Chapter

Vascular Access Management for Haemodialysis: A Value-Based Approach from NephroCare Experience

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Abstract

A good functioning vascular access (VA) is a prerequisite to obtain a successful dialysis treatment. This chapter reviews VA management in advanced chronic kidney disease (CKD) patients drawn from the experience of a large network dialysis care provider with the following sections: overview on VA management in advanced CKD that follows patient pathway and patient profile, current practice patterns in line with best clinical practices; VA creation addressing crucial themes: when and what type of VA to construct, how to assess patient pre-emptively, how to proceed for the construction and monitoring to prevent early failures and complications; VA management with particular focus on clinical monitoring, surveillance and interventional procedures required to preserve patency and functionality of VA; the often-forgotten patient perspective is VA usage. What information to share, how to proceed for preventing pain, and fears related with VA needling? What should patients know about their VA and how to manage in daily life? Competences, skills and responsibilities of nursing staff when using and managing VA; and future of VA in terms of innovative concept for creating and maintaining VA conduits in dialysis patients.

Keywords: haemodialysis, vascular access, vascular access centre, arteriovenous fistula, arteriovenous graft, central venous catheter, vascular access complications, best nursing practice, value-based haemodialysis

1. Background

VA is an essential component of the life-sustaining therapy in end stage kidney disease patients relying on a sustained extracorporeal circulation for haemodialysis (HD) or haemodiafiltration (HDF) [1, 2]. Indeed, VA is often referred to as the lifeline or Achilles heel for a dialysis-dependent patient [3]. VA performance is a key factor to drive success or failure in all forms of extracorporeal renal replacement treatment [4]. Furthermore, VA dysfunction or complication is the major cause of morbidity requiring interventional procedures (angioplasty and revision) or hospitalisation [4–6]. Furthermore, VA morbidity represents a tremendous burden both for patient and health care system [7, 8]. VA management in chronic kidney disease patient is of tremendous importance in quality care of dialysis patients, since it represents a daily duty for care givers in the nephrology area to ensure success of renal replacement therapy, to improve patient outcome and to reduce burden of VA morbidity [1, 9].

2. Overview on VA management in dialysis patients

2.1 VA types

VA for HD belongs to three main categories: (1) arteriovenous fistula (AVF) made of native or autologous vessel (aAVF) or heterologous vessel (hAVF) [10]; (2) arteriovenous graft (AVG) made of synthetic polymer or bioprosthesis; and (3) venous–venous access consisting mainly in tunnelled central venous catheter (tCVC) inserted preferably in the superior vena cava system [11]. A schematic representation of various VA types is in **Figures 1** and **2**. aAVF is still the preferred VA strongly recommended by best practice guidelines due to its long-term patency superiority, higher performances and fewer complications in majority of patients [11–13].

Several autologous AVF types have been developed to fit with patient anatomic and physiologic characteristics. Briefly, according to their location on the upper arms, they are categorised either as distal (wrist) or proximal (elbow or upper arm); according to the type of anastomosis, they are categorised as side to side anastomosis or artery side to vein end anastomosis [14, 15] or vein transposition [16].

If the end-stage kidney disease (ESKD) patient is not a suitable candidate for an AVF, the AVG is the second VA option. Compared to the AVF, the AVG has better mechanical strength, earlier use, decreased primary failure rates, development of graft stenosis, a fivefold increase in infection risk, a poorer long-term patency, higher levels of complications and more interventions than AVF [17]. AVG should be preferred over a CVC because of fewer complications and better survival rates [18]. AVG access is made usually of synthetic material (e.g., PTFE) or biomaterial and realise a conduit between artery and vein [17]. Recently, a new biologic human acellular vessel, as a potential solution to AVG disadvantages, has been evaluated with promising evidence [19]. Human acellular vessels were implanted

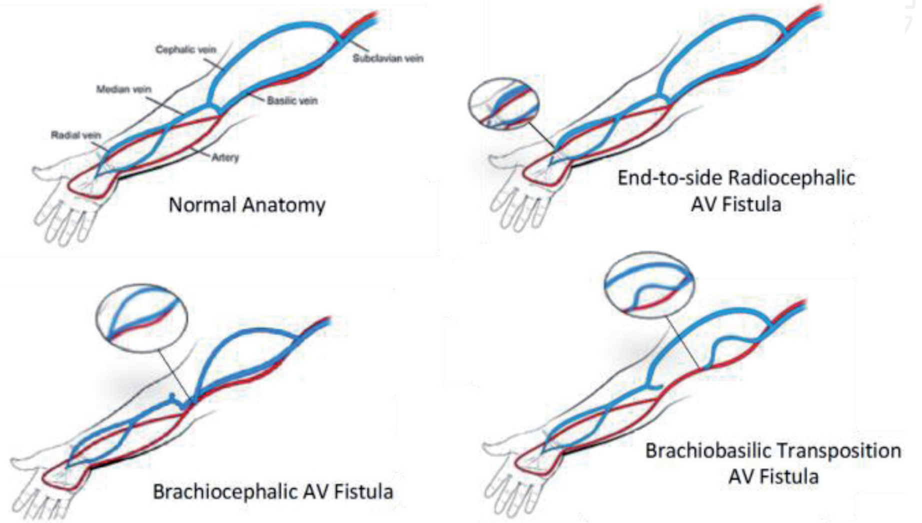

Figure 1.
Autologous AV fistula.

