Hemodialysis vascular accesses: What every radiologist should know

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Learning objectives

Pre-surgical imaging through Doppler ultra-sound has a significant impact on surgical decisions, allowing for a greater percentage of native fistulae to be constructed over other types of vascular accesses, with a higher maturation and lower access failure rates. The periodic evaluation of vascular accesses allows early detection of stenosis, thus permitting its endovascular correction. Treating stenotic lesions helps maintain the accesses' patency and functionality, avoiding thrombosis.

Endovascular salvage thrombectomy procedures of thrombosed vascular accesses are both effective and safe and do usually do not preclude surgical thrombectomy in case of procedural failure. Stents should be used sparingly but they are useful in certain conditions.
Background

Vascular accesses' related complications are responsible for significant morbidity and mortality within patients on hemodialysis. The growth of graft placement over native fistulae creation observed in the later part of the last century has led to increased cost and worst outcomes for these patients. Acknowledgement of this fact was responsible for the introduction of several consensus and initiatives, as the k-doki guidelines and the fistula first breakthrough initiative (FFBI), pushing for the recognition of native fistulae as the preferred vascular access. Fistulae are associated with a higher patency and lower complication rates than other vascular accesses, namely grafts and central venous catheters. Today, the goal has shifted from fistulae creation to maintaining fistulae patency, through a more pro-active and preemptive approach. An aggressive approach towards hemodynamic access monitoring allow for the early detection of access dysfunction. The major cause of this dysfunction is the progression of stenotic lesions, which can occur anywhere between the arterial inflow to the venous outflow. If left untreated, the stenosis will lead to a reduction of the blood flow rate (BFR) across the access and subsequent inefficient dialysis treatment, thus increasing patients' morbidity and mortality. Likewise, a decreased flow will put the access at risk of thrombosis, which can eventually imply the loss of the access. Losing an access not only implies the loss of valuable vascular territory, but usually also implies the placement of a central venous catheter for short-term hemodialysis treatments, associated with complications like central venous stenosis which often result in the loss of the entire limb as an option for access creation. The care of these patients should therefore be a multi-disciplinary effort, with a central database and careful periodic evaluation of the patients.
<table>
<thead>
<tr>
<th>Clinical and angiography correlation</th>
<th>Value</th>
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<tbody>
<tr>
<td>Arterial inflow stenosis</td>
<td>0.55</td>
</tr>
<tr>
<td>Venous outflow stenosis</td>
<td>0.78</td>
</tr>
<tr>
<td>Arterial inflow and venous outflow stenosis</td>
<td>0.54</td>
</tr>
<tr>
<td>Central venous stenosis</td>
<td>0.17</td>
</tr>
</tbody>
</table>

Fig. 1

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Imaging findings OR Procedure details

The radiologist has an important role in the care of these patients. If the decision of kidney replacement therapy falls on hemodialysis, a vascular access must be planned and created. Doppler ultrasound has been shown to greatly influence the surgeons' decision regarding the type of access chosen, allowing for more fistulae to created (from 14-34% to 63-64%). It is also associated with a higher rate of fistulae maturation and lower rate of access failure.

An arterial diameter of more than 2mm is recommended by some studies and an arterial diameter of less than 1.6mm is associated with a high risk of fistula failure. The venous side is also mapped using Doppler ultrasound with a venous diameter of 2.5mm, continuous with the central veins and without evidence of venous obstruction being associated with lower failure rates.

After access creation, its evaluation should be done by monitoring (physical examination) at least monthly and surveillance (which uses one of several methods to measure flow across the access, including Doppler ultrasound and magnetic resonance angiography). The patient should be referred for venographic evaluation and eventual treatment in case of persistent abnormalities in any of the monitoring or surveillance parameters, not in case of a single abnormal value. A decreased flow rate (less than 600ml/min for grafts and less than 400 - 500 ml/min for fistulae) not only precludes effective dialysis treatments but also puts the access at risk of thrombosis, being also an indication for venographic evaluation. Abnormal arterial or venous static pressure ratios could point to a stenosis and are also an indication for imaging evaluation.

This aggressive approach avoids the progression to dysfunctional stenosis, which are in turn associated with abnormal recirculation values, high venous pressures, decreased blood flow, arm swelling, ineffective dialysis and higher negative pre-pump arterial pressures.

On venography, a hemodynamically significant stenosis is defined as a reduction in caliber >50%. Any stenosis greater than 50% in a patient with clinical abnormalities compatible with a stenosis should be treated through percutaneous transluminal angioplasty (PTA). Balloon angioplasty is considered to be successful if the residual stenosis is less than 30% and the patient is able to complete at least one effective dialysis treatment through that access.

But if you can identify a stenosis, how do you know what the normal caliber of the vessel is? For instance, a venous stenosis is usually associated with a pre-stenotic or post-stenotic increase in caliber, so where do you measure the normal diameter? Also collateral venous circulation can distribute the pressure increase and prevent venous dilation.

