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HOW TO INCREASE THE USE OF NATIVE ARTERIOVENOUS FISTULAE FOR HAEMODIALYSIS

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Abstract: The arteriovenous fistula (AV fistula) is the preferred vascular access for haemodialysis. Recent clinical practice guidelines recommend the creation of vascular access (native fistula or synthetic graft) before the start of chronic haemodialysis therapy to prevent the need for complication-prone dialysis catheters. Late referral to a nephrologist is an important factor contributing to the high rate of dialysis-catheter use and the low rate of AV fistula use. Efforts to improve the vascular access experience of patients in the initial stages of haemodialysis therapy need to focus on all persons involved in predialysis care, including patients, referring physicians, surgeons, and nephrologists. An aggressive policy of venous preservation early before the beginning of any renal replacement therapy is needed. The placement and adequate maturation of AV fistula before the initiation of haemodialysis therapy requires timely patient education and counselling, selection of the preferred renal replacement modality, selection of an access type and location, and creation of the access at least several weeks to months in advance of its expected date. However, AV fistula failure has become more common over the last three decades as more patients are older, and have diabetes or vascular disease. AV fistulae failures have been attributed to inadequate vessels used for surgery. Preoperative vascular mapping has been shown to result in an increased placement of AV fistulae. In general, physical examination and ultrasound assessment are available and obligatory for vascular evaluation. The ultimate goal of preoperative assessment is to completely prevent non-maturation by optimal selection of the site of anastomosis and by identification and treatment of pre-existing lesions before vascular access creation.

Key words: arteriovenous fistula, predialysis nephrologic care, referral, haemodialysis, duplex sonography, Doppler, blood flow, resistance index.

Introduction

The provision of adequate haemodialysis is dependent on repeated and reliable access to central circulation. An ideal access delivers a flow rate adequate for the dialysis prescription, has a long use-life and a low rate of complications (e.g. stenosis, thrombosis, aneurysms, limb ischaemia, and infections). Although no current access type fulfils all of these criteria, the native arterio-venous (AV) fistula come the closest to doing so. Nowadays, the most frequent problem with AV fistula is primary failure and unsuccessful maturation with inadequate blood flow during haemodialysis treatment. The first AV fistula was created in 1966 by Brescia, Cimino and co-workers [1]. Since then, elderly and diabetic patients have been accepted for long-term dialysis treatment, and a rising proportion of patients on haemodialysis for more than 20 years have been found to have specific vascular, mainly arterial, problems [2]. A too high proportion of patients begin haemodialysis treatment with a central venous catheter because an AV fistula was not previously created or was not matured on time. At the initiation of haemodialysis treatment, 23 to 69% of patients use a dialysis catheter, from 2 to 15% grafts and from 16 to 72% native AV fistulae [3]. The complications of central venous catheters are well-known: a high rate of infection and stenosis or even thrombosis of the host-vein. Recent clinical practice guidelines recommend the creation of vascular access (native fistula or synthetic graft) before the start of chronic haemodialysis therapy to prevent the need for complication-prone dialysis catheters [4, 5, 6]. The use of a temporary catheter, compared to the AV fistula, has been associated with a worse outcome in prevalent haemodialysis patients [3, 7].

