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New Approach in Creating an Arteriovenous Fistula: First Year of Experience Implementing the New Method in R. N. Macedonia

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Abstract

Introduction. Arteriovenous fistula (AVF) for Hemodialysis (HD) is a surgical anastomosis between the native blood vessels, and it has become a symbol for superior vascular access (VA) for patients on HD. The aim our study was to compare the successful creation and adequate maturation of AVF using vessel loops instead of arterial bulldogs (small metallic vascular clamp) during surgical intervention.
Methods. The study was retrospective, analyzing the outcome of AVF in patients with Chronic Kidney Disease (CKD) stage 4/5 who underwent AVF creation after hospitalization at our clinic. In 2016 we used arterial bulldogs, and in 2018 we used vessel loops during surgical intervention. Three different types of AVF were created: the distal (radial-cephalic), middle-forearm (radial-cephalic) and proximal (brachial-cephalic). The successful creation and adequate maturation of AVF was defined as successful cannulation of AVF for efficient HD treatment, and AVF blood flow of ≥600 ml/min measured by Doppler ultrasound (DUS).
Results. We analyzed 341 created fistulas during the period from January to December 2016, and 367 fistulas created during the period from January to December 2018 in patients with CKD stage 4/5. In 2016 the average age was 62.2±11.2 years, mean HD vintage was 12.8±23.2 months, and 57.5% (196/341) were males. The successful creation and adequate maturation was achieved in 58.65% (200/341), but in preventive fistulas successful creation and adequate maturation was 69.8%. In 2018 the average age was 61.4±14.2 years, mean HD vintage was 14 months, and 64.85% (238/367) were males. The successful creation and adequate maturation were achieved in 74.11% (272/367), but in preventive fistulas successful creation and adequate maturation was 82.69%. In both years the distal location of AVF was predominate site with higher percentage of successful creation and adequate maturation. The smallest percentage of successful creation and adequate maturation of AVF was found in middle-forearm location, and it correlates with deep location of radial artery that lead to kinking of the anastomosis.
Conclusion. The surgical technique during the AVF creation plays important role. Our analysis showed that creation of AVF was better in 2018 when we used vessel loops, in comparison to 2016 when we used arterial bulldogs. The atraumatic needles, microsurgical instruments and vascular loops decreased mechanical stress in the blood vessels. Use of the vessel loops provides lower mechanical trauma of blood vessels than metallic vascular clamp, with adequate bleeding control.

Keywords: Arteriovenous fistula, surgical anastomosis, vessel loops

Introduction

Arteriovenous fistula (AVF) for Hemodialysis (HD) is a surgical anastomosis between native blood vessels, and it has become a symbol for superior vascular access (VA) for patients on HD. For the patients, VA is the "umbilical cord" keeping them alive, but it can be a constant source of stressful experience as well [1].
A successful creation and an adequate maturation, can provide efficient HD treatment and long-term patients' survival. Compared with prosthetic graft and central venous catheters, AVF is associated with lower incidence of complications and longer survival [2,3]. The Kidney Disease Outcomes Quality Initiative (KDOQI) guidelines recommended that patients with glomerular filtration rate (GFR) of less than 30 ml/min/1.73 m^2 or Chronic Kidney Disease (CKD) stage 4/5 should be educated on all modalities of renal replacement therapy (RRT): hemodialysis (HD), peritoneal dialysis (PD) and transplantation (Tx), and an AVF should be placed at least 6 months prior the anticipated start of HD treatment [3].
The first AVF was created by Brescia, Cimino and Appel in 1966 [4]. After an AVF creation, vascular

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remodeling occurs with hemodynamic and morphological changes in the blood vessels, that leads to increased diameter and wall thickening and thus, allowing an adequate blood flow for efficient HD [5]. The hemodynamic and morphological changes are the biggest in the first 24 hours after creation. However, AVF still presents a significant medical challenge for the specialists involved in its creation and maintenance. The continuing contemporary technological development in medicine provides better quality of life for patients on HD, but also leads to increased number of newly created VA for HD worldwide. It is essential for all patients to be individually evaluated before the VA creation, in order to secure the most appropriate VA for HD.
In N. Macedonia arteriovenous fistulas are created by a nephrologist since 1976. The Department of Vascular Access, at the University Clinic of Nephrology in Skopje, is the leading institution in the field of VA creation for patients on HD in N. Macedonia which created almost 90% of all VA in the country [6]. The process of AVF creation is surgical intervention, that is performed under local anesthesia (2% Lidocaine) with construction of a termino-lateral anastomosis (end of vein to side of artery) with continuous polypropylene sutures (6-0 Prolene) using microsurgical instruments and 3.5 times magnifying glasses [7].
The aim of our study was to compare the successful AVF creation after using vessel loops instead of arterial bulldogs (small metallic vascular clamp) during the surgical intervention.

