Limb ischaemia caused by formation of dialysis fistula is rare but serious complication. The severity of symptoms may vary but rest pains and necrotic lesions are observed in most advance cases. In these patients different invasive procedures for treatment are performed – from simplest dialysis fistula ligation to complicated vascular reconstructions.

The aim of the study was to evaluate treatment results of upper limb ischaemia triggered by dialysis fistula.

Material and methods. We have analysed methods and results of treatment of 14 patients with symptomatic upper limb ischaemia caused by dialysis fistula treated in our department between 1st January, 2006 and 30th June, 2013. Treatment was subject to anatomical situation and clinical symptoms. In three patients the ligation of dialysis fistula was performed, four patients underwent inflow reconstruction – in one case by ligation of ligation of vein branch, in three patients by cephalic transfer of arterial anastomosis. In 2 patients hyperkinetic fistula aneurysm was excised and replaced by PTFE bypass, in three patients fistula reconstruction with DRIL method (distal revascularization – interval ligation) was performed, in one patient surgical operation of brachial artery stenosis was conducted. One patient underwent brachial artery angioplasty.

Results. Rest pains occurred in all patients (100%), regressive changes in 10 patients (71.4%). Eight patients (57.2%) had concomitant diabetes, seven (50%) ischaemic heart disease, five (35.5%) chronic lower limb ischemia and hyperparathyroidism was observed in five patients (35.5%). The imaging studies in all patients revealed pathological steal syndrome (stealing blood to the fistula), in majority concurrent with other pathologies – obstruction stenosis of peripheral artery, defects in blood out flow from the limb. As a result of the surgical treatment, symptoms of limb ischaemia subsided in all patients.

Conclusions. Critical limb ischaemia caused by dialysis fistula is a dangerous complication. In most cases there are several causes of ischaemia. Treatment methods should be selected individually for each patient and clinical situation. Clinical symptoms should subside as a result of optimal choice of treatment and, if possible, maintaining of dialysis access.

Key words: hand ischemia, dialysis fistula, vascular access complications

Chronic renal failure is diagnosed more and more often especially in aging populations in developed countries. For many years there has been a liberalization of eligibility rules of patients for renal replacement therapy. Currently, older people, who were previously rejected due to significant advanced morbidities, are included in dialysis programme. For these reasons, the number of patients treated from end-stage renal failure is constantly increasing. At present, in Poland nearly 20 000 people are treated with renal replacement therapy. The majority of patients with end-stage renal failure are treated with haemodialysis that requires a properly functioning dialysis access. Many years of experience have shown that dialysis fistulas are better vascular access than dialysis catheter. Therefore, the tendency to create dialysis fistulas in as many patients as possible is justified.

Renal insufficiency accelerates and exacerbates the development of atherosclerosis, also
in upper limbs arteries. In advanced cases wall calcification in form of Monckeberg’s arteriosclerosis (fig. 1) may be observed. Pathological vascular wall remodelling in patients with end-stage renal disease may be exacerbated by concomitant diseases – mostly by diabetes and disorders of calcium and phosphorus metabolism triggered by secondary hyperparathyroidism.

A process referred to as fistula maturation begins after the formation of an arteriovenous fistula. It involves widening the vein diameter, remodelling and thickening of its wall due to increased blood flow through the afferent artery and efferent vein. At least 500 ml/min of blood passes through correctly functioning dialysis fistula, of which 220-350 ml/min is taken from dialysis apparatus. Most of the blood flowing into the limb gets, thus, to the dialysis fistula, what in most cases does not lead to the decrease in peripheral blood flow and does not cause hand ischaemia. Symptomatic upper limb ischaemia occurs in 1 to 28% of patients undergoing dialysis (1, 2). The severity of clinical symptoms of limb ischaemia may vary – from paraesthesia in fingers, through the rest pain, to necrosis (3, 4) (fig. 2). Sometimes the only symptom is the exacerbation of ischaemia during dialysis, which may result from a decline in systemic blood pressure and increase in blood steal to fistula. The mechanisms leading to the formation of symptomatic limb ischaemia triggered by dialysis fistula are complex and not fully understood. Risk factors include: age, diabetes, chronic lower limb ischaemia, proximal fistula, previous operations of dialysis fistulas (4, 5).