Referral to nephrologist

Insufficient care of patients with chronic kidney disease before end stage renal disease (ESRD) could be one of the causes of the unacceptably high mortality rates in patients on renal replacement therapy. Several studies have reported an association between late referral and more frequent use of temporary catheters at entry [3–7]. Late referral to a nephrologist is not the only factor contributing to the high rate of dialysis-catheter use and the low rate of AV fistula use. Evidence is also lacking on the extent to which the timing of referral to a nephrologist affects the eventual choice of initial AV fistula type [8]. Efforts to improve the vascular access experience of patients in the initial stages of haemodialysis therapy need to focus on all persons involved in predialysis care, including patients, referring physicians, surgeons, and nephrologists. An aggressive policy of venous preservation early before the beginning of any renal replacement therapy is needed. It is important to instruct the patient in time and to motivate him to preserve the forearm veins. The puncture of a vein will leave a scar. When an AV fistula is created, such scars interfere with harmonious dilation and remodelling, cause turbulent flow, and predispose patients to stenosis. The rule should be: strict avoidance of cannulation of the veins of both forearms proximal to the wrist. For vein puncture, the veins of the dorsum of the hand should be used as an alternative. If difficulties arise, the hand should be warmed in a hot bath. When unavoidable, vein puncture should be performed on the dominant arm to preserve the non-dominant arm for the AV fistula, or, alternatively, the rotation of puncture sites could be used. Phlebocatheters should not be threaded to the central veins through the cephalic or basilic veins at the elbow. Instead, central vein catheters should be inserted into jugular veins (preferably on the right side). Insertion via subclavian veins is to be avoided because (it frequently gives rise to subsequent stenosis). The same applies for transvenously inserted pacemakers. In cases where vein diameter/flow is the critical factor influencing the decision to use the central vein (e.g. when concentrated, potentially caustic/toxic solutions are to be infused), one should consider using the femoral veins [9]. The placement and adequate maturation of AV fistula before the initiation of haemodialysis therapy requires timely patient education and counselling, selection of the preferred renal replacement modality, selection of an access type and location, and creation of the access at least several weeks to months in advance of its expected need [10]. An early constructed AV fistula could also have a beneficial effect on the rapidity of worsening kidney failure. Malovrh found in a prospective randomized study after 24 months of observation that in the group with AV fistula, 14/30 (47%) patients began with haemodialysis (HD), 16 pts had a mean creatinine clearance (CC) of 13.1 ± 2.2 mL/min, a mean blood pressure (MBP) of 118 mmHg, and no sign of cardiac insufficiency. In the group without AV fistula, 27/30 (90%) ($p < 0.01$) pts began with HD and the central vein catheter was used as a vascular access, while in the remaining 3 pts the mean CC was 10.7 ± 1.0 mL/min ($p < 0.01$) and the MBP was 123 mmHg (NS). There was no difference in the quality of predialysis renal care between the two groups [11]. Jeong et al. found the mean dialysis-free time longer in the group with AV fistula than in the catheter group (14.2 ± 9.4 vs. 5.9 ± 4.1 months, $p < 0.001$) and the mean change in estimated glomerular filtration per month after AV fistula construction dropped from -0,63 to -0,21 mL/min/1.73 m^2 while it was similar in the catheter group without AV fistula (-0.63 vs. 0.67 mL/min/1.73 m^2) [12].

The cost of vascular access care is high among all patients and the highest among patients in whom AV graft is placed. These results support DOQI guidelines recommending the initial placement of an AV fistula [12, 13]. The cost of vascular access-related care was five times lower for patients treated with HD who began the study period with a functioning AV fistula compared to those treated with a percutaneous catheter or AV graft [14].