Material and methods

The study was retrospective which analyzed the outcome of AVF in patients with CKD stage 4/5 who underwent AVF creation in 2016 and in 2018, hospitalized in University Clinic of Nephrology, Skopje, N. Macedonia. Three different types of AVFs were created: the distal (radial-cephalic), middle-forearm (radial-cephalic) and proximal (brachial-cephalic). Primary thrombosis of AVF was defined as an immediate failure of fistula within 24 hours of creation and primary failure was defined as thrombosis of fistula within 3months. The successful creation and adequate maturation of AVF was defined as successful cannulation of AVF for efficient HD treatment, and AVF blood flow of > 600 ml/min measured by Doppler ultrasound (DUS).

Protocol of Arteriovenous fistula creation

The process of creation of AVF began after complete physical and mental preparation of the patients in aseptic operating room. The surgical intervention was performed under the local anesthesia (2% Lidocaine). We used combination of 10 ml 2% Lidocaine and 10 ml NaCl 0.9% in previously selected location on fore arm by DUS. A vein diameter >2.0 mm and an artery diameter >1.6 mm was considered adequate. We used DUS (Mindray® DC-T6 2010) which was equipped with a linear probe with a minimum frequency of 7 MHz for B-mode. Calculation of the AVF blood flow by DUS used the following formula: vascular area x mean velocity x 60, and blood flow was expressed in milliliters per minute (ml/min).
First, a longitudinal 4-5 cm skin incision was made along the course of artery and vein (distal, middle and proximal side of forearm). From the selected cephalic vein, a segment of 3-5 cm in length was isolated from the surrounding tissue (Figure 1).

Fig.1. Location of blood vessels

Fig. 2. Gentle tension by vessel loops

The separation was done with the help of vessel loops that were placed around the vein with Kelly tweezers. Usage of vessel loops allowed good vascular control, gentler clamping and it eased locating venous branches that were usually removed to improve the mobility of the vein. Then, the focus was on the artery that was exposed with her concomitant veins below fascial fiber. The artery was carefully mobilized with vessel loops in the same manner as the vein. The gentle lift of the artery with vessel loops provided tension in the tissues, thus facilitating the dissection and avoiding injuries (Figure 2). Gentle handling was essential in mobilization of both, the artery and vein. We used the small angle-microsurgery instruments and vessel loops to elevate the vessels that provided adequate vascular control and retracted the artery and the vein without trauma. First, the cephalic vein was cut on the most distal part and the end of the vein was punctured with a hoarsely needle, and distended with 20 ml heparinized NaCl 0.9% solution, 3 times with proximal compression (Figure 3). The adequate distension of the vein was confirmed with minimal resistance to infusion fluid.

Fig. 3. Distention of the vein

The radial artery was usually exposed at the medial side of the incision and was retracted with vascular loops from both sides. The arterial bulldogs (small metallic vascular clamps) were used in brachial artery, when huge calcification was found inside the arteries and in arteries with diameter size bigger of 40 mm. After ensuring good control of the artery with vascular loops, a small incision on the artery was made (Figure 4). The length was 10 mm for radial and 5 mm for brachial artery. In attempt to prevent muscle spasm, mechanic dilatation of radial artery was performed with passing a blunt-ended probe or artery dilatator, but only in radial artery, and not in brachial artery.

