Preoperative ultrasonographic examination of the radial artery and the cephalic vein and risks of dialysis arterio-venous fistula dysfunction

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Summary

Background: Hemodialysis used as renal replacement therapy requires a well-functioning vascular access. Arterio-venous fistula (AVF) created on the forearm is the best vascular access, but it also reveals numerous complications such as: lack of fistula maturation and hemodynamically significant stenoses. Many risk factors of fistula dysfunction are still not identified.

Material/Methods: Radial artery and cephalic vein diameter and patency were ultrasonographically examined before forearm AVF creation. Intima-media complex width, blood flow and peak systolic velocity in distal part of radial artery were measured. Presence of thrombosis and post-inflammatory changes in cephalic vein were also checked. Forearm AVF was created in 66 patients. Fistula US examination was performed 3 and 12 months after operation with measurement of vessel diameter and blood flow. Fistula patency was observed in 24 months after creation. Comparison of pre- and postoperative US examinations between groups with well functioning and thrombosed fistulas was performed.

Results: Primary patency of forearm AVF after 12 and 24 months was 65.2% and 53.0%, respectively. Patients with well functioning forearm AVF have significantly bigger cephalic vein diameter and peak systolic velocity in radial artery. We did not observe significant influence of radial artery intima-media complex width and radial artery diameter on AVF function. In postoperative examination, fistula diameter and flow significantly influenced the risk of AVF thrombosis.

Conclusions: US examination of radial artery and cephalic vein performed before forearm AVF creation enables identification of patients with greater risk of fistula dysfunction. Cephalic vein diameter and peak systolic velocity are prognostic factors of fistula function. Control postoperative US examination of forearm fistula enables detection of AVF at risk of thrombosis.

Key words: ultrasonographic examination • risk factor • arterio-venous fistula

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Background

End-stage renal failure (ESRF) requiring renal replacement therapy (RRT) is an important health issue in developed countries. The prevalence of patients with ESRF in developed countries amounts to 750 per 1 million population, and the treatment utilises 2–7% of the health care budget [1]. The length and quality of life of dialysed patients depends on many factors, including: basic disease, coexisting diseases, and the type of vascular access for dialyses.

Hemodialysis requires a properly functioning vascular access, allowing for cyclic (a few times a week) collection of blood for a few hours – several hundreds mililitres per minute. Many types of vascular accesses for dialysis have been described so far. According to the existing studies, the best arterio-venous fistulas (AVF) are the ones created from patient’s own forearm vessels [2,3]. Creation of a fistula is connected with a considerable rate of failures and complications, and it is not tantamount to obtaining an access for RRT. The AVF, to be functional, requires vessel remodelling – lumen dilatation, wall thickening, blood flow increase. This process is called fistula maturation. The most common cause of forearm AVF dysfunction is, apart from non-maturation, the thrombosis, resulting in most of the cases from a previously existing stenosis leading to a disturbed blood flow [4,5]. Preoperative functional and morphological changes of the vessels used for dialysis AVF creation influence the risk of dysfunction of the vascular access [6].

Qualification of patients for fistula creation bases on physical and imaging examination results (Doppler ultrasonography most of the time) [7]. Basing on the hitherto studies, many authors recommend veins of minimum 2.5 mm and arteries of minimum 2 mm in diameter for fistula creation [8,9]. However, there is no agreement concerning the threshold, i.e. minimal diameter of arteries or veins used for forearm anastomosis. Therefore, in some of the medical centres, patients with vessels of as little as 1.5 mm in diameter are also qualified for forearm fistula creation.

Material and Methods

Patients

Between 01 June 2006 and 30 September 2007, at the Department of General and Vascular Surgery of CSK MSWiA Hospital, 91 patients with renal insufficiency were qualified for primary arterio-venous fistula creation, for the purposes of dialysisotherapy. After conducting physical examinations and US of the forearm vessels, 68 patients of the aforementioned group were qualified to forearm fistula creation. In 2 of them, the fistula was not performed, due to postinflammatory changes found intraoperatively in the cephalic vein.

All the patients included in the study were of Caucasian race. Their mean age amounted to 62.8 years (median 64, range 27–89 years). The study included 46 men and 22 women. Their mean body mass index was 25.6 (range 17.6–42.1, standard deviation 4.6). The follow-up of fistula functioning lasted 24 months.

Ultrasonographic examinations

US examination of the upper limb (planned for surgery) was performed before fistula creation. The examination was performed by means of a Hitachi EVB 8500 device with the linear head, 7.5 MHz frequency. Patency of the brachial artery, the radial artery, and the cephalic vein, in the whole forearm and arm, was assessed. In the cephalic vein, the following elements were assessed: the presence of stenosis, postinflammatory changes in the whole vessel, diameter in the distal forearm – in a standard location of anastomoses with the radial artery. The presence of haemodynamically significant stenoses in the arteries of the upper limbs was also studied. Further measurements included the rate and velocity of radial artery blood flow, at rest. Examinations of the peripheral part of the radial artery aimed at revealing the presence of thrombotic lesions and at measuring the thickness of the intima-media complex.