Evaluation of the patient before surgery

The risk factor for primary failure is not well established, although the quality of vessels is thought to play an important role [15–17]. One of the most important predictors of successful AV fistula development is the ability of the arterial and venous vessels to dilate under the influence of increased shear rates – vessel remodelling [18, 19]. The pre-operative physical examination of the patients' forearm venous and arterial vessels includes an inspection of the vein with a tourniquet in order to induce venous congestion and the quality of the arterial pulse. In many patients, especially obese persons, the clinical detection of veins and the evaluation of their dilatation possibility are impossible. Previous insertions of central vein catheters may cause central vein stenosis and consecutive outflow problems after AV fistula construction. An atherosclerotic and calcified narrowed artery will deliver only a limited blood flow rate and will not undergo adaptive flow-mediated dilatation to deliver sufficient fistula blood volume – a prerequisite for venous dilatation and satisfactory blood flow [16, 19, 20]. The immediate success and flow rate of a newly-constructed AV fistula was mainly dependant on the arterial inflow and venous outflow. In complex cases, particularly in patients with a history of previous failed fistulae or prior vein cannulation, vein mapping using duplex sonography is an additionnal valuable tool. Also, in patients who previously had chronic cannulation of the subclavian or jugular veins, the central veins should be evaluated by duplex ultrasonography or venography to exclude any underlying stenosis or occlusion. It was suggested that duplex imaging should be used to evaluate all patients prior to the creation of an AV fistula. Duplex scanning is a promising method for establishing certain morphological and functional parameters of peripheral blood vessels because it is non-invasive and safe and may be used in lieu of venography and arteriography at facilities where this modality is available and reliable for venous and arterial assessment. This method has been recently used to visualize and measure arterial and venous vessel diameters, and has shown a good correlation between pre-operative determination and peri-operative findings [15–16, 18–20]. Malovrh demonstrated an immediate patency rate of 92% in patients with a preoperative internal diameter > 1.5 mm in the feeding artery, as compared to a maturation rate of 45% in patients with an internal diameter < 1.5 mm. At 12 weeks, the patency rate in the two groups was 83% and 36%, respectively [16]. Increased artery intima-media thickness (IMT) is known to be a risk factor of early AV fistula failure. High-resolution ultrasonography is a simple and effective tool in measuring artery IMT. The measurement of artery IMT by ultrasonography is recommended before AV fistula creation in uraemic patients who have poor vascularity, such as older patients, diabetics and patients with severe atherosclerosis [17, 18]. Kim et al. found that early failure of radiocephalic AV fistula was closely associated with pre-existing IMT of the radial artery [21]. Besides morphological evaluation, the functional characteristics of the arteries could be evaluated by duplex sonography [16, 22]. The feeding arteries dilate during access maturation. Consequently, it is obvious that not only the initial diameter, but also arterial compliance affects access outcome. The distensibility of the arterial wall can be assessed preoperatively by evaluating the Doppler waveform in the radial artery during reactive hypaeremia (RH), induced by reopening a fist that was clenched for two minutes. The high-resistance triphasic Doppler ultrasound signal with clenched fist (regular signal of peripheral arteries) changes to a low-resistance biphasic waveform after releasing the fist and the resistance index (RI) at RH can be calculated using the formula: (peak systolic velocity – peak diastolic velocity)/(peak systolic velocity). A preoperative RI of > 0.7 in the feeding artery after release of the fist indicates that arterial blood flow will not increase sufficiently. In such case chance for successful creation of an AV fistula is reduced. Preoperative screening to exclude an inappropriate response to RH is recommended. This manoeuvre is especially helpful in planning the location of the initial operation, i.e. selecting the wrist/forearm or elbow region [16, 18, 23]. The preoperative Doppler ultrasound criteria for AV fistula outcome are: arterial luminal diameter > 1.6 mm, venous luminal diameter (without use of tourniquet) > 2.0 mm, arterial RI < 0.7 (at RH). Routine preoperative sonographic vascular mapping results in an increase of patients with suitable veins. Many patients were found to have large calibre veins that were simply too deep to be visualised. Malovrh reported that the veins were clinically visible only in 54/116 (46.5%) of patients; among the 62/116 (53.5%) patients with no visible veins, they were detected by ultrasound in 48/62 (77.4%) patients [18]. After AV fistula construction, the "fistula vein" under the influence of increased blood flow and intravenous pressure is dilated. This ability of the vein could be determined by measuring the increase of the vein's inner diameter (IDV) after proximal vein compression. A blood pressure cuff should be placed around the upper arm as proximally as possible and inflated at 50 mmHg for two minutes. Vein diameters < 1.6 mm have been associated with AV fistula failure [15, 18, 20, 23, 24], while good patency rates were obtained in patients with AV fistulas that were created on the basis of a selection of adequate veins (diameter of cephalic vein at the wrist ≥ 2–2.5 mm or upper arm veins > 3 mm) [19, 20, 22]. In the failed group of AV fistulas, IDV increased after proximal compression by 11.8% compared to 48% in the group of successful AV fistulas [18]. On the basis of this increase, we were able to anticipate the increase of vein diameter at different intervals after construction, and predict the time of AV fistula maturation. Venous distensibility may be helpful in choosing the most suitable access type for each individual patient [25, 26]. To determine if there is any disturbance in venous outflow, the continuity of the shape of the Doppler vein signal (DVS) and respiratory filling is used. At deep breath, the venous flow is increased because of low resistance to venous flow. If there is venous outflow disturbance (stenosis), DVS is not changed [18]. Duplex ultrasound is an accurate method for the investigation of arteries in the upper extremity with a sensitivity of 90% and a specificity of 99% for the detection of obstructive disease [20]. Use of duplex ultrasound influences the choice of access placement [18, 24]. In case of small-sized artery and/or small-sized vein, found by ultrasonography, handgrip training and intermittent compression of the upper arm veins, performed daily, increase the diameter of forearm arteries and veins and improve endothelium-dependent vasodilatation [27]. Persic et al. examined 129 patients aged 75 ± 6 (65–93) years, 58% men, 37% diabetics by ultrasound before AV fistula construction. The inner diameter of veins (under compression) and arteries, were measured. The presence of arterial calcifications was noted. The positions for possible native AV fistula construction (radiocephalic and brachiocephalic) were suggested and an AV fistula was constructed by a trained nephrologist. An adequate cephalic vein was present in 76 (59%) in the right arm, and in 83 (64%) patients in the left arm. Suitable veins in the forearm were recorded in 73 (57%) patients on the right and in 76 (59%) patients on the left side. The inner diameter of radial artery 2.3 ± 0.4 mm and calcification in 36% was found. In 32% of patients, one native AV fistula was possible, in 17% two, in 23% three and in 18% four, while in 10% no AV fistula was possible. In 84% of patients an AV fistula was constructed, with no significant difference in nondiabetic vs. diabetic patients (88% vs. 80%) or females vs. males (87% vs. 83%). It was concluded that a native AV fistula can be constructed in the majority of elderly patients, often in multiple positions, with no significant differentces in terms of sex or diabetic status [2].

