Planning and follow-up of endovascular procedures

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Learning objectives

1. To describe indications, technique, pitfalls and general yield of Doppler US for the diagnosis of arterial stenosis.

2. To present the role and advantages of US over other diagnostic procedures in the diagnosis and therapy of post-procedural complications.
Main

Arteries in the human body can be divided into 4 main groups based on how we examine them with ultrasound:

1. **Aorta**
2. **Large arteries running superficially, easy access**
3. **Arteries partially covered by structures which allow no ultrasound display of certain segments**
4. **Small arteries**

The abdominal aorta can easily be visualized while the whole course of the thoracic aorta can only be examined by means of transesophageal echocardiography (TEE). Finding the origin of celiac trunk and superior mesenteric artery is generally straightforward (FIG. 1 on page 6) with the exception of severe obesity or severe overlying bowel gas.

Renal arteries require better color sensitivity and some experience - the left decubitus position seems to be the most useful to visualize their origin (FIG 2 on page 6). [1]

The inferior mesenteric artery, the lumbar and bronchial branches are not visible in normal circumstances.

Large superficial arteries as the common carotid and the carotid bifurcation (FIG. 3 on page 7), femoral and popliteal arteries and brachial artery are most straightforward to examine. Only severe and circumferential calcifications and extreme tortuosity can cause trouble. Complementary display modes like B-flow or power Doppler are very useful in such cases [2] (FIG 4 on page 8).

There are some segments which can never be seen with ultrasound, for example the vertebral arteries under the transverse processes or the subclavian artery under the clavicle. It is often difficult to examine the iliac vessels because of bowel gases. In such cases the negative predictive value of the distally recorded normal waveform can be used. Indirect signs of stenosis can help to determine which patients need further diagnostic workup before endovascular or surgical therapy (FIG 5 on page 9).

Visualization of small arteries of extremities requires good ultrasound equipment with high frequency transducers. Successful imaging of ulnar, radial or smaller arteries and the whole course of tibial and peroneal arteries needs not only technical ability but it is also very time consuming, especially in thick legs. In our practice radial and ulnar artery ultrasound examination before and after coronary bypass surgery is part of the routine workup (FIG 6 on page 10). However, before below-knee interventions, other imaging modalities are required, especially for diabetic patients with high prevalence of multiple lesions in tibioperoneal arteries. [3,4]
The three most important parameters of Doppler examination to achieve successful visualization are: Doppler gain, PRF and steering (FIG 7 on page 11, FIG 8 on page 13). A well known rule of proper Doppler gain setting is to over-enhance it until color noise appears and then reduce it till the noise disappears. PRF has to be set to have no aliasing in normal segments. The use of manufacturer presets is suggested. However in some cases we have to adjust other parameters such as wall filter, color sensitivity, pocket size etc. to get optimal images.

It is generally accepted that in peripheral vessels the arteries are displayed in red and the veins in blue when the flow direction is normal. On the Doppler spectrum the normal arterial flow is to be displayed above the baseline and the venous flow under it. It is important to be confident in the direction of flow and the orientation of the transducer.

To obtain better color signal and to take accurate velocity measurements, tilting (or steering) of the color box and the Doppler beam is mandatory. The rule is to have as low angle between the axis of the vessel and the Doppler line as possible.

What are we looking for?

The goal of the examination before endovascular procedures is to find and to grade stenosis [5] (FIG 9 on page 12). The most important feature is velocity elevation in the stenosis. With a precise angle correction the highest systolic velocity can be measured and based on it the grade of stenosis can be estimated. Generally the cut-off value of 125 cm/s is used in internal carotid artery for a >50% stenosis.

However, other factors have to be taken into consideration. The velocity elevation is relative and the cardiovascular status of the patient influences it individually. [6] One also has to look at the morphology of the vessel on the B-mode image. It is better to give ranges of stenosis instead of exact values, for example:

under 50%
50-75%
76-80%
81-95% (around 90%)
subtotal occlusion.