After 12 and 52 weeks from AVF creation and in the presence of abnormal AVF functioning, US examinations of the AVF vessels were performed. We assessed the patency of the fistula, as well as the presence and potential degree of stenosis in the fistular vessels – both the arterial and the venous ones. The measurements involved also the diameter of the arterialisated cephalic vein and the AVF blood flow.

Statistical analysis

The statistical analysis was performed by means of the following software: Statistica 6.0, produced by StatSoft. Mean values with standard deviation (SD) were calculated. Differences between the two groups were analysed with student’s t-test. After evaluating the significance, the differences between particular groups were defined with the use of Scheffe’s test (post hoc analysis). P value <0.05 was assumed as statistically significant.

Results

Functioning of arterio-venous fistulas

AVF non-maturation

Two patients were disqualified from AVF creation during the procedure, due to postinflammatory lesions found in the cephalic vein. Eleven patients were diagnosed with a primary AVF dysfunction in the first 6 weeks from the moment of surgery (16.2%). The most common cause of patient’s disqualification from forearm AVF formation procedure was the lack of patency or the postinflammatory lesions in the radial vein, within forearms. These pathologies were revealed in 20 patients during their qualification for treatment. Five patients were found to have obstructed or critically stenosed radial arteries, disturbing blood inflow. In two individuals there were two coexisting pathologies (venous and arterial), disqualifying the patients from the procedure of vascular forearm access formation.

Thrombosis of AVF

After 24 months from the procedure, patency of the forearm AVFs was present in 35 patients (53.0%). After 12
months, it was 65.2% (Figure 1). Thrombosis of fistulas undergoing normal process of maturation could be found in 20 patients, after 9.2 months on average (±6.8). The most common cause of fistular thrombosis (95%) was the stenosis of the venous part of AVF.

Ultrasonographic examination of the radial artery and the cephalic vein, within the forearm, before creation of the vascular access for RRT purposes

Differences in the radial artery diameter (Figure 2) between individuals with a patent fistula (2.59±0.47 mm) and patients with abnormal function of the vascular access (2.41±0.44) were not statistically significant. Preoperatively, peak systolic velocity measured at rest in the peripheral part of the radial artery was statistically significantly higher (44.0±15.45 cm/s) in patients with properly functioning fistulas than in patients with abnormalities in the fistular function (33.25±18.46) (P<0.05). The thickness of the intima-media complex in the radial artery did not differ significantly between the properly functioning fistulas (0.58±0.23 mm) and those vascular accesses that underwent thrombosis or nonmaturation (0.63±0.29 mm).

Preoperative diameter of the radial vein, measured in the peripheral part of the forearm with a properly functioning vascular access, amounted to 2.7±0.65 mm and was statistically significantly higher than the diameter of the malfunctioning fistulas – 2.35±0.48 mm (Figure 3).

Ultrasonographic examination of the forearm fistulas created for the purposes of RRT

Examinations of blood flow in forearm AVFs showed a statistically significant difference in blood flow rate in the third postoperative month between the properly functioning fistulas (574±216 ml/min) and the fistulas which subsequently thrombosed or did not maturate properly (307±219 ml/min) (P<0.001). A similar statistical difference (P<0.001) was found when comparing the flow in fistulas after 12 months (754±248 ml/min vs. 455±173 ml/min). Diameter of the properly functioning fistulas was also statistically significantly larger after 3 (4.81±0.87 mm) and 12 months (6.22±0.97) than the diameter of those accesses that were not functioning properly (4.24±0.84, P<0.001 and 5.4±1.26, P<0.001, respectively) (Figure 4).

Discussion

At present, in patients with end-stage renal failure, vascular changes (concerning both veins and arteries) influence the risk of early and late disturbances of AVF functioning [6]. Initially, patients with renal insufficiency experience functional changes. They are followed by morphological changes. Renal disease accelerates and significantly aggravates atherosclerosis formation. Arteries in patients with end-stage renal disease are stiffer, with a thicker intima-media complex [10,11] and a thickening of intima [12], as compared to the vessels of healthy individuals. Veins of patients with renal insufficiency include abnormalities connected with past thrombosis, inflammation and injuries [13]. Such changes are the cause of hardships with AVF formation and disturbances of their functioning.

A routine preoperative Doppler US examination, so called ultrasonographic mapping, has increased the number of venous accesses created from patient’s own vessels (especially the ones located in the forearm) in the recent years. According to the available literature, in 60–70% of patients qualified for dialysotherapy, it is possible to create the AVF, by performing a preoperative Doppler examination [14,15]. In 40–50% of those cases, forearm access is
feasible [16]. In our centre, ultrasonography of upper limbs is performed routinely during patients’ qualification to the procedure of vascular access creation, which allows for avoidance of unnecessary intraoperative disqualifications. Our study is the first published observation of ultrasonographic evaluation of the end-to-end fistulas (the end of the radial artery and the end of the cephalic vein) created for RRT. This kind of AVFs are not frequently used, due to more difficult anastomosis between the venous end and the side of the radial artery. However, end-to-end fistulas are associated with a lower risk of such complications as: steal syndrome and peripheral ischaemia. In our material, patency of the forearm fistulas is comparable to the results of meta-analyses of functioning of such venous accesses used for RRT. This information is extremely important, especially when combined with the fact that 72.5% of
primary vascular accesses for RRT purposes are placed in the forearm.