Arterial spasm in uraemic patients undergoing construction of the AV fistula could be an important reason for their primary failure, especially in the marginal quality of the arteries. Owada used ultrasonic Doppler flowmetry for detecting such phenomena. Arterial blood flow was significantly decreased 5 minutes after anastomizing the radial cephalic vein with the radial artery (14.3 ± 4.5% of the initial value vs. initial blood flow; $p < 0.001$), indicating vasospasm [29]. Spasm of the artery could be prevented by increasing blood flow through the artery. In a two years period, Malovrh analysed 102 native AV fistulae. In 58 pts, the mean IDA was 2.8 ± 0.4 mm, RI at RH was 0.62 ± 0.07, arterial blood flow (ABF) 44 ± 9.2 ml/min. The primary patency rate was 96.5% (56/58). In the risk group of elderly and diabetic patients with a marginal quality of the vessels, study with expansion of blood volume was performed to find out if this could prevent early AV fistula functioning after AV fistula construction. During the surgical procedure, 22 pts with IDA 1.8 ± 0.5 mm, RI RH 0.83 ± 0.5, received a mean 720 ml (range 320 to 870 ml) of plasma expander. The primary patency rate in this group was 86.4% (19/22). During surgery, 22 pts with IDA 2.0 ± 0.2 mm, RI RH 0.87 ± 0.6, did not receive plasma expander. The primary patency rate was 27.3% (6/22) ($p > 0.001$). In our study, the infusion of plasma expander increased the primary patency rate. On the basis of the morphological and functional characteristics of arteries determined by duplex sonography before surgery, the need for the expansion of blood volume could be predicted [29–31].

