Placing a primary arteriovenous fistula that works—more or less known aspects, new ideas

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ABSTRACT

Despite the pre-operative availability of well-defined criteria to create a primary arteriovenous fistula (AVF) a high early failure/missing maturation is complained worldwide. Based on new results from basic research using numerical techniques, the authors try to guide attention to a widely neglected field in published data: the unremarkable, small, but essential surgical details in creating a successful AVF. The aim is to describe their significance and to give them a place in a cross-border context.

In this issue of NDT, Ene-Iordache et al. [1] present their study ‘Effect of anastomosis angle on the localization of disturbed flow in side-artery-to-end-vein fistulae for haemodialysis access’. Many nephrologists may be astonished to find such a specialized article highlighting a small detail of surgical technique.

For the authors of this editorial, experienced nephrologists and active in access surgery over a period of many years, the work of Ene-Iordache et al. represents a landmark in the field of the unremarkable, widely unknown, rarely published if ever, but absolutely determining aspects of arteriovenous fistula (AVF) creation—worthwhile to talk about. We will try to describe their significance and to give them a place in a cross-border context [2].

There is general consensus in the literature and all guidelines on the superiority of AVF over arteriovenous graft (AVG) and central venous catheter regarding patient’s survival and complications such as thrombosis, infection, access-related
hospitalization and quality of life. Timely creation of an AV fistula aiming at a functioning vascular access (VA) at the start of haemodialysis therapy is generally recommended [3, 4].

Reality is different and reveals two phenomena: a worldwide rising rate of central vein catheters at launch of haemodialysis therapy and, simultaneously, a high early failure/missing maturation rate after creation of primary AVF [5, 6]. Many authors have identified a handful of parameters as 'risk factors': advanced age, female gender, diabetes mellitus and systemic arterial damage by e.g. hypertension as well as the surgeon’s experience. There are brilliant articles on probability risks, all written during the pre-operative period, trying to anticipate post-operative evolutions/results [7, 8].

Nothing seems to be wrong, but where is the relevance of all these thoughts and ideas?

The authors are curious about one fact: there seems to be a gap between the value of pre-operative clinical and ultrasound evaluations, which have made a rising number of AVF creation possible, and the high early fistula failure/missing maturation rates—it seems to be contradictory. A never-ending, resultless discussion started on treatment of all kinds of stenoses, ligation of side branches, etc. But: the essential is what happens within the gap, more exactly: in the operation room, during the operation.

This pivotal question is missed throughout the literature: would not the prevention of technical AV fistula failure be by far the best procedure? Intervention in case of failure means to run behind a problem.

In 2012, we have adequate tools in the pre-operative period to provide reliable information for the first access operation. Duplex sonography may provide useful data on the pre-operative morphological and functional characteristics of vessels used for AVF construction. The goal is to achieve a satisfactory arterial inflow by selecting the optimal location of the first arteriovenous anastomosis, especially in patients with diabetes and in the elderly; here, it is mandatory to select a segment of the artery with greater diameter, less wall structural changes and best functional characteristics [9].

There is nothing to add even today, still state of the art.

Why to discuss a percent restriction as given, e.g. in the KDOQI Guidelines [10]? It seems much more obvious to follow the idea that every patient is a candidate for a primary AVF creation possible, and the high early fistula failure/missing maturation rates—it seems to be contradictory. A never-ending, resultless discussion started on treatment of all kinds of stenoses, ligation of side branches, etc. But: the essential is what happens within the gap, more exactly: in the operation room, during the operation.

In addition, it should be emphasized that the peripheral location of the anastomosis is preferred as long as the pre-operative evaluations can recommend it. But a pulseless radial artery will never convert to a feeding artery providing a flow volume of up to 1000 mL/min. Following a clinical experience, the pattern of arterial calcification decreases proximally to the upper arm region. There is no venous dilatation without arterial dilatation; less arterial calcification means better arterial dilatation leading to better flow volume. No AVF maturation without remodelling of both vessel components.

The decision about the type, side and site of first AV fistula must be made on the basis of the patient's vascular conditions as evaluated before; it means to realize an individually tailored concept aiming at an optimal result for any patient [11].

