Doppler ultrasonography of hemodialysis fistulas complications

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Learning objectives

To assess the Doppler ultrasonography features of hemodialysis fistulas complications.

Background

Hemodialysis arterio-venous fistulas are defined as long-term vascular accesses allowing extra-corporal removal of blood toxins in case of chronic renal failure.

There are two types of fistulas: native and prosthetic and there is an order of preference for the creation of a permanent vascular access:

- Radial-cephalic fistula
- Brachial-cephalic fistula
- Brachial-basilic transposition fistula
- Arteriovenous graft

Native and prosthetic fistulas complications are the most frequent causes of hospitalization in hemodialysis patients. Their prompt identification is mandatory in order to not interrupt their hemodialysis program.

Fistulas' complications can be divided into 2 groups: early (within 3 months of their creation) and late complications. They are caused either by inflow or outflow anomalies (1).

Doppler ultrasonography is frequently used for the identification of these complications. It is generally performed for the following indications:

- Abnormal fistula functioning including:
  - Difficult cannulation
  - Thrombus aspiration
  - Increased venous pressure
  - Increased recirculation time
  - Low urea reduction rate
• Clinical signs of fistula insufficiency:

- Decrease or absence of thrill
- Distal limb ischemia
- Clinical signs of infection
- Located masses suggestive of aneurysms or pseudo-aneurysms

Findings and procedure details

The data have been collected during one year.

The age of our patients ranged between 27 and 80 years.

Color doppler ultrasonnnography procedure:

Our ultrasonography examinations were performed with an ultrasound duplex imager (Philips IU 22) with pulsed, color flow and spectral analysis. Linear probe with frequencies varying between 7 and 12 MHz was used. Patients were placed in supine position.

The feeding artery and draining vein of the fistulas were examined in all cases.

Doppler ultrasonography data of 26 patients (11 men and 15 women) with complicated hemodialysis fistula were reviewed.

Findings:

Twenty four patients had native fistulas (radial-cephalic: n = 8, brachial-basilic: n=12, brachial cephalic: n=4). Two patients had prosthetic fistulas.

Doppler ultrasonography was practiced for one or more of these signs:

- Upper limb swallowing (n=13)
- Local inflammatory signs (n=6)
- Diminished thrill (n=5)
- Tingling and trophic disorders (n=4)
- Difficulties in hemodialysis access (n=2)
- Systematic control (n=3)
The complications observed, often associated, were:

1. **Local infection and collections (n=5):**

Infection is the second most common complication of hemodialysis fistulas after thrombosis. It occurs predominantly in synthetic grafts and results either from operative contamination, exogenous contamination during puncture or bacteriemic seeding. Patients generally present with fever and inflammatory local signs such as swallowing and rubber. Ultrasonography grayscale examination reveals edema of the soft tissues and collections. Abscesses should be distinguished from serous collections secondary to filtration of serum through the graft. Diminished flow and vein thrombosis can be associated (figure 1).

2. **Excessive Flow (n=8):**

Excessive flow is defined with an arterial flow exceeding 1-1.5 l/ min with a cardio-pulmonary recirculation exceeding 20%. It can result in pulmonary edema, cough, recurrent pulmonary infections, steal syndrome and heart failure. In our practice, we consider that there is an excessive flow when it exceeds 1.2 l/ min on spectral analysis. We always verify that there is no modification of ulnar and radial arteries flow after fistula occlusion in order to eliminate a steal syndrome (figure 2).

3. **Steal syndrome (n=4):**

It occurs in approximately in forearm and arms fistulas in 6 % and 10-20% of cases respectively. It occurs frequently in fistulas with large anatomoses and high flow. Its clinical manifestations can include various signs and symptoms ranging from coldness, pallor, mild paresthesia, and pain during dialysis to severe symptoms such as pain at rest, palsy, ulceration, tissue necrosis and loss.

The steal syndrome can be generalized resulting in lower limbs and bowels ischemia and in heart attack. On Doppler examination, arterial steal is defined as retrograde flow in the native artery distal to the anastomosis. There is an inverted or a bidirectionnel flow (anterograde in the systole and retrograde in the diastole. The compression of the fistula results in gradual restoration of the anterograde flow. In our practice, we also evaluate the peak systolic velocities (PSV) of the radial and ulnar arteries when the fistula is functioning and then when it is occluded. When the ratio of velocities (PSV fistula occluded/PSV fistula functioning) is superior to 2, steal syndrome is considered to be real (figure 3).

4. **Diminished Flow (n=4):**
The flow is considered diminished when it is lower than 600 ml/min. It generally reveals an early failure of the fistula or a lack of its maturation. It results from inflow or outflow problems.

Inflow problems include pre-existing arterial anomalies (anatomically small artery or atherosclerotic disease) and acquired juxta-anastomotic stenosis.

Outflow problems include anatomically small or fibrotic veins and pre-existing side branches.

1. **5. Artery stenosis (n=3):**

Artery stenosis can be pre-existing or secondary to the operative procedure. It should be suspected when there is an "aliasing" in an arterial segment and when there is an elevation of the PSV (figure 4).

1. **6. Vein stenosis (n=4):**

Vein stenosis is considered to be significant when there is a reduction of at least 50% of the vessel diameter. Gray scale examination shows decrease in lumen diameter. On color Doppler, there is an "aliasing" in the stenosis zone. Duplex Doppler shows a PSV superior to 400 cm/s. It can also show a ratio of PSV at stenosis to PSV at 2 cm beyond anastamosis superior to 2. When this ratio is between 2 and 3, the stenosis is estimated between 50 and 75%. When it is superior to 3, the stenosis exceeds 75% (figure 5).