Native arteriovenous fistula

Despite the increasing number of patients with diabetes, peripheral vascular disease, and those of older age, the creation of a native AV fistula is possible in the vast majority of cases [32–33]. The long-term survival of the radiocephalic AV fistula varies widely: 85% survival in the first year and 80% in the second year [34]. Despite the advantages of the AV fistula, early occlusion or failure to mature occurs in 10–24% of patients [35]. It is difficult to compare the failure rates, as there are two different "schools of thinking". Some teams attempt AV fistula creation only when the arteries and veins are of optimal quality. If these conditions are not found at the wrist, the AV fistula is created at the elbow or the upper arm. Lazarides et al. analysed data from 1516 patients receiving Iong-term HD. They suggested that an AV fistula at the elbow should be considered second best [36]. Nevertheless, an AV fistula at the wrist should always be the first choice for vascular access. Malovrh analysed 115 patients on HD treatment. The AV fistula was constructed at the wrist in 56%, at the mid-forearm in 11%, and at the elbow in 33% of patients. The reason for a mid-forearm AV fistula was the artery in 69% and the vein in 31% of patients, and for an elbow AV fistula the artery in 40% and the vein in 60% of patients. The elbow AV fistula is a reliable means of establishing vascular access for haemodialysis, if a primary AV fistula at the wrist is not technically possible, or as a secondary procedure. In contrast, other groups, especially those using microsurgery and working in close cooperation with interventional radiologists, will attempt AV fistula creation even when venography or duplex sonography shows evidence of small vessels. The latter bears the risk of higher initial failure rates and delay in achieving a functional vascular access for the patient, but less risk of mid-term and long-term morbidity, since steal syndromes and excessive high flows are much less frequent in forearm fistulas [37]. The transposition of the autologous basilic vein to the brachial artery provides suitable vascular access in the absence of a superficial vein owing to the fact that this vein is not usually damaged by cannulation. The procedure is usually accompanied by transposetion of the vein for easier cannulation. A patency rate of 75% at 8 years or 76.7, and a 49.2% patency rate for the brachial artery and the basilic vein fistula at 1 and 4 years, respectively, were reported [34, 38]. In high-risk patients, the autologous transposed brachiobasilic fistula has an equivalent patency and lower complication rates than those reported for PTFE interposition grafts [39]. However, there has been no clinical trial comparing these two types of upper arm

AV fistula, so no definitive advice can be given. The selection of an appropriate AV fistula will depend on the quality and topography of vessels involved. The creation of an AV fistula is an interdisciplinary task. In several countries, the task of coordination is delegated to a "fistula manager", who integrates the activities of the nephrologist, ultrasonographer, surgeon, and interventional radiologist [32]. The creation of fistulae should be delegated to a restricted number of dedicated surgeons and/or nephrologists interested in VA construction, because good results are only achieved by persons with considerable expertise and an understanding of the goal of the AV fistula. There has been much disagreement concerning the time when an AV fistula is ready for puncture. The DOQI [39] guidelines recommend puncture after 3 to 4 months. According to some authors, this may be too restrictive and it is considered more rational to wait longer than 10 days, except in case of specific circumstances such as skin lesions, infection, etc. [41]. Fistula flow was measured and an immediate, tenfold and more increase of blood flow rate was found in the radial artery, which progressively increased during the first 10 days [18] and tapered off later on. Their practice is to puncture the fistula no sooner than 3–4 weeks after operation. The main reasons for this are the enlargement of the fistula vein diameter and arterialisation of the fistula vein wall.

Monitoring of the arteriovenous fistula

Nurses should be trained to recognize fistula problems and to pay attention to the progressive increase of venous inflow pressure and post-puncture bleeding. Regular fistula inspection and physical examination of the fistula is advisable every 4 weeks [41]. The main purpose is to detect the development and progression of stenosis in time to prevent any eventual thrombosis, so that one is not forced to surgically correct an established thrombosis. The final trigger causing thrombosis is the critical reduction of arterial blood flow below 200 ml/min. Several procedures help to recognize critically low blood flow rates: auscultation (high frequency bruits at the site of stenosis), hand elevation (collapse of the post-stenotic venous segment and persisting congestion of the prestenotic segment), prolonged bleeding after removal of the needle, and elevated venous inflow pressure during dialysis treatment [34]. Complete documentation enabling systematic and continuous nursing care of vascular access (VA) has been prepared for short- or long-term monitoring of all changes. The documenttation consists of three documents: basic information about the patient (age, sex, primary renal disease, date of vascular access construction, location, when VA was first used, etc.), a drawing of the AV fistula (artery and vein, place of anastomosis, marked puncture spots; enclosed is also a photo of the AV fistula), and a document presenting, in chronological order, any changes in puncture spots [43]. Early diagnostic procedures could be conducted and, if needed, early corrections (surgical or radiological) could be made. These documents provide new opportunities for a long-lasting (extensive) AV fistula presentation, and may also be used to learn something new about AV fistulas for each patient.

