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Ultrasound-guided angioplasty of dialysis fistula – technique description

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Summary

Endovascular procedures are commonly used for treatment of vascular pathologies. These interventions are routinely performed under angiographic control. Angioplasty is increasingly more often used for correction of dialysis fistula – especially dilatation of stenosis. We describe the technique of dialysis fistula angioplasty under ultrasound control. Benefits of this procedure include lack of nephrotoxic contrast, what is especially important in chronic kidney disease patients in pre-dialysis period. Advantages of ultrasound guidance during dialysis fistula angioplasty lead to cause more and more frequent employment of this technique.

Key words: endovascular procedure • dialysis fistula • angioplasty

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Background

Properly functioning arterovenous dialysis fistulas constitute the best vascular access for dialysis. Unfortunately, their function is often disrupted by stenosis of vessels forming the fistula and decresed blood flow. Normal function of fistula may be restored with classical surgery or endovascular procedures. Open surgery causes significant tissue damage and the treated fragment cannot be temporarily punctured. Endovascular procedures also have their limitations. They should not be performed if stenosis is located at the site of vessel anastomosis. Endovascular intervention requires exposure to X-rays and administration of contrast medium that may be potentially damaging to the kidneys or may evoke an allergic reaction. In the recent years we observe an increasing role of ultrasonography in imaging of dialysis fistulas. Superficial location of fistulas allows for simple and reliable visualization of vessels that make up the fistula. Many reports confirm the effectiveness of ultrasound studies in detection of pathologies of dialysis fistulas [1]. In the recent years some articles were published on the use of ultrasonography as a method of imaging of arteries and veins during intravascular procedures performed on dialysis fistulas. Angioplasties of stenosed vessels forming the fistulas were most frequent [2–4]. Ultrasound guided percutaneous thrombectomies of dialysis fistulas [5] with stent implantation were also described [6]. Benefits associated with ultrasound guidance during intravascular procedures compared to radiological assessment include the following: avoiding nephrotoxic contrast administration, x-ray exposure and lower costs. Elimination of contrast is particularly important in patients with advanced chronic renal failure during a pre-dialysis period and in people with contrast allergies. Therefore, ultrasound guided intravascular procedures are especially useful in patients diagnosed with non-maturating fistulas caused by presence of stenosis [7,8].

Intervention Technique

Qualification for the procedure requires thorough clinical examination – the fistula is inspected visually, palpated and auscultated in order to identify presence of a murmur and/or pulsation. Presence of a hemodynamically significant stenosis causes attenuation of murmur toward the heart and pulsation between the arterovenous anastomosis and the stricture. Fistula stenosis suspected based on clinical examination or dialysis parameters requires ultrasound examination. The following features are assessed during the study: lumen of vessels comprising the fistula