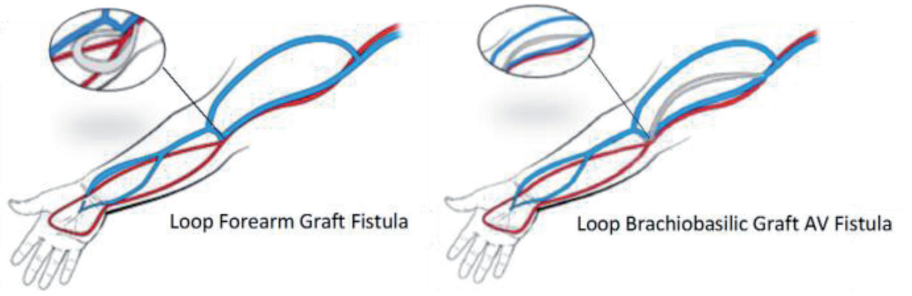

Figure 2.
Heterologous AV graft.

into 60 patients. The vessels had no dilatation and rarely had post-cannulation bleeding. At 12 months, 28% had primary patency, 38% had primary assisted patency and 89% had secondary patency [19]. AVG may be constructed either on the forearm as straight conduit (radial artery to cephalic vein), or as looped conduit (brachial artery to cephalic vein), or on the upper arm as straight conduit (brachial artery to axillary vein) or looped conduit (axillary artery to axillary vein). Less commonly AVG looped is created on the lower extremity (femoral artery to axillary vein) or as transthoracic conduit (axillary artery to contralateral axillary vein).

Although AVF is the preferred vascular access, double-lumen non-tunnelled catheter is the VA of choice when urgent or emergency HD is requested or when AVF/AVG becomes dysfunctional. Tunnelled dialysis catheters can be safely used as vascular access till the maturation of fistula and may be an alternative to arteriovenous fistula or graft for long-term VA if indicated. tCVC can be considered as permanent VA vein, in patients with recurrent access thrombosis, low blood pressure (cardiomyopathy), severe vascular disease ("steal" syndrome), trypanophobia (fear of needles), in case of premature exhaustion of veins needed for AVF creation and reduced life expectancy. Catheters are available in a variety of materials, configurations and tip designs, with the aim to maximise the blood flow, reducing recirculation preventing the catheter tip obstruction. There are well-established guidelines for selection of an insertion site for CVCs. The preferred site is the right internal jugular vein. In case, for different reasons, it is not possible to utilise the above vascular approach, and the second option is the left internal jugular vein. Other options are the subclavian veins keeping in mind the higher risk of subsequent stenosis or venous occlusion. The femoral vein for long-term CVC access should be avoided in patients waiting for kidney transplantation due the iliac vein risk stenosis.

2.2 VA prevalence

Interestingly, percentage of various VA types varies tremendously among HD population worldwide. Several factors contribute to heterogeneity of VA prevalent use and distribution that include dialysis vintage (incident vs. prevalent), age (young vs. old), gender (male vs. female), ethnicity, comorbidities (high vs. low risk), dialysis modality (HD vs. HDF) or dialysis setting (in centre vs. home or self-care).

Furthermore, it is of utmost importance noting that practice patterns have likely a strong impact on VA choice and prevalent use [20]. In other words, VA choice is not only driven by patient conditions or treatment modalities but also depends strongly on local or regional practice patterns including referral time to nephrologist, CKD patient management, care access, VA expertise and commitment, also patient choice. As an example, prevalence of AVFs in incident patients (<6 months) may vary from 20 to 80% from one country to another considering comparable patient profile, while the use of CVCs may vary from less than 5–80% in the same condition [20, 21]. Comparing VA repartition in prevalent patients, the same heterogeneous distribution holds true, with prevalence of 30% to over 90% of AVFs from one country to another with comparable patient profile [22, 23].

2.3 VA strategy planning

VA creation strategy planning is important to ensure best outcome to dialysis patients. It is now well established that careful clinical assessment and non-invasive vascular network mapping (US Doppler) facilitate VA construction and increase success rate [24–26]. Best practices emphasise and recommend such an approach to reduce failure rate and optimise VA creation, maturation and management [11, 12].

Early referral of advanced chronic kidney disease patient to nephrologist and to expert vascular surgeon may facilitate decision for VA choice and creation [27]. VA nurse coordinator has been shown to facilitate management of ESKD patients, to reduce CVCs use and to improve VA outcome in incident patients [28–30].