Adequate length of both vessels is necessary for the anastomosis to be made without tension. Also, the angulation of anastomosis is important to avoid later kinking. Properly constructed end-to-side anastomosis

Fig. 4. Lateral incision of artery

Fig. 5. Termino-lateral (end-to-side) anastomosis

resulted with the highest fistula blood flow and minimal distal venous hypertension. The termino-lateral (end of vein to artery side) was the preferred anastomosis (Figure 5), using continuing polypropylene su-

ture (6-0 Prolene) with the aid of 3.5 times magnifying loop. At this stage, we used the heparinized solution for washing the lumen of the artery and vein for removal of clots. A palpable thrill was used as an indicator for successful AVF creation. Palpable pulsation and the absence of the thrill or bruit indicate outflow obstruction and may signal impending thrombosis. After the operation, patients start with exercises with a ball on the same arm where the AVF is. The skin incision was covered with light gauze and dressing.
After the AVF creation, we performed monitoring of AVF maturation with DUS according the current guideline, that define a mature access as one that has a blood flow of at least 600 mL/min, diameter of fistula vein 6 mm and less than 6 mm below the skin surface "Rule 6" [3].

Results

We analyzed 341 created fistulas in 2016 and 367 created fistulas in 2018 in patients with CKD stage 4/5 in one nephrology facility. We compared the successful creation and adequate maturation of AVF between 2016, when we used arterial bulldogs and 2018 when we used the vessel loops.
Three hundred and forty-one fistulas were created in patients with CKD stage 4/5 during the period from January to December 2016. Mean age was 62.2±11.2 years and mean HD vintage was 12.8±23.2 months. From those, 57.5% (196/341) were males, and 42.5% (145/341) were females. The primary cause for CKD in all patients was as it follows: Diabetes mellitus (DM) n=100 or 29.33%; Obstructive Nephropathy (ON) n=57 or 16.72%; Hypertension (HTA) n=53 or 15.54%; Glomerulopathy (GP) n=26 or 7.62%; Autosomal dominant polycystic kidney disease (ADPKD) n=23 or 6.74%; and Other n=82 or 24.05% (Table 1). The distal AVF was dominant location in 50.4% (n=172) of created fistulas, followed by middle-forearm location in 34% (n=116) and proximal in 15.6% (n=53) of created fistulas. The successful creation and adequate maturation were achieved in 58.65% (200/341). The primary failure within 3 months of creation occurred in 41.35% (141/341), in which early thrombosis or thrombosis with 24 hours after creation occurred in 30.20% (103/341) (Table 2). The successful creation and adequate maturation of AVF per location was: 68.60% (118/172) in distal AVF (radio-cephalic); 43.10% (50/116) in middle-forearm AVF (radio-cephalic) and 60.38% (32/53) in proximal AVF (brachio-basilic) (Table 3). Preventive fistulas were 15.8% (n=54) and successful creation and adequate maturation was presented in 69.8% of the total number of created fistulas.

Table 1. Demographics characteristics and distribution of primary renal disease of created fistulae

	2016	2018
Number	341	367
Males	196(57.5%)	238(64.85%)
Females	145(42.5%)	129(35.15%)
Mean age (years)	62.2±11.2	61.4±14.2
HD vintage(months)	12.8±23.2	14
Etiology of renal disease		
Diabetes Mellitus (DM)	100(29.33%)	102(27.80%)
Other	82(24.05%)	104(28.34%)
Obstructive Nephropathy (ON)	57(16.72%)	39(10.63%)
High blood pressure or Hypertension (HTA)	53(15.54%)	71(19.36%)
Glomerulopathy (GP)	26(7.62%)	34(9.27%)
Autosomal dominant polycystic kidney disease (ADPKD)	23(6.74%)	17(4.6%)

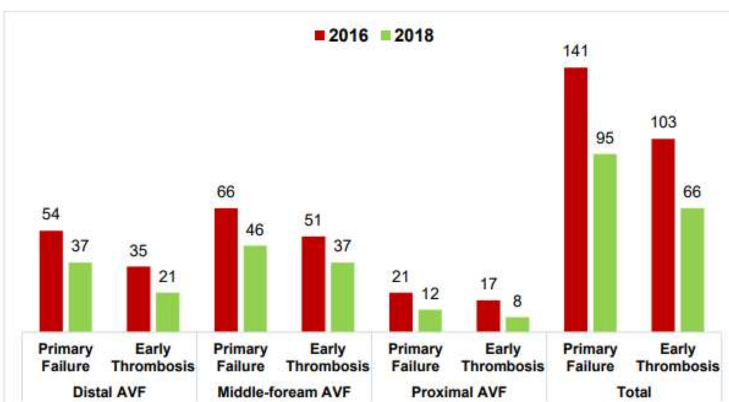

Fig. 6. Early Thrombosis from Primary Failure of AVF by location

In comparison, during the period from January till December 2018, 367 fistulas were created. Mean age was 61.4±14.2 years and mean HD vintage was 14 months, and 64.85% (238/367) were males. Also we analyzed the primary cause for chronic kidney disease in these patients: Diabetes mellitus (DM) n=102 or 27.80%; Obstructive Nephropathy (ON) n=39 or 10.63%; Hypertension (HTA) n=71 or 19.36%; Glomerulopathy

