The anastomosis of the arteriovenous fistula—common errors and their avoidance

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Introduction

In 1966, Brescia, Cimino and colleagues described the surgical creation of an arteriovenous fistula (AVF) to establish a vascular access in haemodialysis patients [1]. Despite the availability and the wide-spread use of grafts in some parts of the world, mainly ePTFE (expanded polytetrafluoroethylene), practically all experts in the field strongly advised creating an AVF whenever possible because of its lower rate of complications [2].

Despite the generally low rate of complications of native AVF, early failure within 1 month has been observed in some series in up to 29% of patients [3,4]. Early failure, defined as non-function of the AVF, is mostly caused by early thrombosis secondary to errors in surgical technique. Thoughtful analysis of the techniques of surgical creation of an arteriovenous anastomosis has identified a number of potential errors which may contribute to such early failure and which will be discussed in the following.

Haemodynamics of the AVF

In the long run, blood-flow rates in a well-functioning AVF can exceed 1000 ml/min or more—a dramatic increase when compared with a blood flow rate of 20–30 ml/min in a normal peripheral artery and the immediate post-operative flow rate of 200–300 ml/min after opening of the fistula [5]. This is accompanied by a decrease in peripheral resistance [6]. In the past, venous dilatation has been the focus of attention, but the adaptive venous response is clearly the consequence of increased flow which in turn depends on arterial dilatation which is the crucial and often limiting step. Obviously, venous remodelling occurs and some authors used the term ‘venous arterialization’ to characterize this process. But this terminology does not take account of the fact that in order to accommodate blood-flow rates increasing by more than a factor of 20–50 over baseline values, the entire vascular bed must undergo dramatic remodelling in order to accommodate the extremely high blood-flow rates. Anything impeding the increase in blood flow and vascular remodelling will endanger the final outcome of a well-functioning AVF. It is for this reason that the surgeon has to carefully avoid any of the following errors which may interfere with the mechanics and the geometry of the anastomosis.

The arteriovenous anastomosis

Prerequisites

The first step is to select a suitable ‘healthy’ artery and vein. This can be done by clinical and ultrasonographic investigation.

Most procedures creating a primary vascular access can be carried out under local anaesthesia. The first potential mistake concerns the incision: skin incisions (and the scar that develops) must never cross the ‘arterialized’ vein, particularly not close to the anastomosis. Transverse skin incisions do not permit exploration of more cephalad segments and cause unnecessary destruction of lymphatic vessels. Consequently, we favour longitudinal incisions and use this approach even in the elbow region.

Formation of post-operative haematoma must be avoided and this requires an extremely ‘clean’ preparation of tissues and vessels using bi-polar electrocoagulation. The goal of atraumatic closure of the skin can be achieved by using a few, but well adapted, subcutaneous sutures and sterile adhesive strips. To achieve high quality surgery, microsurgical instruments, magnification glasses, or a microscope are indispensable [7].

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Technical errors

Whenever the arterial or venous vessels are pulled and stretched, the mechanical trauma will chronically lead to long segment stenosis. Whenever the length of the venous segment is excessive, there is a risk of kinking. The risk is compounded by the fact that during maturation of the AVF, the vein will further elongate secondary to the increase in blood flow rate and vascular remodelling.

Artery-side-to-vein-side anastomosis

When an artery-side-to-vein-side anastomosis is created, the arterial and venous incision should be made exactly on the lateral aspect of the vessels. If vessels that cross each other must be anastomosed, the incisions should be located on the top and the bottom of the respective vessel. In performing these incisions, there is a great risk of causing lesions to the posterior wall. If this occurs, immediate and meticulous repair is mandatory, otherwise there is a risk of late aneurysm formation and/or perforation.

If a stiff arterial vessel has to be operated upon, it is advisable to excise some tissue at the site of the arteriotomy, otherwise turbulences will develop and interfere with the arterial inflow into the vein. The lumen and the distensibility of the vein should be tested by gently compressing the vein and watching the filling of the vessel. The use of a Fogarty catheter for these procedures should be avoided because of the risk of injury to the intima. It is indispensable to test the venous run-off as described because optimal function of the anastomosis requires, among other things, optimal venous drainage.

Artery-side-to-vein-end anastomosis

It is more demanding to create an artery side-to-vein-end anastomosis. This type of anastomosis requires much more care, experience, and power of imagination, i.e. three-dimensional visualization of the final result. With this technique the stump of the vein is isolated and has to be approximated to the artery across a certain distance. Unavoidably, the angle between artery and vein at the site of the anastomosis will differ from case to case. Each angle requires an individual length of the arteriotomy and venotomy [8]. If the vein approaches the artery at a right angle, the length of the arteriotomy should be equal to the diameter of the vein; if the vein approximates the artery under an acute angle, the length of the venotomy and arteriotomy is defined by the longitudinal axis of the artery as shown in Figure 1.

Another point requires attention. If the vein approaches the artery at a right angle, outward directed rotation is necessary to avoid kinking (Figure 2). Such kinking may easily escape detection because it takes place in the most proximal part of the mobilized vein which is often hidden. It is therefore mandatory to inspect this area. If the smooth vein yields the typical thrill upon palpation, torsion or kinking is unlikely. If, in contrast, a water hammer pulse is palpated, one should suspect stenosis, kinking or torsion.

