REVIEW

Upper Extremity Ischemia and Hemodialysis Vascular Access

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Digital ischemia in dialysis patients due to arteriovenous fistulas (AVF) is a rare condition, occurring in 4% of patients. The etiology is different from lower limb ischemia. Blood shunting through the AVF may cause stealing of blood and hypoperfusion in distal tissues, leading to pain, discolorisation and ulcers. High-flow AVFs have greater risk on ischemia than normal flow AVFs, however combined with peripheral arteriosclerotic disease the latter may also leads to ischemia. A non-invasive and angiographic diagnosis is of importance to determine treatment options. Augmentation of arterial inflow by interventional techniques and/or AVF bloodflow-reducing surgical procedures may eliminate pain and heal ulcers. The best results are obtained by bypassing the arteriovenous anastomotic site and interruption of steal phenomenon by ligation of the artery distal to the AV anastomosis.

Key Words: Ischemia; Hemodialysis; Arteriovenous fistula; Banding; DRIL procedure.

Introduction

Critical ischemia of the upper extremity is a rare condition as compared to ischemia of the lower limbs. It has been estimated that the incidence of lower limb ischemia in the population over 60 years of age is 5%. Data on the prevalence of arm ischemia are scarce, however, a 10–20-fold lower incidence may be appreciated. Digital ischemia in end-stage renal failure patients on hemodialysis treatment is a special condition with a different pathophysiological etiology compared to critical ischemia due to peripheral arterial obstructive disease of the upper and lower extremity. Upper extremity ischemia occurs in 3.7–5% of dialysis patients and this percentage increases depending on the type of arteriovenous fistula (AVF). Upper arm AVFs have a higher incidence compared to forearm AVFs. In 10–25% of brachio- cephalic and basilic AVFs, 4.3–6% of forearm prosthetic implants and 1–1.8% of radiocephalic AVFs, symptomatic ischemia may develop. Risk factors are peripheral arteriosclerosis, diabetes, age, previous ipsilateral AVFs and high flow AVFs. Angio-access induced ischemia is a dreadful complication and when not correctly and timely treated, it may even lead to amputation of the hand.

Here we review the pathophysiology, symptoms, diagnosis and treatment options of upper extremity ischemia and hemodialysis vascular access will be discussed.

Methods

The Pubmed database were searched for relevant publications on ischemia and hemodialysis vascular access from 1980 till 2003. Search terms were ischemia, hemodialysis, vascular access and arteriovenous shunts. Only publications on upper extremity hemodialysis vascular access were selected. From these publications the relevant articles with sufficient information on number of patients, diagnosis and treatment options were used for analysis.

Pathophysiology

Due to the presence of an AVF significant general or local changes in bloodflow may occur. By the direct...
connection of an artery and a vein without a capillary bed, a great arterial-venous pressure difference develops due to the low venous resistance, which augments bloodflow. AVFs cause shunting of a high volume of blood from the arterial into the venous system, and this may have an unfavourable effect on the peripheral circulation in the hand. Retrograde flow in the radial artery away from the hand occurs in 70% of radio-cephalic AVFs, and usually does not cause ischemia. However, when collateral blood supply through the ulnar artery is insufficient, distal ischemia may develop. Also, in patients with peripheral arteriosclerotic disease of the arm arteries, shunting of blood through an AVF, adds to the risk of distal ischemia. Finger gangrene may be a more advanced form of hand ischemia encountered in the chronic hemodialysis population. In a recent publication 52% of patients with ischemia showed a diffuse occlusive process involving the distal radial or ulnar arteries, extending into the palm and digital circulation. The process was bilateral and symmetrical and had an angiographic appearance consistent with atherosclerotic occlusive disease. The patients with finger gangrene had significantly more clinical evidence for total body atherosclerosis compared with those patients on chronic hemodialysis in whom finger gangrene did not develop. Of these patients 70% needed major lower extremity amputation. In addition, the patients with finger gangrene had significantly higher prevalence rates of diabetes and coronary artery disease compared with the other patients on chronic hemodialysis.