Vein stenosis can be long or short. They can result from fibrotic changes, calcifications, partial or complete diaphragm and intimal proliferation (figure 6).

1. **7. Vein thrombosis (n=5):**

Thrombosis is the most frequent fistula complication. Early thrombosis is generally caused by a technical error such as choice of an inadequately sized draining vein or bad anastomotic technique. It may also be caused by external compression for hemostasis, hypotension, dehydration, or early puncture of an immature vein. Thrombosis is easily confirmed sonographically, typically, anechoic or hypoechoic clot is seen within the vessel or graft, with absence of blood flow noted during pulsed or color Doppler examination.

Late thrombosis can also result from hypotension, dehydration, compression, or trauma but is more commonly caused by an acquired stenosis of the venous runoff vessels.

Thrombosis can be complete or partial. When there is a complete thrombosis Waveforms demonstrate a "to-and-from" characteristic indicative of a vessel with no outflow. Low PSV, the absence of color flow throughout the access, and the presence of echogenic material within the fistula are other findings compatible with access thrombosis (figure 7).
1. **8. Pseudoaneurysms formation (n=3)**

Pseudoaneurysms can be localized on the arterial or the venous sides (figure 8 and 9). They result from a tear of the graft wall caused by a needle with hematoma formation and have no vascular wall. Pseudoaneurysms with less than 5 mm diameter are frequently stable generally not clinically significant. Pseudoaneurysms with more than 5 mm tend to enlarge and should be managed with surgery or embolization.

1. **9. Vein aneurysm (n=2):**

The increase in blood flow in an AVF causes a continued increase in vessel size. When there is a marked degree of aneurysmal change in a fistula, downstream venous stenosis should be suspected (figure 10). Thinning of the skin should be evaluated carefully as it can lead to ulceration, rupture and severe hemorrhage. Sonographic features of vein aneurysm are characteristic, consisting of an abrupt increase in caliber of a given vessel (> 2 cm). Thrombosis within an aneurysm is usually detectable by sonography.

**Images for this section:**

![Image 1](image1.png)  ![Image 2](image2.png)

**Fig. 1:** Local infection and collection. Twenty seven-year-old woman. Brachial-basilic fistula since 2 months superficialized since one week. Purulent discharge from the
operative wound, fever and chills. (a) : Normally functioning fistula. (b) + (c) : Collection of the arm near to the fistula containing a foreign body (arrow).

**Fig. 2:** Excessive flow without steal syndrome. Eighty-year-old woman. Brachial-cephalic fistula since 5 years. Swallowing of the left upper limb. (a): Excessive flow of the fistula=2162ml/min (b): Radial artery PSV with functioning fistula (c): No significant modification of the radial artery PSV when the fistula is occluded (Ratio<2)

**Fig. 3:** Steal syndrome. Twenty-year-old woman. Brachial-basilic fistula since 3 years. Cold sensation of the hand during hemodialysis since 3 months, fingers ulcerations (a) : Excessive flow of the fistula=1636 ml/min (b) + (c) : Radial and ulnar PSV decrease and spectral demodulation (d) + (e) : Radial and ulnar PSV increase with occluded fistula (PSV Ratio=4.5).
Fig. 4: Pre-anastomotic arterial stenosis. Fifty three-year-old man with radial-cephalic fistula and presenting with diminished thrill. (a): Diminished flow of the fistula (less than 1ml/min) (b) + (c): Pre-anastomotic stenosis of the artery with "aliasing" on the color Doppler examination (arrow)
Fig. 5: Severe vein stenosis. Seventy-height-year-old woman. Brachio-basilic fistula since 2 years. Pain of the hand. (a): Normal flow of the fistula (b): Senosis of the basilic vein (c): High PSV in the stenosis area (>600cm/s) (d): Low PSV below the stenosis vein (=100cm/s with a ratio>6)
Fig. 6: Various types of vein stenosis (a)+ (b): Long stenosis due to fibrotic changes (c): Calcification of the vein wall resulting in stenosis (arrow) (d): Vein stenosis caused by a diaphragm (arrowhead) (e): Short venous stenosis

Fig. 7: Partial thrombosis of the vein. 51-year-old woman. Brachial-basilic vein since 2 years. Difficulties of vein cannulation. (a): Normal flow of the fistula = 1124ml/mn (b)+ (c): Partial thrombosis of the basilic vein (arrow).
**Fig. 8:** False aneurysm of the artery. 48-year-old woman. Radial-cephalic fistula since 2 months. Swallowing of the forearm. (a): Low flow of the fistula (b) (c): False artery of the radial artery

**Fig. 9:** Pseudoaneurysm of the vein. Fifty-year-old man with brachial-basilic fistula. Increase in venous pressure. (a): Normal fistula flow (b): Pseudoaneurysm of the vein

**Fig. 10:** Vein aneurysm. 47-year-old woman. Radial-cephalic vein since 7 years. Swallowing of the cephalic vein of the forearm. (a): Low flow of the fistula = 44ml/mn (b): Aneurysm of the cephalic vein with a diameter=3.2cm (c): Downstream vein stenosis
Conclusion

The Doppler ultrasonography is a safe, practical and reliable imaging technique that offers an anatomic and hemodynamic analysis of hemodialysis fistulas. Consequently, it allows a prompt diagnosis of their complications whether they are local, arterial or venous.

Personal information

References