Handling of the vein

The vein must be mobilized and adapted to the artery. It is important, however, to limit the length of the mobilized vein to an absolute minimum. Mobilization implies trauma to and devascularization of the venous wall secondary to interruption of vasa vasorum and removal of the adventitia. Obviously, this increases the long-term risk of scar formation of the damaged venous wall. This is particularly true since after creation of the anastomosis, high-flow rates and high pressure further increase the risk of scar formation and, in addition, aggravate the risk of torsion and kinking. Because trauma to the vein must be avoided, we do not recommend the ‘smooth loop technique’ of Karmody [9], although at first sight it appears attractive because it provides a favourable haemodynamic configuration (Figure 3). For the same reason, other types of ‘venous transposition’ should be avoided whenever possible. More favourable conditions are found when a pre-dilated basilic vein in the upper arm will be placed in a subcutaneous position (‘superficialization’).

It is an error to clamp the thin-walled vein during the procedure. Clamping causes injury and oedema, particularly to the intimal layer. This carries the
long-term risk of stenosis. Instead of clamping one should prevent venous backflow during suturing by gently applying proximal digital pressure.

A known complication is arterial as well as venous spasm. Should this occur we advise to rinse the vessel from the outside using warmed 0.9% saline with or without addition of papaverine or nitroglycerine. If this alone is not effective, mechanical tricks such as proximal venous compression or, if everything fails, introduction (with utmost caution) of a Fogarty catheter or olives can be successful. It is wrong to suture the skin without making sure that vascular spasm is absent. Even a high blood-flow rate alone will not be able to overcome and resolve venous spasm.

The suture

A standard technique should allow the placing of any needle stick to be extremely well controlled. The technique of Tellis \[10\] is very advantageous and this is true even for the very small vessels of paediatric patients; the suture starts in the centre of the back wall of the arteriotomy and venotomy. Suturing is continued passing the corners with excellent visualization throughout the procedure as shown in Figure 4. This variant can be used in artery-side-to-vein as well as side-to-side anastomoses.

End-to-end anastomoses

In the past, end-to-end anastomoses had been fashionable. This has several disadvantages. The diameters of the artery and the vein differ, and this has to be overcome by inserting a rhombus-like vein patch into the suture. The suture itself is performed in three independent sections without any connection of the closing knots. The main objections arise from the fact that one has to sever the distal radial artery. This procedure is dangerous in diabetic and elderly patients who constitute the majority of the patients that are seen to date. As an initial vascular access procedure this technique should be abandoned today.

A comment concerning grafts

Although grafts should be avoided as the primary vascular access whenever possible, I wish to comment on the graft-vein anastomosis. Following the recommendations of one of the manufacturers of PTFE grafts, the graft should meet the vein at an angle of approximately 60°. This implies, however, that the high-velocity blood-flow bounces against the opposite wall of the vein. Intimal hyperplasia is then unavoidable. I have found that the frequency of intimal hyperplasia can be substantially reduced with a simple trick, based on mechanical considerations. If the graft approaches the vein in an almost parallel position and the length of the graft-vein anastomosis is increased up to 20–30 mm by creating a sharp angle tip (Figure 5), blood will flow through the anastomosis without a major change in direction, thus avoiding turbulence. Using this technique, we have had excellent results for many years; but I admit that controlled evidence is not available. I am convinced that the frequent and costly complications of graft-vein anastomosis could be reduced by modification of the anastomosing technique when this simple mechanical principle is respected. Whether this procedure allows elimination of the vibrations at the graft-vein anastomosis is not known, but is certainly an interesting scientific topic.

The suturing material

No reliable information is available on which suturing material is best: polypropylene, polytetrafluoroethylene
and others are currently in use; some authors recommend absorbable material. Reliable studies are not available to compare the different types of suture material and therefore the selection has to be based on individual experience.

Non-surgical causes of early clotting

It is beyond the scope of this brief report to discuss the non-surgical causes of early AVF failure: Systemic clotting disorders, hypotensive episodes (particularly during haemodialysis sessions secondary to excessive ultrafiltration), or haematoma formation. The latter may be due to bleeding after over-heparinization or following very early cannulation with injury to the vessel wall or following inappropriate compression after withdrawal of the cannula.

Comment

Creation of an arteriovenous anastomosis—is it a simple procedure that can be delegated to the inexperienced surgical beginner? The answer clearly is no.

In my experience, creation of the initial vascular access with the arteriovenous anastomosis as central procedure is more challenging than most revisions that may seem spectacular to the non-expert.

The surgeon has to be aware of the anatomical, physiological, haemodynamic, and mechanical principles underlying the procedure and this has to be combined with manual skill, experience, and creativity. There is no place for compromise. Even minimal errors are not tolerated: the vulnerable venous vasculature is abruptly confronted with the unusually high-flow, high-pressure, high-velocity conditions and this constellation punishes all surgical mistakes. Even minor narrowing in the beginning will eventually translate into late stenosis. So, not only the early, but also the late failure rate reflects on the quality of the vascular surgeon.

Failure and success are close neighbours. Our patients will be grateful for the successes.

References