On the other hand, high bloodflow volumes through an arteriovenous anastomosis, may cause a stealing of blood from the peripheral tissues with distal hypoperfusion and ultimately ischemia. In fact, in these patients reversed flow may be noticed in the artery distal of the anastomosis and this phenomenon can be detected by ultrasonography. This is a true steal syndrome, occurring in patients with healthy vessels. In contrast, patients with pre-existent peripheral arterial obstructive disease, may have a further deprivation of the distal circulation by the shunting of blood away from the peripheral tissues.

The amount of bloodflow through an AVF depends on the diameter of the inflow artery. In radiocephalic AVFs, bloodflow may amounts 500–800 cc/min and this increases in AVF with large calibre arteries. In AVFs with the anastomosis to the axillary or brachial artery (brachio cephalic/basilic AVF; thorax and crossover loop graft) the flow may increase in time to more than 21/min (Tables 1 and 2). However, with an adequate collateral circulation, digital pressures usually remain sufficient enough to avoid ischemia (>50 mm Hg).

Symptoms and Diagnosis

In most dialysis patients with AVFs, the peripheral circulation will be hampered in some extent, however, this usually does not lead to clinical symptoms of ischemia. In distal AVFs, with bloodflows of 500–800 cc/min, the systolic finger bloodpressure is usually above 100 mm Hg. In patients with an elbow AVF, the flow may increase to more than 1500–2000 cc/min, causing a steal syndrome with lowering of systolic digital pressures to 50 or 60 mm Hg. Together with for example poor distal or collateral vessels, this may cause symptoms of ischemia. As in lower limb ischemia, four stages of ischemia may be present:

Stage I: pale/blue and/or cold hand without pain
Stage II: pain during exercise and/or hemodialysis
Stage III: restpain
Stage IV: ulcers/necrosis/gangrene

Usually the diagnosis of ischemia can be easily made by physical examination. Cold fingers with a pale or blue–purple discoloration can be present without pain sensations. Usually distal radial pulses are only palpable when the AVF has been manually compressed. In a more advanced stage, pain during dialysis or at night may occur and when not treated in time skin necrosis and ulcers may develop. Non-invasive investigation with digital bloodpressure measurement, duplex ultrasonography and eventually transcutaneous PO2 measurement is obligatory for the final diagnosis. Digital pressures of <50 mm Hg, a digit/brachial index (DBI) of <0.6 and TcPO2 of <20–30 mm Hg can be found. Duplex scanning is important to measure the amount of bloodflow through the AVF and in addition the peripheral and collateral vessels can be visualized in an attempt to search for stenoses and obstructions. As final step for the diagnosis and in the work-up for interventional or surgical treatment, angiography has to be performed. A Seldinger angiographic technique is essential with visualisation of the subclavian, axillary, brachial, radial and ulnar arteries. As steal from the distal vessels can be expected, images with and without compression of the AVF are necessary. Magnetic resonance angiography (MRA) may be used as an alternative method for imaging of the AVF and distal vessels.

Diseases like neuropathy (carpal tunnel syndrome),

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dystrophy and oedema due to venous hypertension, may mimic the symptoms of ischemia and can be ruled out by specific examinations. A special condition called ischemic monomelic neuropathy may develop in diabetic uremic patients. Usually these patients have preexistent diabetic neuropathy, which worsens after the creation of an AVF. Mild ischemia may be present, however, correction does not result in any improvement.8

Treatment Options

Radiological intervention. Catheter-based intervention may be the first option in the treatment of angioaccess-induced ischemia. Arterial stenoses proximal to the AVF are usually eligible to percutaneous transluminal angioplasty (PTA) and may augment bloodflow to the peripheral tissues with relief of pain and healing of ulcers.9–11 Even very distal forearm arterial lesions may be accessible by small-calibre catheters and balloons and intervention by means of PTA may be successful. The outcome of these interventions depends strongly on the experience and dedication of the interventional radiologist.

Surgical intervention. The type of the operative revision depends on the etiology of the peripheral hypoperfusion: ischemia due to true steal syndrome in high-flow AVFs (>1000–1500 cc/min) or ischemia due further deprivation of distal circulation in patients with peripheral arteriosclerotic disease and normal flow AVFs (500–800 cc/min).