To compare AV fistulae and AV grafts is not logic as long as these comparisons do not use defined parameters such as diameters of artery and vein, different wall characteristics and different types of anastomoses. For the experienced VA surgeon, AV fistulae and AV grafts have their own, special indications for the individual patient.

Creating a well-functioning AV fistula means placing an unphysiologic high-flow construct into an ill vascular bed (Beathard G, personal communication) initiating a process of remodelling as an adaptation to the high-blood-flow conditions. To make things even more complex, two different types of vessels are involved in this process of remodelling, artery and veins, linked up by sewing the anastomosis.

Clinical and theoretical details of manual and conceptual skill to create an AV fistula are widely unknown in the literature like as being hidden in a shadowy existence.

Most publications use descriptions of an arteriovenous anastomosis like wrist or brachial-cephalic fistula, thus neglecting several determining factors:

(i) type of anastomosis such as side-to-side, end-to-end or side-artery-to-end-vein.
(ii) characteristics of arterial and venous wall.
(iii) angle between artery and vein.
(iv) length of anastomosis.

In addition, the following factors are involved in a successful AVF creation:

(i) torsion phenomena.
(ii) active venous dilatation prior to sewing the anastomosis.
(iii) arterial and venous spasm.
(iv) non-tension-free anastomosis.

Placing an artery-side-to-vein-side anastomosis (SSA) or functional SSA or, sometimes, artery-side-to-vein-end anastomosis (SEA) can/will result in a sharp angle between artery and vein. So it will be the surgeon’s choice for a 6-, 8-, 10- or more-mm-long anastomosis; there may be consensus on the idea that a length of >10 mm gives no more benefit. It is worthwhile to remember that, in 1966, Brescia et al. [12] used to sew 3–5-mm-long side-to-side anastomoses. The experience of many years advises to start the anastomosis suture in the centre of back wall [13].

The procedure is completely different in most SEAs. Here, the venous stump must be cut in any case in a direction parallel to the longitudinal axis of the artery. That means: in the case of an acute angle, the cut will be longer in the case of a rectangular approach of the vein to the artery where the cut of the vein is identical to the venous diameter. This is demonstrated in Figure 1.

Respecting this simple rule, each, SEA can be created with the ideal, perfectly tailored length of the anastomosis; particularly, there will be no venous material missed nor wasted—both conditions would complicate later remodelling processes.
The article by Ene-Iordache et al. [1] demonstrates, for the first time, with scientific, experimental evidence that this sharp angle does not ‘harm’; they found that smaller angle anastomoses develop less areas covered by low flow oscillating wall shear stresses; they will tend to develop less intima thickening and the authors concluded that ∼30° anastomoses represent the solution that minimizes the disturbed flow zones in side-to-end radial-cephalic AV fistulae.

It is well known that the disturbed flow patterns, strongly dependent on blood vessel geometry and haemodynamic conditions, cause a local wall remodelling and the preferential localization of stenotic lesions by triggering neointima formation [14]. In an experimental study in a pig model, Krishnamoorthy et al. demonstrated that there is a clear link between AV fistula anatomical configuration, wall shear stress profiles and the pattern of luminal stenosis and intima-media thickening. Thus, the haemodynamic wall shear stress profiles influence the magnitude and pattern of AV fistula stenosis [15].

In a retrospective study aimed to analyse the angiographic prevalence of stenosis in the different fistula segments, Badero et al. [16] reported data on 484 dysfunctional AV fistulae and showed that the swing segment, the segment of the vein mobilized for arterial anastomosis, had 54.7% of stenoses. The remaining stenoses were distributed among the cannulation area, arterial anastomosis and central veins. Actually, the swing segment may experience turbulent flow and altered mechanical shear stress that triggers neointima formation and results in stenosis.

The impact of anastomosis angle on pressure drop and flow distribution was also evaluated in a mathematical study using a side-to-end AV fistula model [17]. Interestingly, the pressure decreased with a larger anastomosis area and an angle wider than 43°, while it was almost stable for smaller angles. Even more astonishing: when the anastomosis angle exceeded 58°, the proximal arterial inflow was not sufficient to deliver enough flow, leading to distal arterial flow reversal.