Also, why do you use the cut-off of 50% to declare a stenosis hemodynamically significant? Of course the blood flow across the access is must more reduced if the stenosis is greater than 50% but even stenosis lesser than 50% show a decrease in blood flow.
And why do you consider a residual stenosis of lesser than 30% to mean PTA failure? In the earlier reports on balloon angioplasty, during the 90's, a 20% residual stenosis was proposed, in addition to the complete or substantial relief of symptoms. The very first suggested standard for reporting angioplasty procedures in the setting of lower limb ischemia suggested the use of only clinical criteria to determine the technical success of these procedures. These cut-offs are useful conventions but care should be taken when interpreting and making therapeutic decisions. For instance, given multiple stenotic venous outflow lesions, which are more frequent than isolated ones, the total resistance could be calculated much like the resistance on an electrical schematic diagram, adding the resistance of each non-significant or significant stenosis. This can explain why accesses without a single hemodinamically significant stenosis can thrombose unexpectantly. The use of non-compliant balloon allows for the use of ultra-high pressure balloons without rupturing normal venous segments, provided that the right size balloon is chosen. Normally the balloon should be 15 - 20% larger than de vessel's diameter (which most often means 1mm larger than de vessel's diameter) and should extend about 5mm from each side of the stenosis.

Angioplasty works by a crushing effect on the vessel's wall, inducing damage to the endothelium. This means that with every procedure the risk of re-stenosis is increased and a cycle of repeated procedures is initiated in order to maintain the access patent. Vasospasm is a common immediate complication resolved either by nitroglycerin (100µg) or waiting a short period of time. It is important to recognize vasospasm and resist the temptation to repeat the PTA with a larger than necessary balloon diameter in order to avoid unnecessary rupture.

Stent placement is always a compromise and should be reserved for failed PTA with surgically inaccessible venous stenosis or failed PTA with unresolved venous rupture. When the segment restenosis, the stent cannot be removed and balloon angioplasty is of little help because the stent prevents the lumen's expansion. There is also a short limit of stents that you can place inside each other.

The post-procedure prognosis can be estimated more accurately by the pre-PTA BFR across de access and the difference between the pre-PTA and the post-PTA BFR than by the venography images of the procedure.

Endovascular thrombectomy allow for salvage of thrombosed vascular accesses. Compared to surgical thrombectomy, both are equally effective, even though the surgical technique shows a slightly better long-term patency in arterial-venous fistulae. Never the less, endovascular thrombectomy does not preclude the surgical technique while a failed surgical approach could preclude the endovascular technique.

Several percutaneous thrombectomy devices are currently available in the market, besides manual PTA technique where balloon inflation helps to macerate the clot so that it can be later aspirated or pushed into de right atrium.

A major concern during thrombectomy procedures has been the risk of clinical significant pulmonary thromboembolic (PE) events. Several studies have shown that, even though PE does occur in up to 93% of patients submitted to thrombectomy (as demonstrated by scintigraphy), clinically significant events are only likely in patients with severely
diminished cardio-vascular reserve. This is true even when massive clot burden, as high as 50cc is released towards the pulmonary vascular bed, and can be explained by the small size of the macerated clot, inducing only sub-segmental PE events. An echocardiogram should also be requested prior to the procedure in order to exclude a patent foramen ovale (PFO).
Images for this section:

**Fig. 2:** Multiple stenosis in sequence have a total resistance much greater than each isolated stenotic lesion.

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**Fig. 3:** Long stenosis of the arterial inflow
Fig. 4: Stenotic lesion with a pre-stenotic and post-stenotic venous dilation.
**Fig. 5:** The same stenosis was dilated with balloon PTA.

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**Fig. 6:** juxta-anastomotic stenosis dilated with a 5 x 40mm balloon.

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Fig. 7: Large aneurisms can hold up to 50cc of clot

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**Fig. 8:** Aneurysm formation at the puncture site.

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**Fig. 9:** Thrombosed fistulae

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Fig. 10: Stent occlusion with evidence of collateral venous drainage.

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Conclusion

Vascular accesses' complications are responsible for significant mobility and mortality of patients on hemodialysis. Maintaining the patency and functionality of vascular accesses in patients on hemodialysis is a crucial part of these patients' care.

Pre-surgical arterial-venous mapping has a strong impact on the surgeon's decision process and optimizes fistulae creating and maturation.

The radiologist plays an important part of a multi-disciplinary effort to maintain the accesses' patency and functionality. A preemptive approach towards stenotic lesions avoids progression to a dysfunctional access, helps maintain patency and avoids the use of central venous catheters. Salvage procedures on thrombosed accesses are safe and can avoid the loss of the access or maintain its function until a new access is fully maturated.
References