(GP) n=34 or 9.27%; Autosomal dominant polycystic kidney disease (ADPKD) n=17 or 4.6%; and Other n= 104 or 28.34% (Table 1). The distal AVF was dominant location in 45.78 % (n=168) of created fistulas same as 2016, followed by middle-forearm location in 37.06% (n=136) and proximal in 17.16% (n=63) of created fistulas.
The successful creation and adequate maturation were achieved in 74.11% (272/367). The primary failure within 3 months of creation occurred in 25.89% (95/367), in which early thrombosis or thrombosis within 24 hours of creation, occurred in 17.98 % (66/367) (Table 2). Successful creation and adequate maturation of AVF per location was: 77.98% (131/168) in distal AVF (radio-cephalic), followed with 66.17% (90/136) in middle-forearm (radio-cephalic) and 80.95% (51/63) in proximal AVF (brachio-basilic) (Table 3). Preventive fistulas were 14.17% (n=52) and successful creation and adequate maturation was presented in 82.69% of created fistulas.

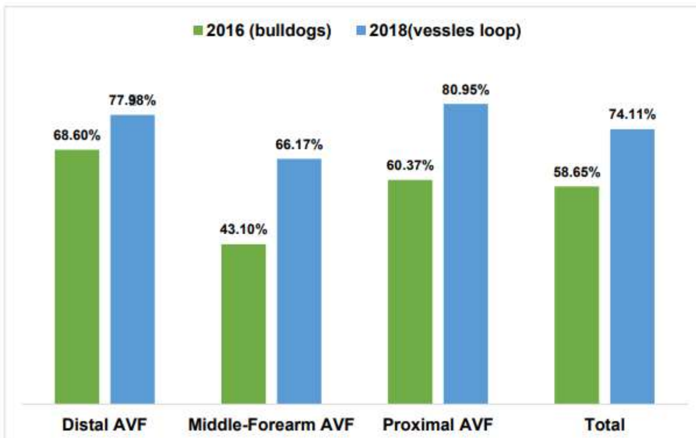

Fig 7. Comparison of the creation and maturation of AVF

Discussion

The AVF remains the preferable choice for VA in patients on HD, being associated with lower complication and longer patency rate, in comparison to the tunneled central venous catheters and synthetic grafts. In addition, VA failure is a common and serious complication leading to increased temporary catheter use, access creation at multiple sites, and after many years of multiple access failures, catastrophic inability to undergo HD in some cases. The goal of the specialist involved in creation of AVF is to obtain blood flow volume ≥600 mL/min that allows adequate HD treatment. Careful planning of VA is of crucial importance for patients on RRT. Physical examination and preoperative vascular mapping with DUS determine the forearm location of AVF creation [8]. Also, the surgical technique during the AVF construction plays an important role. Appropriate length of the blood vessels and reduced angulation between them, avoids kinking of the vessels [9]. The atraumatic needles, microsurgical instruments and vascular loops decrease mechanical stress in the blood vessels. Regarding the above, creation of AVF is still a complex procedure that requires multidisciplinary approach. Building and nurturing a team of dedicated VA specialists may be what maximize success. Surgeons who had created at least 25 arteriovenous fistulas during training had significantly lower rates of AVF failure than those placed by surgeons who had created fewer than 25 with a relative risk of 0.66 [10]. It allows team members to gain experience in the various techniques available and to monitor success as well as complication sat at a local level.
Laskar *at al*. compared continuous versus interrupted suture of AVF in 40 participants. Access survival at 2 years, was found to be similar in both groups [11].
One of the criticisms of the interrupted suturing technique is that it is more time-consuming [12]. Lykoudis *et al.* in their study, were using combined technique in suturing-interrupted sutures around the heel of the anastomosis and then continuous sutures for the rest [13]. In our study, we used the continuous polypropylene sutures (6-0 Prolene) using microsurgical instruments and 3.5 times magnifying glasses for anastomosis of AVF creation. Three randomized control trials (RTCs) that compared clips versus sutures in performing end-to side anastomosis for AVF creation, but all three found uncertain effects on primary patency or AVF maturation [14-16]. Also, no study addressed end-of vein to end-of artery anastomosis or other newer techniques that are less often performed [1]. We used the end-of vein to side-of artery (terminolateral anastomosis) for AVF creation.
In our analyses from 2018 we used the vessel loops, the successful creation and adequate maturation of AVF was 74.11% (272/367) and the primary failure within 3 months was 25.89% (95/367). Going backwards in 2016 on the other hand, when we used arterial bulldogs,