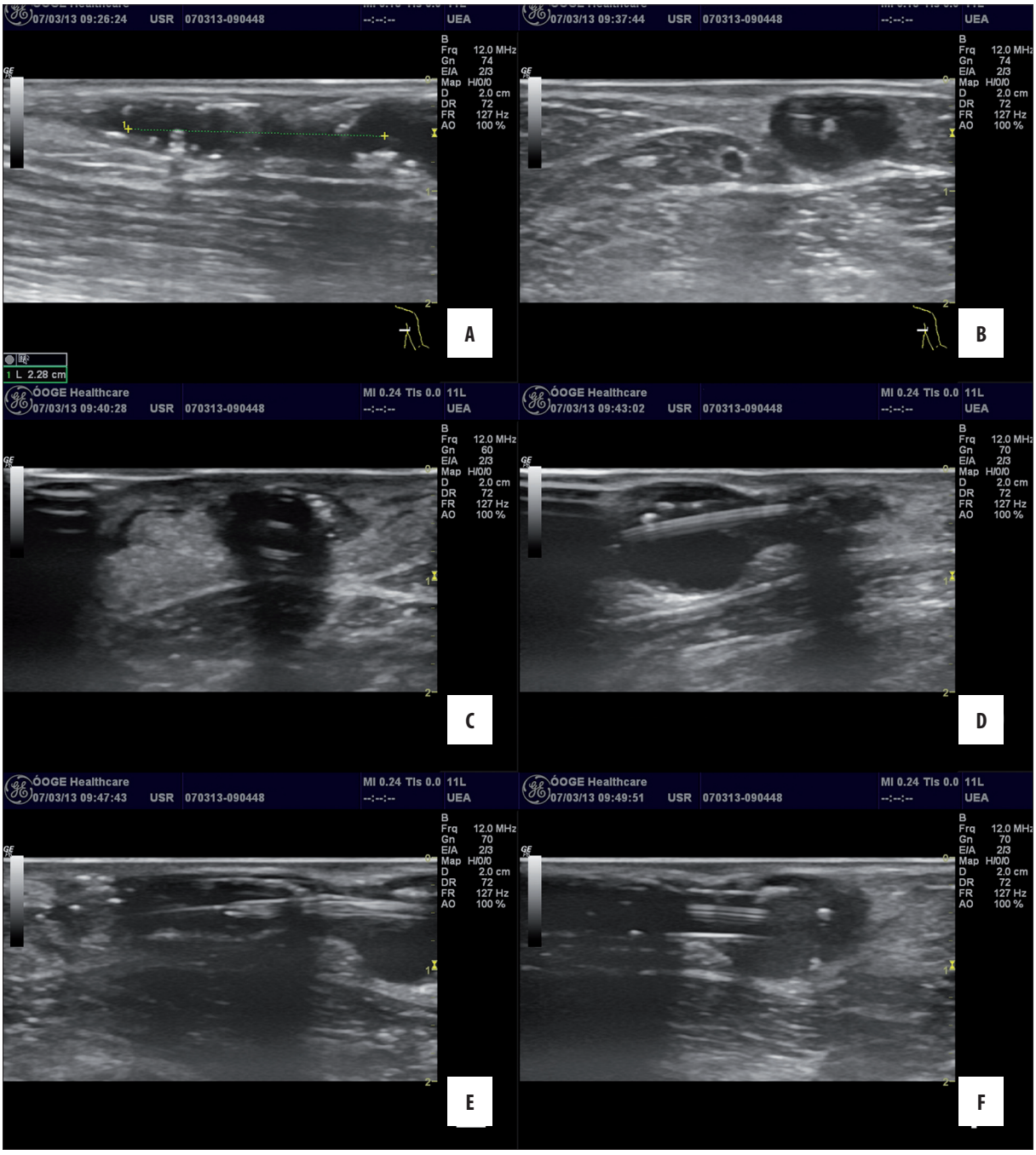

Figure 1. Steps of dialysis fistula angioplasty under ultrasound guidance. Significant stenosis of dialysis fistula (**A**), leader in the lumen of dialysis fistula (**B**), introduced vascular sheath (**C**), balloon placed in the stenosis (4×80 mm, REEF, Invatec, Italy) (**D, E**). Balloon angioplasty of stenosis in dialysis fistula (**F**).

and blood flow parameters. In case of hemodynamically significant stricture patient is referred for a repair procedure. Stenosis may be dilated during conventional surgery or an intravascular procedure. Currently, dialysis fistula strictures located away from the anastomosis are qualified for endovascular treatment. Preparation for such procedure is similar to that for other intravascular interventions. We repeat ultrasound examination of the fistula immediately before surgery in order to localize and assess the degree of stricture. Examination is performed using a GE LogiQ apparatus (GE HealthCare, USA) with 11L linear probe. Subsequently, we set up sterile surgical field and ultrasound equipment for intraoperative examination. We administer heparin intravenously (50 mg/kg b.m.) before the procedure. We choose the puncture site as far away from the stricture as possible, but at a safe distance from place of anastomosis with the artery (at least 5 mm). Puncture is performed in the direction of blood flow. Proper choice of puncture site is one of the most important elements that determines success of the procedure. Small distance between fistula puncture site and the stricture may cause significant difficulty during intravascular

