Surgical alternatives to central venous catheters in chronic renal replacement therapy

Volker Mickley
Department for Vascular Surgery, Stadtklinik Baden-Baden, Germany

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Introduction

Disadvantages and risks of ‘permanent’ central venous catheters (CVC) in chronic renal replacement therapy (RRT) have repeatedly been emphasized in the literature [1–3]. Central venous access has been shown to be the most important independent risk factor for infection and death in patients on chronic RRT. The relative risk of bacteraemia is > 7-fold higher in CVC patients when compared with fistula patients [4], and catheter-associated bacteraemia is burdened with a 20–40% rate of metastatic complications or death [5–7]. As a consequence, the relative risk of infection-related death is 1.4–2-fold higher but also the risk of death from cardiac causes and overall mortality are significantly enhanced in CVC patients, when compared with end-stage renal failure (ESRF) patients with arteriovenous fistula (AVF) [8,9]. Furthermore, a peripheral arteriovenous (av-) access has been shown to be more reliable than CVC in terms of patency rates [10], recirculation, flow rates achieved and Kt/V delivered [8,11,12]. In conclusion, av-access is very likely to provide a better quality of a longer life than CVC [8,13–15].

Nevertheless, the use of CVC for chronic haemodialysis has been recommended for children and for elderly patients, for patients with severe heart failure and limited life expectancy, for those with repeated episodes of access thrombosis due to low blood pressure or hypercoagulability, and for patients in whom creation or maintenance of an av-access is difficult or impossible due to exhausted peripheral veins or due to severe peripheral arterial occlusive disease (PAOD) and in steal syndrome [5,16–21]. Before blindly following these recommendations (and thereby providing the majority of ESRF patients with...
CVC access for haemodialysis), one should perhaps look for possible vascular surgical alternatives.

**Children**

Creation of a peripheral AVF in children is no doubt a surgical challenge. The calibre of the vessels is small and they often lie beneath a relatively thick layer of subcutaneous tissue. Furthermore, they tend to respond to manipulation with severe vasospasm. All this poses specific problems to the surgeon. However, with adequate microsurgical techniques including the use of a microscope for optimal visualization, a tourniquet allowing for clamp-free ‘no-touch’ anastomoses, and eventual later superficialization of the access vein, excellent patency rates can be achieved even with peripheral radiocephalic AVF in children weighing <10 kg [22–26]. In children as in adults, AVFs have been shown to be more durable and reliable than grafts and CVC for haemodialysis [27–29].

**Elderly patients/limited life expectancy**

Worldwide the mean ages of incident and prevalent haemodialysis patients are rising [30–32]. In parallel these patients exhibit significant co-morbidity, e.g. diabetes mellitus, cardiac disease and PAOD. These factors reduce the survival of patients but also that of their accesses. Although often cited as an indication for CVC haemodialysis access, the term ‘limited life expectancy’ has never been defined, neither with respect to its degree nor with respect to its possible causes. Old age itself is a potential risk factor for AVF-associated complications and AVF failure [33,34], but in and by itself, it is not a sufficient reason for CVC implantation. When there are better alternatives there is no ethical justification for the generalised and uncontrolled use of catheters, which are known to shorten life expectancy. A closer look at each elderly patient’s individual risk profile is needed to identify and create the access, which is most suitable for the individual case.

**Diabetes mellitus**

The most frequent reason for reduced survival of ESRF patients is diabetes mellitus [35]. Even after adjustment for age and co-morbidity, the mean half-life of non-diabetic haemodialysis patients has been reported to be more than four times longer than that of diabetic patients [36]. In comparison with diabetic patients with an AVF, however, the mortality of diabetic patients with a CVC is further increased by 50% [8].

In terms of patient survival, AVF remains the ideal vascular access for diabetics. In many of them, however, a peripheral radiocephalic fistula will not mature, if the artery exhibits extensive medial calcification and has lost its capacity to dilate and undergo progressive remodelling. For these patients a more central AVF at the cubital fossa is a good alternative [20,33]. The risk that a steal syndrome develops in patients with an elbow fistula is 4-fold higher, however, compared with patients with a peripheral AVF [37]. The risk is also 10 times higher for diabetics when compared with non-diabetics [33]. In order to reduce the risk, it has been proposed that in diabetic patients the small perforating vein rather than the cephalic vein should be sutured to the brachial artery or to the proximal radial or ulnar artery [33].

Another problem often encountered in type 2 diabetic patients is obesity. In extreme cases, forearm and upper arm cephalic and basilic veins are so deeply buried in subcutaneous fat, that even after successful construction and sufficient maturation of an AVF, the fistula vein cannot be cannulated. Diverse surgical procedures have been published as alternatives for graft or catheter implantation. Both the forearm and the upper arm cephalic vein can be superficialized by resection of their overlaying fatty tissue. The upper arm basilic vein can be transposed from its subfascial and medial course to a more lateral and subcutaneous one [38,39].