The aim of the study was to evaluate treatment results of upper limb ischaemia triggered by dialysis fistula.
MATERIAL AND METHODS

Patients treated in the Department of General and Vascular Surgery at Central Clinical Hospital of the Ministry of Interior between 1st January, 2006 and 30th June, 2013 due to critical hand and/or forearm ischaemia triggered by dialysis fistula were involved in the retrospective analysis. During this period 14 patients with critical hand ischaemia triggered by dialysis arteriovenous fistula were treated. The average age of patients was 59.4 years (range between 23 and 80 years). Eight men and six women were subjected to treatment. In addition to demographic data, the history of vascular access, ischemic symptoms, concomitant diseases, the treatment, postoperative complications and the outcome were recorded. Tests confirming the blood steal to fistula and imaging the causes of peripheral ischaemia were conducted before qualifying a patient for the surgery. The following tests were performed: saturation measurements on the fingers of both upper limbs, Doppler test assessing blood flow in the fistula and arteries both peripheral and distal to dialysis fistula. After confirmation of limb ischaemia as the cause of the disease, arteriography was performed visualising the upper limb arteries from the aortic arch to the finger arteries and dialysis fistula. Angiography was performed with fistula opened and closed by the external pressure. The type of planned repair surgery was adapted to the clinical condition and the cause of ischemia identified in the imaging studies. The following surgeries were conducted: fistula ligation, fistula inflow reconstruction by changing the type of arteriovenous anastomosis (fig. 3), proximalization of anastomosis (fig. 4), reconstruction of dialysis fistula aneurysm (fig. 5), DRIL surgery (distal revascularization – internal ligation; Schanzer vascular surgery) (fig. 6) and endovascular treatments.

RESULTS

Symptoms of ischaemia occurred between first day and 20th month after the last surgery creating or reconstructing dialysis vascular access (median – 7 days). Median number of surgeries of dialysis fistulas performed in patients with critical limb ischaemia amounted to four (range from 1 to 20). All patients who suffered critical ischaemia had dialysis fistula formed on the arm (tab. 1). Diabetes was observed in eight cases (57.2%), ischaemic heart...
disease in seven (50%), chronic leg ischaemia in five (35.5%) and hyperparathyroidism in five (35.5%) as well. Symptoms observed in patients included rest pains in all 14 cases, finger and hand ulcer in 10 cases (71.4%), including four who suffered from necrosis exceeding first phalanx of a finger (tab. 1). Ultrasonography and angiography revealed that all patients suffered from blood steal to fistula and decreased inflow to the peripheral tissues. Two thirds of the patients presented several concomitant causes of ischaemia. The type of surgery was adopted to a given patient and the clinical situation. The main goal of treatment was to improve the blood supply to the limb. We also tried to retain functioning dialysis fistula, however it was not achieved in all patients. Table 1 presents surgery methods used by us.

The treatment was successful in all patients – relief of rest pain and ulcer healing was observed. Amputations and removal of necrotic tissue was performed in patients with dry necrosis (four patients with amputation below the first phalanx of a finger). In 11 cases fistulas were used as a dialysis vascular access, in the remaining three new access was created or dialyses were stopped without harm for clinical condition. We recorded two postoperative complications: wound infection in 1 patient (7.1%) and wound haematoma in 1 patient (7.1%). Both complications did not require surgical treatment.

DISCUSSION

Critical ischaemia manifested by rest pain and tissue necrosis is a dangerous complication after formation of arteriovenous dialysis fistulas. Adequate treatment of those patients should be administered as soon as possible. Proper care includes performing accurate diagnostic imaging – Doppler sonography and angiography. During the ultrasound the blood flow rate in the arteries of the limbs and in the fistula should be assessed. Angiography should visualise arteries from the aortic arch to fingers arteries and vessels of dialysis fistula. Imaging of limb arteries with closed dialysis fistula is essential as well.