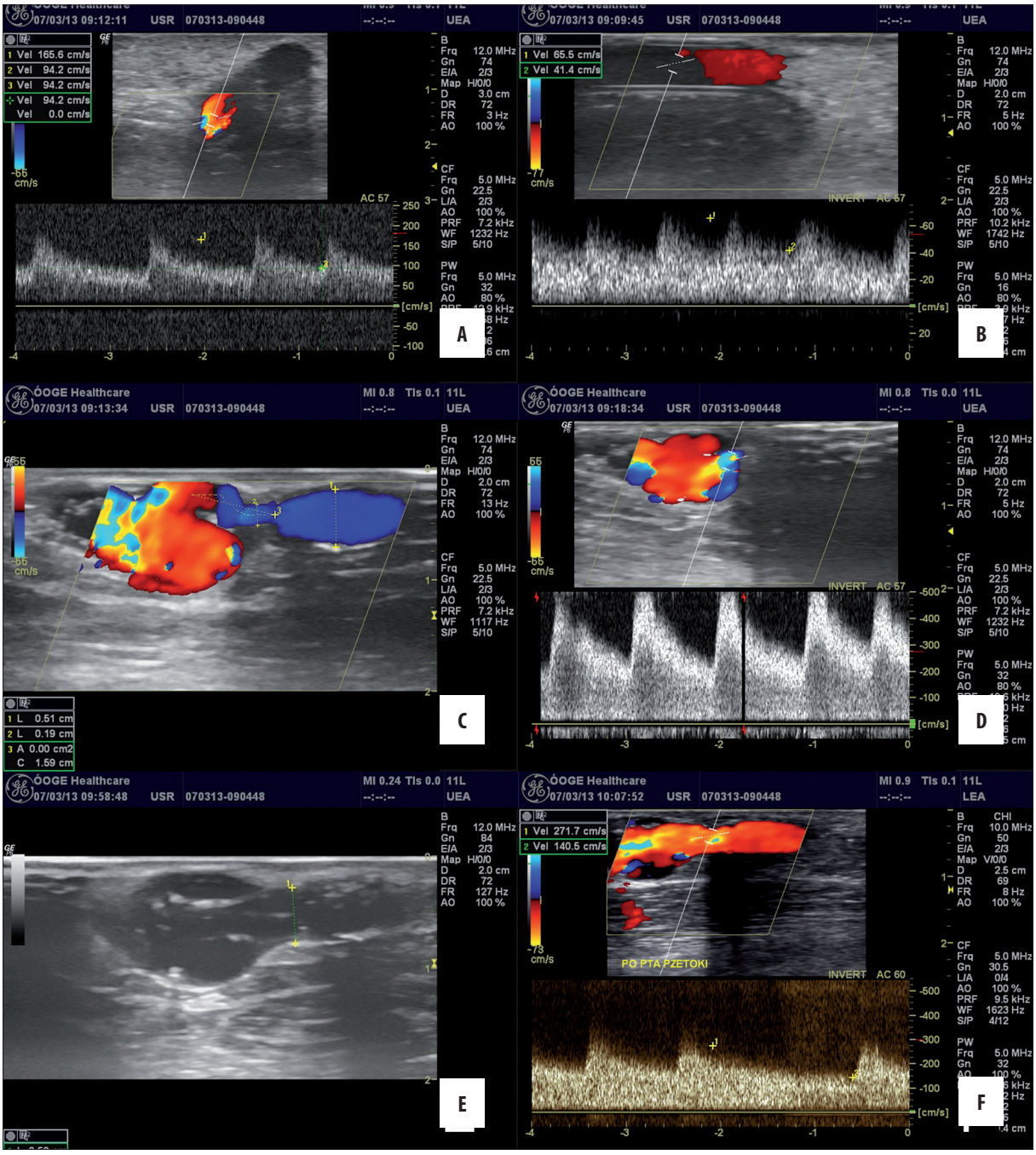

Figure 2. Angioplasty of stenosis in dialysis fistula performed under ultrasound guidance. Blood flow in arteriovenous anastomosis PSV 165.6 cm/s, EDV 94.2 cm/s (**A**), in proximal segment of a fistula, PSV 65.5 cm/s, EDV 41.4 cm/s (**B**). Pre-stenosis fistula diameter – 5.1 mm, significant stenosis of 1.9 mm diameter and 15.9 mm length (**C**). Blood flow through the stenosis, PSV approximately 550 cm/s, EDV 300cm/s (**D**). Control US after angioplasty – fistula diameter is 5 mm (**E**), with blood flow PSV 271.7 cm/s, EDV 140.5 cm/s (**F**).

intervention. Following introduction of the leader through a needle, we make a 2-mm skin incision using a no. 11 scalpel blade. Subsequently, we introduce a vascular sheath into the fistula. We use 6F vascular sheaths that allow for introduction of 6-mm balloons. With ultrasound we monitor the depth to which catheter is introduced into the fistula. After introducing the catheter we insert a hydrophilic leader (180 cm, HydroSteer, St. Jude Medical, USA). One should avoid inserting the leader to deeply, as loss of control over the end of the leader may cause damage to large vessels. Based on ultrasound image of the lesion we choose the diameter and length of the balloon used for intervention. Subsequently, the balloon is advanced into the stricture. Angioplasty may be only performed under ultrasound guidance or with help of radiologic imaging during deployment of a balloon filled with contrast. During angioplasty we use high-pressure balloons (REEF, Invatec, Italy), which are inflated up to 20 atmospheres, as indicated in treatment of dialysis fistulas. After angioplasty balloon is removed and effectiveness of the intervention is assessed