High-flow AVFs

Flow-reduction procedures or bypass surgery are the options in these patients. Reduction of flow can be obtained by banding or tapering of the AVF. A small piece of Teflon/Dacron is sutured circumferentially around the AVF, 2 cm distally from the anastomosis, and tightened to a lumen reduction of 4 mm.12,13 Banding, however, has a high risk on AVF thrombosis and it is difficult to determine to what extent the AVF should be narrowed.13 Berman et al. have used banding in 29 patients with high flow AVFs and ischemia. Successful reversal of ischemia and maintenance of the access site was achieved in only 15 patients and the authors state that access thrombosis is usually the prevalent outcome once flow is reduced enough to relieve the ischemia.21 An alternative method is the application of a weck clip, usually in prosthetic AVFs. Interposition of a segment of 4 mm prosthesis or the use of a tapered graft running from 4 (arterial) to 7 mm (venous) are also effective methods to reduce AVF flow considerable. AVF bloodflow measurement by means of a flowprobe or duplex ultrasonography, digital pressure measurement or photoplethysmography during operation are indicated to elucidate the effect of flow reduction.14–17 A venous or prosthetic bypass from the radial artery to the outflow vein of a brachiophecalic/basilic AVF with ligation of the vein towards the anastomosis results in a 50% reduction of flow through the AVF. However, this technique still yields the risk on steal from the peripheral vessels.

Normal flow AVFs

In patients with normal bloodflow through their AVFs often concomitant arteriosclerotic disease causes insufficient peripheral and/or collateral perfusion. Flow reduction is no option in these patients because of the risk of AVF thrombosis or insufficient dialysis treatment due to recirculation after flow reduction. Distal radial artery ligation in radiocephalic AVFs is indicated to prohibit steal from the palmar arch. In

Table 1. AVF flow and digital pressure in patients with normal arteries.

<table>
<thead>
<tr>
<th>Type of AVF</th>
<th>AVF flow (cc/min)</th>
<th>Digital pressure (mm Hg)</th>
<th>Risk of ischemia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiocephalic</td>
<td>500–800</td>
<td>&gt;100</td>
<td>–</td>
</tr>
<tr>
<td>Forearm loop graft</td>
<td>800–1300</td>
<td>&gt;70</td>
<td>±</td>
</tr>
<tr>
<td>Brachiocephalic/basilic</td>
<td>1000–2000</td>
<td>&gt;50</td>
<td>+</td>
</tr>
<tr>
<td>Axil-axillary/jugular vein</td>
<td>1500–2000</td>
<td>&gt;70</td>
<td>–</td>
</tr>
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</table>

Table 2. AVF flow and digital pressure in patients with obstructed arteries.

<table>
<thead>
<tr>
<th>Type of AVF</th>
<th>AVF flow (cc/min)</th>
<th>Digital pressure (mm Hg)</th>
<th>Risk of ischemia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiocephalic</td>
<td>200–255</td>
<td>25–35</td>
<td>+</td>
</tr>
<tr>
<td>Forearm loop graft</td>
<td>560–740</td>
<td>30–50</td>
<td>±</td>
</tr>
<tr>
<td>Brachiocephalic/basilic</td>
<td>600–900</td>
<td>20–30</td>
<td>+ +</td>
</tr>
<tr>
<td>Axil-axillary/jugular vein</td>
<td>750–1000</td>
<td>30–40</td>
<td>±</td>
</tr>
</tbody>
</table>
elbow AVFs, the bloodflow to the peripheral tissues can be augmented by a bypass from the brachial artery above the AV anastomosis to the radial or ulnar artery. In addition the brachial artery just distal to the AV anastomosis has the best change of large volumes of blood through the AVF. Either a ‘non-smooth’ anastomosis (90, 180° angle) may add to a greater anastomotic resistance and thus limitation of flow. Therefore, a limited length of the arteriovenous anastomosis, amounting for not more than 7 mm, should be pursued and in this way this may prevent the shunting of large volumes of blood through the AVF. Either a ‘non-smooth’ anastomosis (90, 180° angle) may add to a greater anastomotic resistance and thus limitation of flow.

Nevertheless when ischemia is suspected, an adequate diagnosis and timely intervention is obligatory, to avoid amputation. In addition to a non-invasive AVF assessment, upper extremity angiography with and without AVF compression, is mandatory not only for the diagnosis but in particular to outline the strategy for treatment.