**Cardiac failure**

In patients presenting with severe cardiac failure at the time of diagnosis of ESRF, obviously RRT will have to be started using CVC. After some weeks of haemodialysis, however, cardiac function should be re-evaluated to identify those patients in whom cardiac function has sufficiently improved to justify creation of a peripheral AVF.

When cardiac failure develops or deteriorates during the course of CRRT, high access flow may be one of the reasons [40]. If flow measurements reveal access flows far above the level needed for sufficient haemodialysis, flow reduction can be performed. Depending on location and configuration of the av-access, different techniques must be applied [41]. In case of a peripheral radiocephalic fistula, ligation of the artery proximal to the anastomosis (Figure 1) will reduce

![Fig. 1. Proximal artery ligation (X, ligation of radial artery proximal to high flow radiocephalic anastomosis (dotted circle)); with kind permission from P. D. Bourquelot.](https://academic.oup.com/ndt/article-abstract/18/6/1045/1852348/fig1)
access flow by $>50\%$, provided the ulnar artery and palmar arch both are patent. In elbow fistulae and grafts with the arterial anastomosis to the brachial artery, the anastomosis is closed. Implantation of an interposition graft from the forearm radial or ulnar artery to the access vein in the cubital fossa (distal arterial extension, Figure 2) leads to a reduction of access flow down to 40%. Banding reduction of the venous diameter was the method of choice previously, but for the following reasons this procedure rarely results in actual flow reduction: (i) intraoperative flowmetry is required but prior surgical dissection causes vasospasm and thereby measurements become inaccurate; (ii) there must be a considerable reduction (of $>80\%$) in vessel calibre; this can be achieved only with tight ligation or deep suture stitches. If not performed very precisely, recurrence of high flow or fistula thrombosis are the consequences [41].

**Central venous obstructions**

In patients with central venous obstruction, of course, CVC are not the solution but part of the problem. The frequency of catheter-associated central venous stenosis and occlusion is as high as 40–50% after cannulation of the subclavian vein [47–49], and may reach 75% after infection of the subclavian catheter [50]. Most of these obstructions do not cause any symptoms, because they develop slowly so that venous collaterals have time to dilate. However, when an av-access is created at a site distal to the obstruction, the resulting high blood flow taxes the collateral transport capacity and the arm begins to swell (Figures 3 and 4). Needling the access becomes more and more difficult and the risks of bleeding, haematoma and infection rise. Several treatment options exist for venous hypertension. Percutaneous dilatation of the stenosis (with or without stent implantation) is often successful and provides satisfactory results, at least for some period of time [51,52]. When interventional treatment failed or was impossible, veno-venous bypass surgery (Figure 5) can be considered [53,54]. In patients unfit for major

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**Difficult access**

There is a limited number of patients in whom the surgeon is afraid that an av-access is difficult to construct or problematic to preserve. This is especially true for patients with exhausted peripheral and obstructed central veins, with severe PAOD and steal syndrome, and with repeat access thromboses due to hypercoagulation or severe hypotension.

**Exhausted peripheral veins**

Successful creation of a functioning peripheral AVF in an adult requires an artery and a subcutaneous vein in its direct vicinity. The calibre of both vessels should be at least $1.5–2\, \text{mm}$. A central stenosis must be absent or corrected. Finally, the vein must be conveniently accessible in the subcutis over a distance of at least $10\, \text{cm}$ [42–45]. These prerequisites may be absent in small individuals, after multiple venous cannulations (for blood tests or infusions) or after preceding access operations.

In these patients, arterialization and superficialization of a subfascial vein (basilic [38,39] or even superficial femoral [46]) can be considered. When these veins are no longer suitable, implantation of an arteriovenous bridge graft is still possible.

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**Fig. 2.** Distal arterial extension (dotted line) from distal radial artery to cephalic/basilic vein after abandoning (X) brachiocephalic or brachiobasilic anastomosis; with kind permission from P. D. Bourquelot.

**Fig. 3.** Patient 1: massive swelling of left arm and breast in a 56-year-old female with a functioning brachiocephalic fistula created 5 years ago after multiple implantations of catheters into both subclavian veins.

**Fig. 4.** Patient 1: phlebography in DSA-technique after injection of contrast medium into the access vein demonstrates excessive venous collaterals around the upper chest due to complete occlusion of both innominate and subclavian veins. Only the central part of the superior vena cava above the right atrium has remained patent.
surgery, access ligation and construction of a new one on the other arm or in the thigh should be preferred.