Conclusion

The number of patients requiring renal replacement therapy by haemodialysis is rising rapidly. Among these the percentage of risk patients such as the elderly, diabetics, and patients with different vascular diseases is increasing. Construction of an appropriate vascular access is a challenge to nephrologists and vascular surgeons. The clinical success of AV fistulae is jeopardized by high early failure and no-maturation rates. Guidelines recommend the use of different diagnostic modalities to enable tailored vascular access creation for individual patients to avoid vascular access failure and non-maturation. Medical history and physical examination are basic. Physical examination can be carried out rapidly at no extra cost or equipment. This diagnostic modality yields more information from venous than arterial assessment. Unfortunately, its utility is less than optimal, especially in the risk group of patients. In this group and whenever the results of clinical examination are uncertain, ultrasound as an additional diagnostic modality should be used because of its non-invasive nature, ease of performance and safety. Various preoperative parameters determined by ultrasound are associated with an increased risk of vascular access early failure and non-maturation. To better predict vascular access a combination of arterial, venous and cardiac parameters should be used instead of a single parameter. Preoperative mapping should ideally be carried out close to the operation date and by a skilled person with an understanding of the goal of vascular access for haemodialysis [44–45]. Since 1995 at our department three nephrologists perform preoperative vessels evaluation by ultrasound routinely for all patients and one of them is also a vascular access surgeon. Before a final decision is made a combination of different clinical and ultrasound parameters is considered. Otherwise two dedicated nephrologists from our department perform vascular access surgery. In 2008, 82% (1107/1343) of prevalent patients in Slovenia had a native arteriovenous fistula as permanent vascular access [46].

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Резиме

КАКО ДА СЕ ЗГОЛЕМИ УПОТРЕБАТА НА СОПСТВЕНА АРТЕРИОВЕНСКА ФИСТУЛА ЗА ХЕМОДИЈАЛИЗА

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Апстракт: Артериовенската фистула (АВ фистула) е преферирани васкуларен пристап за хемодијализа. Последните насоки во клиничката практика препорачуваат создавање на васкуларен пристап (сопствена фистула или синтетички графт) пред почетокот на терапијата за хронична хемодијализа за да се спречи потребата за катетри за дијализа склони кон компликација. Доцното упатување на нефролог е важен фактор кој придонесува за високата стапка на употреба на катетри за дијализа и ниската стапка на употреба на АВ фистула. Напорите за подобрување на искуството со васкуларниот пристап на пациентите во почетните фази на терапијата со хемодијализа треба да се фокусираат на сите лица кои се вклучени во преддијализната нега, вклучувајќи ги пациентите, докторите, хирурзите и нефролозите кои ги водат пациентите. Потребна е агресивната политика на зачувување на вените на почетокот пред која било заместителна ренална терапија. Поставувањето и соодветното созревање на АВ фистулата пред започнувањето на терапијата со хемодијализа бара навремена едукација и советување на пациентот, избор на преферираниот заместителен ренален модалитет, избор на видот на пристап и локацијата, и создавање на пристап најмалку неколку недели до месеци пред очекуваниот датум. Сепак, инсуфициентноста на АВ фистулата станува се почеста во текот на последните три децении како што повеќе пациенти се постари, и имаат дијабетес или васкуларна болест. Инсуфициентноста на АВ фистулата се припишува на несоодветните садови употребени во операцијата. Предоперативното васкуларно мапирање се покажало дека резултира со зголемено поставување на АВ фистулата. Во принцип, физикалниот преглед и ултразвучната проценка се на располагање и задолжителни за васкуларна евалуација. Крајната цел на предоперативната проценка е целосно да се спречи несозревањето со оптимален избор на местото на анастомозијата и со идентификација и третман на претходно постоечките лезии пред создавањето васкуларен пристап.

Клучни зборови: артериовенска фистула, преддиајлизна нефролошка нега, упатување, хемодијализа, дуплекс сонографија, Доплер, проток на крв, индекс на резистентност.

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