The majority of our patients had some vascular pathologies leading to the development of limb ischaemia symptoms. In all patients blood steal to the fistula was observed causing hypoperfusion of peripheral tissues. This is consistent with other studies which revealed blood steal in most cases, but in the majority it did not lead to the development of symptoms of limb ischaemia (1, 4, 5). However, concomitant stenosis/occlusion in arteries peripheral to arterial anastomosis of the fistula was observed in a significant percentage of patients with steal syndrome. The causes of that included concomitant diabetes, hyperparathyroidism and several previous vascular surgeries creating dialysis fistula.

Optimal treatment of patients with upper limb ischaemia caused by dialysis fistula should lead to a recovery from critical ischaemia and, if possible, retaining of patients fistula. Moreover, the treatment should be adjusted to a given case and clinical conditions – the progress of ischaemia, the incidence of the ischaemia after fistula creation, the type of vascular access and its history, the anticipated duration, potential alternative dialysis access and concomitant diseases (6). In some cases, attempts to retain functioning fistula through reconstructions are irrational. Such cases include: cases with expected short survival time, no need for dialysis (improvement of patient’s renal functions, renal allotransplantation), cases when fistula reconstruction will be a very extensive surgery.

Arteriovenous fistula was ligated in three patients because in each case we considered it to be an optimal solution. One patient was subjected to this procedure due to expected
### Table 1. Data of patients with upper limb ischaemia after dialysis fistula placement – demography, fistula type, symptoms, ischaemia cause and treatment used