Steal syndrome

Both diabetes mellitus and PAOD are risk factors for CVC-related bacteraemia, reduced catheter and patient survival [5]. On the other hand they are also risk factors for the development of a peripheral steal syndrome after successful creation of an an-access. In their large series of primary autologous fistulas, Konner et al. [33] reported seven events of ischaemia per 100 patient years in diabetics, but only 0.6 events in non-diabetic patients. In elbow fistulas, a steal syndrome was reported to occur four times more frequently than in wrist fistulas or in grafts [33,37]. A modification of surgical technique is believed to reduce the frequency of steal syndrome in elbow fistulae, i.e. suturing the tiny communicating vein rather than the cephalic or basilic vein either to the cubital artery or even to the proximal radial or ulnar artery [33]. The use of tapered or stepped grafts with an arterial anastomotic segment of small calibre has been proposed for patients at risk, when an autologous fistula cannot be constructed.

Peripheral arterial steal is a normal phenomenon in an-access for haemodialysis: in distal radiocephalic fistulae ~75% of the blood flow through the fistula comes from the proximal radial artery, but 25% comes from the distal radial artery through a patent ulnar artery and palmar arch [55]. In elbow fistulae the periarticular arterial collaterals serve the same purpose. Only in severe PAOD with greatly enhanced resistance of the forearm arteries and severely impaired function of natural collaterals, will a steal phenomenon deteriorate into a steal syndrome with pain at rest and with acral necrosis. Under these conditions, during diastole virtually all blood flowing in the collaterals is drained into the access [56]. The likelihood that a steal syndrome develops depends on the amount of intra-access blood flow but primarily on the extent of PAOD (Figures 6 and 7).

Of course, a steal syndrome will disappear when the access is abandoned, but a new access even on the other arm will also carry a significant risk that the problem returns. Formerly banding the access was the preferred treatment for a steal syndrome. Banding, however, can only be performed if the blood flow of the access is high. Banding a low-flow access will result in insufficient dialysis or even access thrombosis. As in cardiac failure resulting from high access flow, sufficient banding means that one has to suture the access at its anastomosis so as to reduce the lumen by 80% and thus creating a haemodynamically relevant stenosis. Combined intraoperative monitoring of both peripheral circulation (transcutaneous pO2-measurement) and access flow (duplex sonography) must be performed to make sure that the Scylla of persisting peripheral ischaemia as well as the Carybdis of insufficient access flow have been avoided [57,58]. Even when these prerequisites are met, banding reduces access patency rates, because fistulas and grafts are progressively more likely to clot as access flow decreases.

The only treatment option to correct a steal syndrome in a patient with low-flow access is the distal revascularization–interval ligation (DRIL) procedure [56], because access flow is not directly influenced. The artery distal to the access anastomosis is ligated. Thereby retrograde diastolic inflow into the fistula is...
stopped. This first part of the DRIL procedure is completely sufficient for the treatment of steal syndrome in distal radiocephalic fistulas as long as the ulnar artery and the palmar arch are patent thereby providing sufficient blood flow to the hand [60]. In elbow fistulas, a (vein) bypass is additionally implanted connecting the brachial artery above the anastomosis with the cubital artery distally to the ligation (Figure 8). Functioning vein valves in the graft or a reasonable distance (of >5 cm) between the proximal graft anastomosis and the access anastomosis prevent retrograde diastolic flow. The DRIL procedure results in immediate relief of signs and symptoms of steal syndrome in the great majority of patients and provides excellent long-term patency rates both for bypasses and accesses [56,59,61].

**Recurrent access thromboses**

Frequent thromboses of av-access for haemodialysis without underlying morphologic causes may be the result of hypercoagulability and episodes of severe hypotension [62,63]. Interestingly most of the patients with recurrent access thromboses due to a hypercoagulable state had synthetic grafts [63,64] possibly indicating that autologous av-access might be the better alternative for these patients. In patients with episodes of severe hypotension, a central av-access (brachial artery-transposed basilic vein fistula, subclavian artery-to-internal jugular vein bridge graft) has been recommended, because it is believed that the high flow of a central access will prevent its thrombosis [62,65].

**Conclusion**

There is a significant and still rising number of haemodialysis patients who pose serious problems of access creation and maintenance. Easy and quick implantation of a CVC seems to be an intriguing alternative to complex and time-consuming surgical procedures. The potentially deleterious side effects of CVC should be a sufficient reason, however, to avoid them whenever possible.

Untreatable cardiac failure, which does not improve despite efficient RRT, remains a valid indication for CVC implantation. In the majority of problematic patients (children and elderly diabetic patients, patients with recurrent access failure due to low blood pressure or hypercoagulability, patients with exhausted peripheral veins or severe PAOD and steal syndrome) it is usually possible to find surgical alternatives, which are better than CVC.

**Conflict of interest statement.** None declared.

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