After occlusions or very severe stenosis when one segment is supplied through another branch flow reversal can be found (FIG 10 on page 14). The common pitfall for distinguishing an occlusion from a stenosis is inadvertent sampling of a collateral branch that is parallel to an occluded segment. This is more likely to occur in the region of the
adductor canal and leads to a false-positive diagnosis of a high-grade stenosis, whereas the arterial segment is in fact occluded.

True **aneurysms** can occur on any vessel but there are predilection sites like infrarenal aorta, popliteal arteries (FIG 11 on page 15). Questions to be answered in such cases are length of affected segment, the highest cross-sectional diameter, site, width and eccentricity of thrombus.

Post-procedurally the **residual or recurrent stenosis** can be estimated (FIG 12 on page 16) and different complications like **pseudoaneurysm** (FIG 13 on page 17), **A-V fistulas** (FIG 14 on page 18), **dissection** (FIG 15 on page 19) and **intima hyperplasia** (FIG 16 on page 20) can be examined. [7]

Fortunately stents and grafts placed into vessel are "transparent" for ultrasound, thus after such procedures the same measurements can be performed as for native vessels. It is important to be aware of the fact that - probably because of the different stiffness of vessels - higher velocity value limit has to be considered as normal than in native vessels (i.e. 250 cm/s instead of 125 cm/s in internal carotid artery) (FIG 12 on page 16). [8,9,10]

**Hematomas** can occur after dilatations and surgical procedures. Infections generally are complications of surgical graft placements. Sonographically we can detect perigraft fluid collections and also can guide needle or drain placement (FIG 17 on page 21).

The best results are achieved when the clinical indication contains exact question regarding a certain vessel or segment and the radiologist is able to answer that using optimal technical parameters.
**Fig. 0:** Abdominal aorta (Ao) with the origin of celiac trunk (C) and superior mesenteric artery (SMA)

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Fig. 0: The left decubitus position is the most useful to see the origin of renal arteries.

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**Fig. 0:** Common carotid artery and carotid bifurcation are generally straightforward to examine.

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Fig. 0: In cases of extreme tortuosity complementary display modes like B-flow or power Doppler are very useful.

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**Fig. 0:** Normal triphasic waveform recorded in femoral artery rules out severe stenosis or occlusion in the iliac arteries (a). However biphasic waveform (b) recorded in another patient in the femoral artery is an indirect sign of severe stenosis and suggests that this patient needs further diagnostic workup before endovascular or surgical therapy.

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Fig. 0: Visualization of radial artery (a,b) before coronary bypass surgery. Changes of flow in ulnar artery (c,d) during compression of radial artery is detected.

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Fig. 0: It seems to be a soft plaque in the bulb of ICA, causing stenosis.

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**Fig. 0:** Different grades of stenosis. See the peak systolic (PS) and end diastolic values (ED). Note that in subtotal occlusion the velocities are decreasing!

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**Fig. 0:** After proper setting PRF and gain, flow appeared in the bulb (same patient as on FIG 7).

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Fig. 0: Flow reversal in the external carotid artery and its side branches. Internal carotid artery is supplied through them. The cause of it was a very severe stenosis just before the bifurcation proved by CT angiography (arrow).

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Fig. 0: True aneurysms of popliteal artery.

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**Fig. 0:** Fortunately stents and grafts placed into vessels are "transparent" for ultrasound (a,b) so measurements can be performed. We have to set higher velocity value limit to consider as normal than is native vessels, so (c) does not mean significant stenosis. However in the case of $343 \text{ cm/s}$ (d) significant restenosis should be reported.

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Fig. 0: Different types of pseudoaneurysms. Typical "to and fro" flow (a). Ruptured pseudoaneurysm (b). Double sac pseudoaneurysm (c) treated by thrombin injection (d).

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Fig. 0: Postprocedural A-V fistula. High velocity, low resistance flow.

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Fig. 0: Dissection in common carotid artery (a,b), aorta (c), femoral artery (d).

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Fig. 0: Severe intima hyperplasia in the femoro-popliteal graft.

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Fig. 0: Hematomas (a,b) and perigraft fluid collections (c,d) in different patients.

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Images for this section:

Fig. 0

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