<table>
<thead>
<tr>
<th>No.</th>
<th>Age</th>
<th>Sex</th>
<th>Fistula type</th>
<th>Number of prior dialysis access surgeries</th>
<th>Clinical symptoms</th>
<th>Pathology found on angiography</th>
<th>Therapeutic procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>23</td>
<td>M</td>
<td>perforating vein</td>
<td>1</td>
<td>pain of the hand and peripheral part of the forearm</td>
<td>steal to the fistula</td>
<td>ligation of outflow to the basilic vein</td>
</tr>
<tr>
<td>2</td>
<td>57</td>
<td>M</td>
<td>brachial-cephalic</td>
<td>2</td>
<td>finger ulcer, aneurysmally distended hyperkinetic fistula, occlusion of the brachiocephalic vein, pathological collateral venous circulation within the neck and chest</td>
<td>hyperkinetic fistula, steal to the fistula, occlusion of the brachiocephalic vein</td>
<td>dialysis fistula ligation</td>
</tr>
<tr>
<td>3</td>
<td>58</td>
<td>M</td>
<td>brachial-cephalic</td>
<td>3</td>
<td>pain of the hand and forearm</td>
<td>occlusion/critical stenoses of forearm arteries, steal to the fistula</td>
<td>dialysis fistula ligation</td>
</tr>
<tr>
<td>4</td>
<td>63</td>
<td>M</td>
<td>brachial-cephalic</td>
<td>3</td>
<td>pain of fingers and hand, finger ulcer</td>
<td>hyperkinetic fistula, steal to the fistula</td>
<td>dialysis fistula ligation</td>
</tr>
<tr>
<td>5</td>
<td>72</td>
<td>F</td>
<td>brachial-cephalic</td>
<td>4</td>
<td>ulcer, pain of fingers and hand</td>
<td>hyperkinetic fistula, numerous stenoses of forearm arteries, steal to the dialysis fistula</td>
<td>proximalisation of the arterial anastomosis with the use of a PTFE 6 mm prosthesis fragment</td>
</tr>
<tr>
<td>6</td>
<td>53</td>
<td>F</td>
<td>brachial-cephalic</td>
<td>4</td>
<td>ulcer, pain of fingers</td>
<td>steal to the fistula, occluded radial artery</td>
<td>proximalisation of the arterial anastomosis with the use of a PTFE 4–6 mm prosthesis fragment</td>
</tr>
<tr>
<td>7</td>
<td>48</td>
<td>F</td>
<td>brachial-basilic</td>
<td>4</td>
<td>ulcer, pain of fingers and hand</td>
<td>occluded radial artery, metacarpal artery, steal to the fistula</td>
<td>DRIL – bypass graft, (PTFE 6 mm), brachial artery ligation</td>
</tr>
<tr>
<td>8</td>
<td>78</td>
<td>F</td>
<td>brachial-basilic</td>
<td>4</td>
<td>hand pain</td>
<td>steal to the dialysis fistula, hyperkinetic fistula</td>
<td>proximalisation of inflow to the fistula with the use of a PTFE 4–6 mm fragment</td>
</tr>
<tr>
<td>9</td>
<td>64</td>
<td>M</td>
<td>brachial-basilic</td>
<td>5</td>
<td>hand pain, finger necrosis</td>
<td>hyperkinetic fistula, steal to the fistula</td>
<td>removal of the aneurysmal fistula fragment, reconstruction of inflow to the fistula – PTFE 4–6 mm fragment</td>
</tr>
<tr>
<td>10</td>
<td>65</td>
<td>F</td>
<td>brachial-basilic</td>
<td>3</td>
<td>hand ulcer, hand pain</td>
<td>hyperkinetic fistula, steal to the fistula</td>
<td>removal of the aneurysmal fistula fragment, reconstruction of inflow to the fistula – PTFE 4–6 mm fragment</td>
</tr>
<tr>
<td>11</td>
<td>63</td>
<td>M</td>
<td>brachial-basilic, DRIL performed earlier</td>
<td>4</td>
<td>hand ulcers, pain at rest, finger necrosis</td>
<td>stenosis of the brachial-brachial bypass formed during the DRIL procedure, steal to the fistula, occlusion of radial artery</td>
<td>reconstruction of the arteriovenous anastomosis, endarterectomy of the brachial artery, reduction of flow through the fistula</td>
</tr>
<tr>
<td>12</td>
<td>65</td>
<td>M</td>
<td>PTFE on the upper arm</td>
<td>4</td>
<td>necrosis, finger ulcer</td>
<td>numerous stenoses of forearm arteries, steal to the fistula</td>
<td>DRIL – by-pass graft made of the saphenous vein, brachial artery ligation</td>
</tr>
<tr>
<td>13</td>
<td>80</td>
<td>F</td>
<td>PTFE on the upper arm</td>
<td>5</td>
<td>finger necrosis, ulcer</td>
<td>numerous stenoses of forearm arteries, steal to the fistula</td>
<td>DRIL – by-pass graft made of the saphenous vein, brachial artery ligation</td>
</tr>
<tr>
<td>14</td>
<td>43</td>
<td>M</td>
<td>PTFE on the upper arm</td>
<td>20</td>
<td>hand pain at rest</td>
<td>critical stenosis of the brachial artery below the PTFE anastomosis with the brachial artery, occlusion of radial artery</td>
<td>brachial artery angioplasty</td>
</tr>
</tbody>
</table>

Upper limb ischaemia after formation of dialysis fistula
survival time less than two months caused by melanoma dissemination. In this case, we used the least burdensome treatment for the patient, that is fistula ligation and catheter implantation. Second patient did not require renal replacement therapy due to well functioning transplanted kidney. In the third case, the cause of hand necrosis was hyperkinetic brachio-cephalic fistula and impaired blood outflow from the limbs caused by occlusion of the brachiocephalic vein. We have decided that the most favourable solution to this patient would be creation of new fistula on the second arm as well as removal of hyperkinetic fistula causing outflow disorders.

In case of hyperkinetic dialysis fistulas, the main cause of ineffective peripheral perfusion is blood steal to the fistula. In those patients it is possible to perform fistula reconstruction aiming at increasing the resistance, reduction of flow and blood steal to the fistula. In three cases we performed fistula reconstruction using DRIL method (distal revascularization – internal ligation) first described by Schanzer (7), involving peripheral revascularization with arterio-arterial by-pass of arteriovenous anastomosis of the fistula combined with artery ligation above the fistula. Such reconstruction leads to change in vascular resistance between the fistula and peripheral arteries of the anastomosis. Extension of inflow path to the fistula results in decreased blood flow through the fistula and increased inflow to the arteries peripheral to the anastomosis. Described effectiveness of DRIL ranges from 56 to 100% of cases depending on the indications (8, 9, 10). This surgery enables to correct any possible stenoses in anastomosis of the fistula with the artery compromising inflow to peripheral parts of the limb. Saphenous vein segment taken from the thigh was used to arterial reconstruction. Nevertheless, ultrasound scanning revealed in one patient no superficial vein suitable for arterial reconstruction of the fistula. In this case we have used vascular graft made of reinforced PTFE of 6 mm diameter (fig. 7).