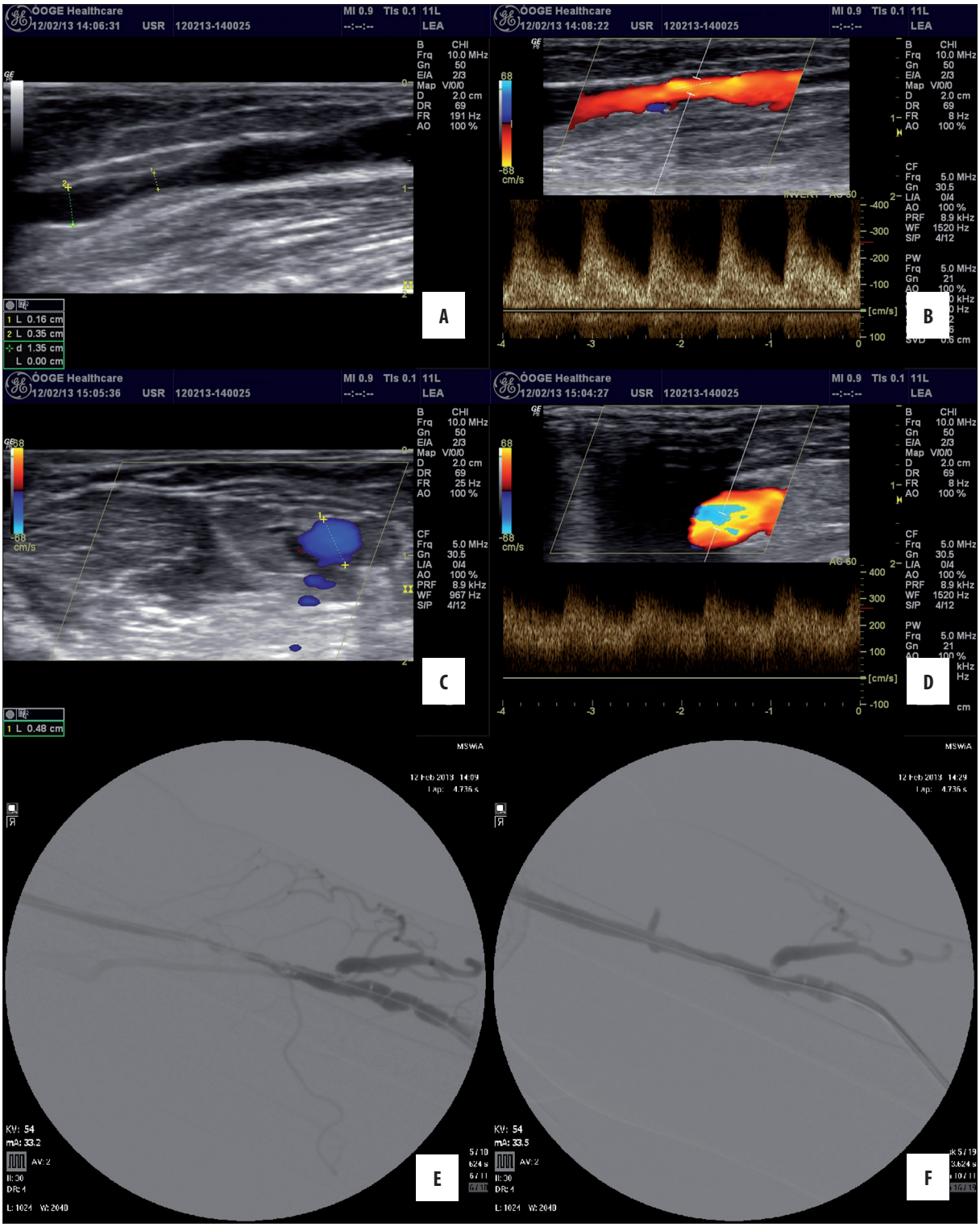

Figure 3. Ultrasound guided angioplasty of brachocephalic dialysis fistula. Tight stenosis in the dialysis fistula – 1.6 mm in diameter (**A**), blood flow through the stenosis (**B**). Control US after angioplasty – dilatation of stenosis to 4.8 mm (**C**) and changes in blood flow (**D**). Control angiography in this same patient before (**E**) and after angioplasty (**F**).