the successful creation and adequate maturation of AVF was 58.65% (200/341), and the primary failure within 3 months was 41.35% (141/341). When the two periods were compared, the creation of AVF seemed better in 2018 when we used vessel loops in comparison to 2016 when we used arterial bulldogs, and the distal location of AVF was dominate with highest percentage of successful creation and adequate maturation. The smallest percentage of successful creation and adequate maturation of AVF was found in middle-forearm location, and it correlates with deep location of radial artery that lead to kinking of the anastomosis.

We have been encouraged to present our first experience in using this new method in AVF creation. In general, it could have been a small step for the mankind but for us it was a novelty, and further analysis are certainly required in order to know the benefit of it.

Reduction of the mechanical trauma during the AVF creation increases the blood flow in the artery leading to an increased in wall shear stress and tension. The blood flow and wall shear stress increase substantially in the vein. This increased flow results in a venous luminal diameter increase, a process necessary for cannulation. The wall shear stress gradually returns back to normal within 12 weeks [17]. Also, the vessel loops generate a lower pressure on smooth endothelial cell lining the tunica intima, defined as the boundary of the endothelial cell to the elastic lamina in the normal artery. The tunica media in an artery is normally much thicker than a vein with an increased amount of elastin [18]. This group of patients with end stage kidney disease (ESKD), have underlying changes in the vein and artery, including increased arterial and venous calcifications [19]. It seems that it correlates with primary renal disease, where DM occurs as the leading cause for ESKD [20]. When we detected a huge artery area of calcification, we did not use the vessel loops, because the artery wall was very rigid and we cannot provide adequate bleeding control. Also, we did not use the vessel loops in case when the diameter of artery was bigger of 4.0 mm, because we cannot provide adequate bleeding control. In both cases we used the arterial bulldogs for bleeding controls.

The last annual registry from 2017 by European Renal Association-European Dialysis and Transplantation Association (ERA-EDTA) showed that DM with 23% is the leading cause for ESKD [21]. In our analyses DM was presented with 29.96% for 2016 and 27.79% for 2018, which makes it one of the leading causes for ESKD.

Further analysis is needed for assessment of long term AVF functional capacity, and also early vascular biological events that need to be unraveled. Anastomotic design and strategies and devices to define optimal wall shear stress are in a developing process [22]. Taking that into consideration, the Optiflow (Bioconnect Systems, Ambler, Pa, USA) is an internal anastomotic connecting device placed inside the artery and vein, with the purpose of improving hemodynamics and standardizing AVF creation. A non-randomized study in 41 patients and 39 matched control patients reported comparable unassisted maturation rates at 14, 42, and 90 days of 76%, 72%, and 68% for the Optiflow group and 67%, 68%, and 76% in the control group, respectively. In this study, there was a trend for earlier maturation in the Optiflow group compared with the control group (p=0.059) [23].

There is a high possibility that factors not connected with patients characteristics and surgical skills are important in determining outcomes, and it might possibly explain the apparent contradiction of ESKD practices (Tx, PD, patterns of vascular access use in HD), where some countries excel in one area and score poorly in another.

Conclusion

In summary, the surgical technique during the AVF construction plays important role. Our analysis showed that creation of AVF is superior when we used vessel loops, in comparison when we used arterial bulldogs. The atraumatic needles, microsurgical instruments and vascular loop decreased mechanical stress in the blood vessels. Use of the vessel loops provides lower mechanical trauma of blood vessels than metallic vascular clamp, with adequate bleeding control. Also, we must continue the improvement of AVF functionality, in order to investigate the hemodynamic, morphological and vascular biology of the AVF and in order to develop better clinical parameters.

Conflict of interest statement: None declared

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