In three patients with brachiocephalic or brachial-basilic fistula with confirmed blood steal to the fistula concomitant with numerous critical stenosis of forearm arterial occlusion, we performed cephalad arterial anastomosis by making by-pass made of prosthesis graft (PTFE 4→6 mm) anastomosed to the side of brachial artery and the end of cephalad venous segment of the fistula (fig. 4). Such treatment resulted in the improvement of limb blood flow and symptom relief. Similar studies have been published revealing improvement of limb blood flow in over 90% patients (11, 12). Authors of such studies have observed a significant increase in arterial pressure in finger arteries and blood flow in forearm arteries without significant influence on the flow size in the fistula (11, 12).

In one patient we performed change of location and type of anastomosis (from anastomosis of perforating vein reaching to medial cubital vein to the side of brachial artery) for anastomosis of cephalic vein to the side of brachial artery in peripheral part of the arm. This treatment excluded outflow from through basilic vein and significantly reduced flow through the fistula. Literature provides descriptions of such reconstructions combined with DRIL surgery (13).

In two patients with brachio-basilic fistula aneurysm due to very severe blood steal to the fistula and peripheral hypoperfusion, we performed reconstructive surgery. It involved removal of aneurysmal dilation of the part of the basilic veins and replacement with segments of conical prosthesis made of PTFE with a diameter from 4 to 6 mm. It is possible to use standard 6-mm grafts. Such treatment reduces the flow in the fistula to the value sufficient to conduct effective dialysis, simultane-
ously increasing inflow to the peripheral parts of the limb.

Other pathologies that occur in patients with upper limb ischaemia and dialysis fistula include stenosis of peripheral arteries and disorders of the blood flow from the fistula. Accurate imaging with the use of angiography reveals stenosis or even occlusions of the forearm arteries. It is a consequence of pathological remodelling of the arteries caused by end stage renal failure, diabetes, hyperparathyroidism and previous surgeries performed within the forearm. In one of our patients symptoms of critical ischaemia in the form of rest pain and necrosis foci in the fingers and hands began 6 years after DRIL reconstruction. Arteriography revealed critical stenosis within anastomoses of the by-pass and brachial artery. Patency restoration and reconstruction of brachial artery and anastomosis reconstruction. Segment of by-pass graft was used for vascular reconstruction.

In addition to classic surgery, in some cases it is possible to use endovascular treatment. Such treatment was performed only in one of our patients. Angioplasty of critical stenosis of brachial artery located below anastomosis with cephalic vein was performed. Current development of endovascular techniques and equipment allows for treatment of pathological changes within the forearm (14) or even within palmar arch. Main advantage of endovascular treatment is the fact that it is minimally invasive and access for surgery is distant from the area where the fistula is punctured.

We did not performed fistula stenosis through external banding (15), its modifications (16), or plication (17). We believe that even in case of using intraoperative measurement of blood flow such types of fistula’s correction are not beneficial for the patient. Hyperkinetic fistulas are most frequently contracted what leads to the formation of aneurysms distant from the surgical stenosis. Similarly, we did not find indication for inflow reconstruction through by-pass with prosthesis from forearm artery to fistula on the arm (18, 19).

CONCLUSIONS

Critical limb ischaemia triggered by dialysis fistula is a serious complication of renal replacement therapy. Blood steal to the fistula is concomitant with other pathological abnormalities – stenoses and/or occlusion of the peripheral arteries, impaired outflow from the limb in large percentage of the patients. Type of ischaemia treatment should be selected individually for each patient and clinical situation. The optimal choice of method should leads to symptom relief and, if possible retaining, of dialysis access.

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