in control follow-up examination. During the study we determine the diameter of vessels that form the fistula as well as blood flow through the fistula. If the result is satisfactory, we remove vascular sheath and suture the skin (Prolene 5.0), which provides hemostasis. It is also possible to use manufactured vessel closure systems. Improvement in perceptible murmur over dialysis fistula is the evidence of successful endovascular treatment. Puncture site is secured with a dressing and slight pressure and presence of murmur over the fistula is controlled. Appropriate

pressure is necessary for successful treatment – it should not be excessive. One should remember about difficulties achieving hemostasis after endovascular interventions on a fistula ensuing from superficial location of a fistula, short puncture canal, structure of vascular wall, which contains less elastic fibers than normal arterial wall, and high vascular blood flow.

Below, we present ultrasound images at various stages of dialysis fistula angioplasty and examples of patients after successful angioplasty (Figures 1–3).

Discussion

Principles of performing angioplasty under ultrasound guidance do not significantly differ from procedures conducted under x-ray control. Ultrasound guided angioplasty is indicated when dialysis fistula stenosis is located peripherally to the clavicle. However, application of ultrasound imaging during endovascular procedures on the subclavian vein and brachiocephalic trunk was also described. In such situations a micro-covex probe is used, which enables visualization of vessels through intercostal spaces [9]. Ultrasound allows for precise determination of puncture site, making it easier to conduct the procedure. The main problem associated with carrying out ultrasound guided fistula angioplasty is the risk of introducing the leader too deep or too shallow, which may result in vein damage or prevent the procedure from being completed. It is possible to use radiological guidance for optimal catheter placement. Use of ultrasonography for visualization of stenosis also allows for precise fitting of balloon diameter to the diameter of the fistula. Appropriate balloon placement may pose a problem in ultrasound imaging performed during angioplasty, which is the reason why we recommend using longer balloons – at least 60-mm long. In our opinion, balloon visibility within the lumen of a fistula is sufficient for safe completion of the procedure.

Puncture of an immature arterovenous fistula increases the risk of thrombosis. It is probably related to the damage to insufficiently thickened wall of a fistula and greater propensity to hematoma formation near the fistula, which may cause compression and fistula stenosis [10]. In immature fistulas the vascular wall is thin and easy to tear, which may be the result of short functioning time or insufficient blood flow. The risk of damage to the wall of a fistula at a puncture site is smaller in vessels with thickened walls, which develop in fistulas that function for at least several weeks. Moreover, fragment of a fistula right before the stricture has a thicker wall than the fragment located more proximal to the heart. Therefore, the risk of damage is smaller when the fistula is punctured between the anastomosis and the stricture. It should be punctured in the direction of blood flow. In our opinion, retrograde punctures should not be used due to difficulty achieving hemostasis after withdrawing a vascular sheath.

Our experience shows that ultrasound guided endovascular treatments should be performed in dialysis fistulas located brachially, made from patient's own veins, with strictures located at a considerable distance from arterovenous fistulas. Vessels in such fistulas are usually wider than dialysis fistulas formed on forearms. On the other hand, fistulas made with artificial material develop numerous strictures and the walls suffer more damage during puncturing than arterialized veins. However, even forearm fistulas and those formed with use of artificial vascular prosthesis may be subjected to ultrasound guided transcutaneous procedures.

Due to a small distance between place of vascular sheath entry and the stricture as well as the risk of vessel damage with a leader tip inserted too deeply, endovascular sets should be as short as possible. There are sets developed for endovascular interventions on dialysis fistulas characterized by smaller shaft lengths (e.g. 50 cm). Smaller diameter of vascular sheath (4F) is also an advantage. However, it is also possible to perform fistula repairs using standard endovascular equipment.

During angioplasty, we used only local infiltration anesthesia at the puncture site, which was sufficient for pain relief during the procedure. Some authors used local infiltration anesthesia along the entire fistula during angioplasty (1% lignocaine with epinephrine and bicarbonates) [4].

Published reports demonstrated very good results of ultrasound guided dialysis fistula angioplasty. Effectiveness ranged between 92 and 97% depending on indications and location of the lesion [4,9]. In our opinion, ultrasound control of dialysis fistula repairs will be used increasingly more often due to frequent indications, effectiveness and small costs.

Conclusions

Ultrasound guided endovascular procedures is an effective and safe method of treating dialysis fistula stenosis in patients with renal failure. This method may be particularly useful in patients in pre-dialysis period diagnosed with stricture of vessels forming the fistula.

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