50% narrowing of the vascular caliber and of higher local velocities together with or without a decreased flow (Fig. 19). Let us not forget that central venous stenoses prove technically challenging to analyze.

The treatment of venous stenosis is identical to that of arterial narrowings except that the endoprosthesis that may be used must be self-expanding (9). If the fistulous flow rate is abnormally high in spite of a venous stenosis, the latter must be monitored carefully but should not be treated in order to avoid excessive flow and a pernicious impact on the heart function.

#### Distal ischemia

Distal ischemia is the result of a serious steal syndrome, of a severe arterial stenosis or of a venous stenosis considered sufficient to create an upstream increase in pressure (39). Various etiologic factors can of course be associated and can all be detected by CDUS.

The treatment of distal ischemia proves delicate. It derives benefit from surgical techniques as well as from radiological interventions (9).

#### Arteriovenous aneurysms and pseudoaneurysms

The literature on arteriovenous aneurysms and pseudoaneurysms remains limited. Their diagnosis rests on direct echographic visualization. They are characterized by a diameter more than twice that of the adjacent normal fistula and can show a more or less intense parietal clotting that is potentially throm-

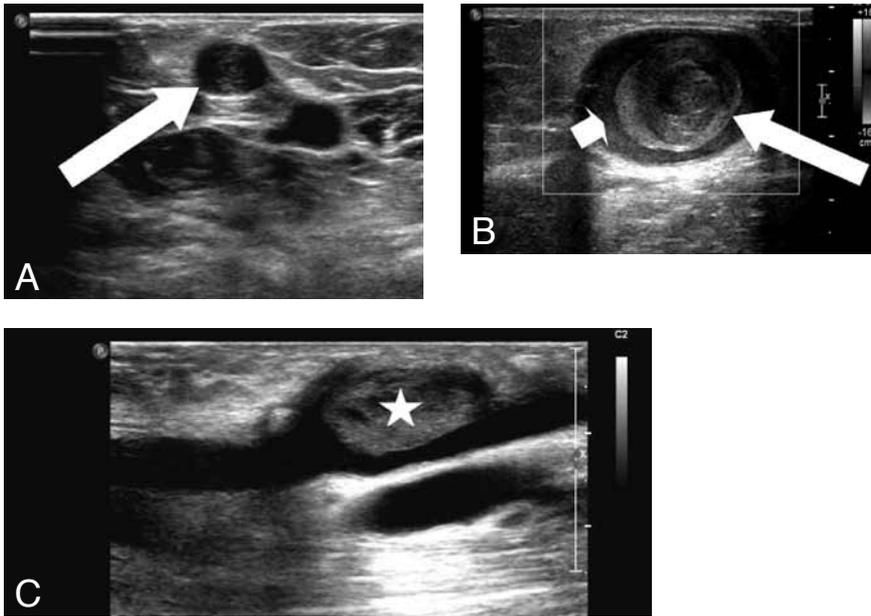


Fig. 23. — B-mode of venous clottings (long arrows and star) with variable echogenicity. The short arrow in figure 19B shows slightly echogenic low speed residual blood flow.

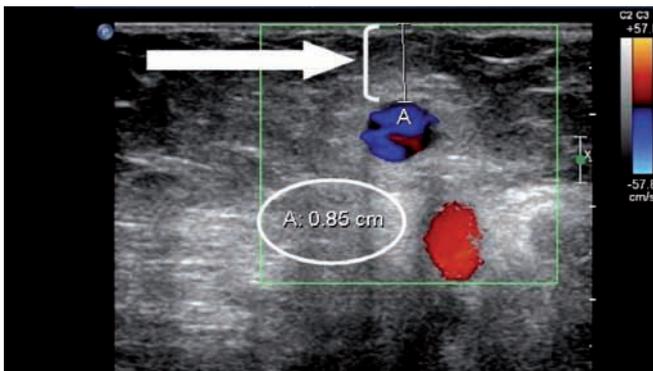


Fig. 24. — Color Doppler of a maturation pseudo delay: the vein (in blue) is situated too deep, i.e. 8 mm, to be easily punctured (arrow and white circle).

bogenous and emboligenous (Fig. 20).

They require surgical treatment, particularly if they develop rapidly (40, 41).

#### *Hematoma, seroma, abscess*

They are often the result of difficult venopunctures and are directly visualized by echography which, in this field, is significantly more efficient than angiography (7). B-mode shows a variable echogenicity structure with a more or less thick wall, potentially responsible for a compressing impact on the draining vein (Fig. 21, 22).

The treatment of such mass syndromes is medical, even surgical when the lesion is severe and potentially associated with a pernicious stenotic effect for the function of the fistula.

#### *Thrombosis*

Fistulous thromboses are optimally visualized by B-mode sonography under the form of endovascular material displaying a variable echogenicity and whose hardness is even more patent as it is detected late (32) (Fig. 23). They can be caused by sudden hypotension, dehydration or even a tight venous stenosis, the

etiology list is not exhaustive (7). Fistulous occlusion, whether it is incomplete or total, poses a threat since it induces severe endothelial alterations that put the longevity of the fistula at risk, even after a rapid intervention (2).