Proximal arterial lesions are suitable to interventional procedures, including PTA and/or stent placement, while the distal revascularisation and interval ligation (DRIL) surgical procedure is applicable to most patients with normal/high-flow AVFs with or without distal arterial obstructive disease.

In summary, promptly intervention for angioaccess-induced upper extremity ischemia in dialysis patients is of utmost importance to avoid finger amputation. A brachial-to-distal arterial bypass with ligation of the artery distal to the AV anastomosis has the best change on relief of symptoms with salvage of the vascular access site.

**AVF closure**

In a high percentage of usually diabetic patients the only way to prevent progression of ischemia and the risk on finger amputation, is surgical closure of the AVF and creation of a new AVF in the contralateral extremity or proximal upper arm arteries. This latter technique consists of a graft implantation in the upper arm with the arterial anastomosis to a sidebranch of the axillary artery, usually the subscapular or thoracic artery. Due to the small size of these arteries bloodflow through the graft will remain limited to 500–620 cc/min. However, graft thrombosis remains substantial with this procedure. In selected patients with extensive arteriosclerotic disease of the upper extremity arteries (and often also lower leg arterial disease), one may decide to place long-term central vein catheters or ports (insertion into the internal jugular vein) to avoid placement of an AVF with subsequently the risk on ischemia. In the ultimate case the treatment modality has to be changed to CAPD (continuous ambulatory peritoneal dialysis).

**Discussion**

Angioaccess-induced ischemia is an uncommon but devastating complication of upper extremity vascular access. When left untreated it may leads to severe restpain, ulcers and necrosis. However, treatment may be difficult and the risk of finger amputation is substantial. Therefore prevention is better than to cure. An adequate preoperative evaluation and meticulous surgical technique are the keystones to avoid this dreadful complication. Physical examination of peripheral pulses, bruits, and bilaterally measurement of arm bloodpressures are essential for the work-up before AVF creation. Duplex ultrasonography is very useful in the assessment of not only superficial veins but also arteries and may detect peripheral obstructive disease. Preoperative measurement of digital pressures may be helpful to indicate patients at risk for ischemia. Patients with preoperative digit-to-brachial indices (DBI) <1.0 are more likely to develop steal, but there is no strict DBI threshold below which steal is inevitable. If there is any doubt concerning the status of the peripheral circulation angiography or MRA is advised to visualize the arterial tree from the subclavian down to the radial and ulnar arteries and palmar arch. In addition, steal is more likely in patients undergoing brachial artery-based AVF and prosthetic grafts compared to wrist radiocephalic AVFs. The reason for this observation is the augmentation of high bloodflow volumes through the arteriovenous anastomosis of large calibre vessels. Therefore, a limited length of the arteriovenous anastomosis, amounting for not more than 7 mm, should be pursued and in this way this may prevent the shunting of large volumes of blood through the AVF. Either a ‘non-smooth’ anastomosis (90, 180° angle) may add to a greater anastomotic resistance and thus limitation of flow.

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**Table 3. Results of distal revascularisation and interval ligation (DRIL) procedure for the treatment of angioaccess-induced ischemia.**

<table>
<thead>
<tr>
<th>Author</th>
<th>No. patients</th>
<th>Success in %</th>
<th>AVF patency (%)</th>
</tr>
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<tbody>
<tr>
<td>Schanzer et al.</td>
<td>14</td>
<td>93</td>
<td>82</td>
</tr>
<tr>
<td>Haimov et al.</td>
<td>23</td>
<td>96</td>
<td>73</td>
</tr>
<tr>
<td>Katz et al.</td>
<td>6</td>
<td>83</td>
<td>100</td>
</tr>
<tr>
<td>Berman et al.</td>
<td>21</td>
<td>100</td>
<td>94</td>
</tr>
<tr>
<td>Lazarides et al.</td>
<td>7</td>
<td>94</td>
<td>–</td>
</tr>
<tr>
<td>Stielri et al</td>
<td>6</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Knox et al</td>
<td>52</td>
<td>90</td>
<td>83</td>
</tr>
</tbody>
</table>

**References**

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