The model of wrist side-to-end radial-cephalic AV fistula introduced by Ene-Iordache et al. [1] simulates the intra-operative haemodynamic conditions of a newly created AVF. The authors evaluated the flow distribution in four equivalent meshes having anastomotic angles of 30, 40, 60 and 90°. Using an indicator of disturbed flow, the relative residence time (RRT), calculated for the overall wall surface, the authors localized the disturbed flow in areas having RRT >1. The disturbed flow was located in all AVF models in the same areas where flow recirculation and stagnation occur, mainly on the swing segment and at the anastomosis floor. Interestingly, smaller angle AV fistulae had smaller disturbed flow areas with lower RRT and there were significant differences in RRT medians between sharper and wider angles [1].

As said, haemodynamic factors may influence vascular damage, and the wall shear stress plays a leading role. Local flow conditions, in particular, low and oscillating wall shear stress phenomena are central to vascular problems: thus, a robust framework for analysing flow conditions in vascular structures could provide an understanding of the mechanisms leading to vascular complications, such as stenoses, aneurysms and thromboses [18]. The computational blood flow modelling combined with three-dimensional imaging may aid the investigator in explaining the specific link between haemodynamic features and vascular disease. This virtual vascular laboratory approach has the great advantage of providing patient-specific haemodynamic information in a non-invasive manner [14]. Computational modelling allows investigation of patient-specific haemodynamics by employing physical laws for quantitative integration of multiple prognostic factors. Qualitatively, visual comparisons between ultrasound and computational fluid dynamic (CFD) images showed good agreement between the two methods. In addition, wall shear stress levels and the oscillatory shear index could be calculated. This method was successfully validated and is deemed suitable for more thorough investigations into the field of vascular complications in AV fistulae [18].

By using dedicated computational modelling tools, we might improve outcomes after VA creation by enabling a better selection of arteriovenous anastomosis configuration. Predictive models aiming at a more accurate risk estimation regarding the development of flow-related complications have been developed. On the basis of the pre-operative collection of structural and functional data at a vascular level, computational modelling tools are developed and validated in the ARCH project, a joint initiative of four medical centres and three industrial partners [19]. In a very recent study, a patient-specific pulse wave propagation model capable of predicting post-operative flow was created for 25 patients awaiting upper arm AVF creation [20]. Input parameters were obtained from clinical measurements and literature. An overlap between predicted and measured post-operative flows was observed in 70% of the patients. This model may be considered a valuable tool in pre-operative work-up of patients awaiting AVF creation.

By using a CFD simulation within idealized three-dimensional models of end-to-side and end-to-end radial-cephalic anastomosis, Ene-Jordache and Remuzzi studied the blood flow inside the AV fistula and the patterns of haemodynamic shear stress, known to be the major determinant of vascular
remodelling and disease [21]. They concluded that the zones of low and oscillatory wall shear stress phenomena were located in the same sites where luminal reduction was documented in previous experimental studies, thus identifying low wall shear stress as playing a pivotal role in triggering intimal hyperplasia.

There is a curious gap in the literature, around the creation of the AV fistula with some contradictory overtones. In 2012, we know what to do pre-operatively but complain high failure/missing maturation rates. Post-operative treatment, whether surgical or interventional, cannot be the only solution.

Here, the key message of the two articles by Ene-Iordache et al. [1, 21] is represented by the statement ... that ∼30° anastomoses represent the solution which minimizes the disturbed flow zones in side-to-end radial-cephalic arteriovenous anastomoses. Furthermore, a series of recently published papers guide our attention to a 'grey zone' that seems to be neglected in the clinical literature. They accordingly use computer simulations to focus on tiny surgical details while creating the anastomosis on a manual as well as a conceptual level.

The experienced access surgeon will be grateful to be confirmed in some details which have become familiar to him over many years; hitherto, he was happy about a well working, aesthetic AVF; now, he knows why it is so.

This is the merit of Ene-Iordache’s work giving new insights from the scientific point of view. The last publication [1] on the angle between artery and vein may be a ‘petitesse’ in the eyes of most readers of NDT, but plays a key role in the creation of a well-functioning AV fistula. This angle is an important part within a series of other components. What counts is the entity of all components; none can be missed.

CONFLICT OF INTEREST STATEMENT

None declared.


REFERENCES


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