The treatment of a complete thrombosis can be performed by a surgeon or by an interventional radiologist (thrombolysis) and the removal of the possible mechanical obstacle must happen at the same time.

#### *AFV nonmaturation*

Let us remember that, when clinical doubt arises as to fistulous maturation, CDUS should be performed as soon as four weeks after fistula construction. AVF nonmaturation is revealed by an absence of development of the draining vein six weeks after shunt creation (28). It is mainly the result of stenosing arteriovenous lesions or of an excess of collaterals in the venous section. These causes are easily detected sonographically (33, 42). Excess of superficial or perforating collaterals on the draining vein implies a rapid decrease of the fistulous venous flow and henceforth dialysis problems. Surgical ligations are apt to solve the problem.

Fistulous immaturity always requires an emergency treatment since the thrombosis occurs early and the shunt proves extremely difficult to reopen (4).

What is called maturation pseudo delay is the result of an excessive depth of the draining vein, more than 5 to 6 mm from the skin surface whereas the other characteristics of the AVF remain normal. This abnormal depth is clearly demonstrated in B-mode and makes puncture for dialysis quite arduous (Fig. 24). It requires surgical treatment consisting in a venous transposition with possible resection of fatty tissues.

#### *Excess flow*

When the diameter of the anastomosis is excessive, it no longer plays its role as a natural brake and the fistulous function races out of control (9). CDUS does display the phenomenon whether in B-mode or in Doppler mode where the flow measurement is abnormally high (Fig. 25). It is estimated that a higher than 2 L fistula flow is, owing to complex mechanisms, potentially pernicious for the cardiac function (9). An excessive fistula flow can also trigger a distal ischemia by steal as we have already explained.

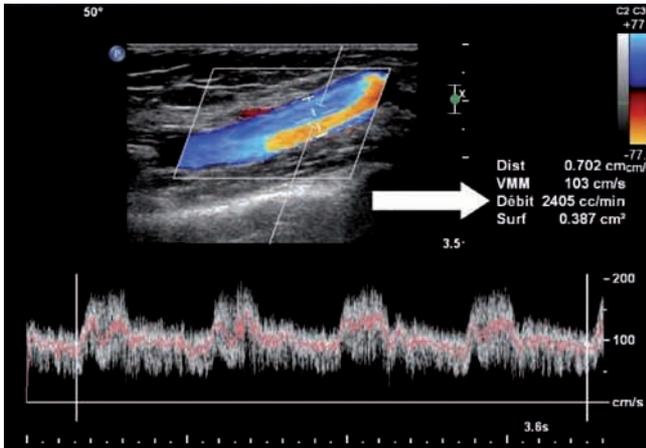


Fig. 25. — Triplex of an excessive AVF outflow at 2.4 L/min.

Excess flow requires an elaborate surgical treatment, starting from ligations and arterial transpositions up to closure of the AVF in the most serious cases (9, 43).

### Prosthetic graft fistulas

We have less experience with prosthetic graft fistulas. They are constructed in the arm essentially, most often with PTFE prostheses and practically do not require a period of maturation (9). We have already underlined the fact that native AVFs must be preferred to prosthetic grafts since the latter are more prone to thrombosis, most often due to a stenosis of the venous anastomosis, but they are sometimes the only solution left for hemodialysis. Anyway, they are a better choice than central catheters (14).

CDUS indications for vascular dialysis grafts keep to the same principles as those mentioned for native AVFs. Careful attention must be paid to the analysis of that sensitive area covering the junction between the prosthesis and the vein.

### Report

Next to an exhaustive anatomical description of the AVF, the CDUS examination report must record a flow rate since the latter determines the efficiency of the hemodialysis. The value will be a marker for future examination since any flow rate drop higher than 20% remains suspicious, as we have already underlined.

In the presence of problematic shunts, we complete the written report with an explanatory diagram

(Fig. 4) illustrating the abnormalities we have discovered. We are convinced that the diagrams prove most helpful for the whole staff to understand the anatomical and functional particularities of these shunts, consequently improving the long-term prognosis of difficult dialysis fistulas.

### Conclusion

Though it is time-consuming and observer-dependent, CDUS is an available and rather affordable method of choice for the construction and the surveillance of dialysis shunts. It is particularly efficient, mainly in experienced hands, and contributes to increase the number of native AVFs. Besides, it enables to detect lesions quite early and allow a quick percutaneous or surgical therapy resulting in a greater efficiency and a longer sustainability of dialysis shunts.

Our policy is to perform CDUS as soon as a clinical problem or a difficulty arises during dialysis. Our uneventful dialysis patients undergo an annual CDUS assessment but we examine them more often in case of anterior fistulous revision.

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