Basing on previous studies, many authors recommend using veins of minimum 2.5 mm in diameter and arteries of minimum 2 mm in diameter to create a fistula [8,9]. However, there is no agreement on the threshold value, below which the arteries or veins should not be used to form forearm anastomoses. Therefore, there exist medical centres which qualify for forearm-fistula procedures patients with vessels measuring less than 1.5 mm in diameter.

Our study showed that in case of forearm fistula, the preoperative diameter of the cephalic vessel is important for the future functioning of the venous access. Larger diameter of the cephalic vein is connected with a lower resistance to blood flow and an increased blood flow rate in the fistula. Larger diameter of the cephalic vein is also connected with a lower risk of thrombosis and postinflammatory lesions, as well as abnormalities of the venous wall morphology. This confirms the significance of the preoperative assessment of the vessels used for dialysis fistula creation.

Our study did not show any significant influence of the radial artery diameter on further fistula functioning. The only important factor influencing the function of the fistula was the peak systolic velocity. Previous studies showed that end-stage renal failure is a risk factor of atherosclerosis within radial arteries. Lower peak velocities observed in the peripheral parts of the radial arteries in those patients may be associated with the presence of more advanced atherosclerotic lesions localised cephalad to the fistula. We did not observe any influence of the intima-media complex width on later fistula functioning, which may be connected with inaccuracy of the performed measurements or with a higher influence of atherosclerosis placed more cephalad, on the disturbances of blood inflowing to the fistula. The previously published data suggested that the lower the radial artery diameter, the higher the statistically significant risk of fistula nonmaturation and of fistula functioning disturbances at a later time [17]. Maybe the absence of such an interrelation in our study is connected with a different kind of AVF used and a small study sample. However, no correlation between the diameter of the radial artery and the later function of the fistula may suggest that when creating vascular access, it should be possible to use patent arteries of diameters lower than the currently recommended ones, i.e. 2 mm [3,18]. Peak velocity measured in the peripheral part of the radial artery may, on the other hand, be the exponent of the range of functional impairment of arteries in patients with renal insufficiency. According to the previous studies, the lack of increased blood flow within the radial artery during passive congestion is connected with a lower flow within the created fistula [19] and an increased risk of early disturbances of fistula functioning [20]. Interrelation between an increased resistive index in the supplying artery and a decreased flow in the created fistula was also shown [21]. Similarly, higher resistive indices in the supplying artery during passive congestion (exceeding 0.50) constitute a risk factor of thrombosis within the forearm fistula [22]. All the above mentioned functional tests are performed in the course of scientific research, not in the clinical practice, and are much more complicated to perform than the measurements of blood flow velocity. In the future, functional tests of arteries and vessels will most probably be commonly used during patients’ qualification to AVF procedures, especially in increased risk groups.

In our study, the diameter of the cephalic vein in the arterio-venous forearm fistula, as well as the blood flow rate in the fistula were connected with the risk of thrombosis within the vascular access for dialysis. This concerns both US examinations performed in the early postoperative period – after 12 weeks from surgery – as well as in the late phase – after 52 weeks from fistula construction. In case of fistulas between the end of the radial artery and the end of the cephalic vein, the flow rate within the fistula amounting to minimum 600–800 ml/min indicates their proper functioning. Previous studies showed that Doppler ultrasonography allows for the detection of stenosed vessels of the existing fistula [23]. A disturbed blood flow or a stenosed fistula found in US should be an indication for angiography and surgery. It seems that asymptomatic stenoses in the fistular vessels may exist preoperatively or develop de novo, postoperatively, as a result of a few factors, such as venous wall arterialisation, connected with an increased pressure, turbulent flow and the presence of valves. Stenoses within the created fistula may also follow from segmental disturbances of vein compliance (which may be the effect of postinflammatory lesions) or of artery compliance (as a result of focal atheromatous lesions).

The role of AVF function monitoring is particularly important with respect to substantially increased remodelling of the vascular walls, which leads to a considerably faster creation of stenoses and obstructions. The role of USG in the diagnostics of AVF pathologies and the role of interventional radiology in the treatment of such pathologies is extremely important.

**Conclusions**

1. Ultrasonographic examination should become a standard procedure introduced before every surgery of AVF creation. It should also be used for AVF function monitoring, in the postoperative period. Owing to ultrasonography, it is possible to reduce the risk of failure during forearm surgeries and the number of unnecessary disqualifications from forearm AVF creation.

2. Postoperative evaluation of the diameter of the cephalic vein (within the fistula) and assessment of the blood flow rate allows for the selecting patients with an increased risk of thrombosis of the arterio-venous forearm fistula for dialysis.

3. The diameter of the cephalic vein and the blood flow velocity in the peripheral segment of the radial artery are connected to the risk of disturbed functioning of the forearm fistula with end-to-end anastomosis.
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