Few general rules for VA creation are recommended from best clinical practice guidelines: first, start with native AVF distal position at the non-dominant wrist and move proximally to the elbow in case of failure, second, favour artery side to vein-end anastomosis with reduced and fixed anastomosis diameter, third, consider using synthetic graft conduct in case of multiple failed attempts and fourth, tCVC might be a suitable option, in case of repeated VA attempt failures, in elderly patients, in patients with limited life time expectancy or as mid or long-term bridging solution to facilitate creation and maturation of AVF or AVG [12].

VA construction should be ideally performed within expert centres adequately staffed, imaging capacities and providing full clinical service to correct immediate or short-term VA dysfunction [31, 32].

2.4 VA performance and outcome

VA performance is crucial to ensure delivery of adequate renal replacement therapy. It relies on four main indicators: access flow, recirculation, pressure changes, and dialysis dose delivery. VA performance is more critical with short dialysis than in long or more frequent dialysis treatment schemes.

VA flow is the main parameter that drives dialysis session efficiency [4, 33]. Ideally, access flow with AVF or AVG should be higher than 500–600 ml/min to ensure extracorporeal blood flow of 350–400 ml/min. Choice of dual lumen tCVC should aim to achieve 350–400 ml/min blood flow on a regular basis [34].

In case of dialysis efficiency reduction due to VA dysfunction, that will be expressed by a Kt/V decline trend over time [35] (better if evaluated with online automated system and in continuous mode [36, 37]) and an increasing of serum potassium, phosphate, urea and creatinine levels. Dynamic pressure changes in vascular access either from venous or arterial side are reflecting VA dysfunction and suggesting a stenosis either on the distal vein or the proximal artery and impeding access flow reduction [38]. VA recirculation is usually very low and less than 1% with well-functioning AVF and AVG [39]. High recirculation (>10%) reflects VA dysfunction (e.g., stenosis of distal vein or proximal artery) and requires further investigation and intervention on VA if needed. It is important noting that tCVCs have by design and functional characteristics, higher recirculation than AVF or AVG. A well-functioning CVC has a recirculation closed to 10%, and higher recirculation is a strong signal of CVC dysfunction [34]. Recirculation is usually measured by dilution methods that sense either changes in US velocity

(Transonic) [33], electrical impedance, optical (CritLine), ionic dialysance change [40] or thermal changes (BTM) [41] with relative good concordance [42]. Fresenius Medical Care (FMC), Europe Middle East Africa (EMEA) and NephroCare (NC) clinics commonly apply the thermodilution measurements [43]. The thermodilution method makes it possible to determine the total blood recirculation with a non-invasive temperature bolus technique, and thus detect vascular problems that could reduce the efficacy of dialysis. This method can be used to assess both grafts/fistula and cardiopulmonary recirculation. In case the VA recirculation is confirmed the colour, Doppler US can provide an accurate anatomical and haemodynamic information, also measuring the access flow. This examination can be performed as part of a routine surveillance program, to detect early VA problems, or suspected dysfunction. However, limitations for its use are lack of staff and/or knowledge in the HD unit. Imaging techniques as the angiography and magnetic resonance flow measurements can allow a better definition of blood flow and stenosis visualising inside the vessel lumens.

In brief, reduced access flow, increased recirculation, low Kt/V and significant pressure changes are all indicating VA dysfunction that needs to be confirmed, explored and treated adequately [44].

A dedicated quality assurance program to VA monitoring and management is strongly recommended in dialysis facilities, as part of best clinical practices, to improve dialysis patient outcome [45] (see Section 4). VA outcome is usually best summarised by three hard clinical endpoints: functionality (e.g., maturation and access flow), technical survival (e.g. primary patency and secondary patency) and VA-related morbidity (e.g., dysfunction, infection and intervention) [46]. In brief, VA outcome depends on three groups of factors: first, patient medical profile (e.g., age, gender, comorbidity, diabetes and vascular calcification); second, VA type (e.g., autologous AVF and synthetic graft); third, practice patterns (e.g., creation skills, monitoring and maintenance) [47]. It is not our intent to review factors implicated in these outcomes but only to provide some brief trends and facts. Autologous AVFs have better survival than synthetic AVGs considering both primary and secondary-assisted patency [48–50]. Median technical survival with AVFs ranges between 3 and 10 years compared to AVGs which range between 1 and 4 years. Substantial loss of AVFs (10–30%) occurs shortly after creation due to thrombosis or poor maturation. Late stenosis or aneurysm may be observed with AVFs in long-term run depending on cannulation technique. Loss of AVGs occurs later due to stenosis in relation with myointimal hyperplasia in almost 90% of cases. Patency of AVGs requires tight monitoring and frequent restoring and maintaining procedural interventions (e.g., percutaneous angioplasty and stenting) [51]. Infection risk is about three times higher with AVGs. Intervention rate (e.g., angioplasty) to keep VA patency is 3–10 times higher with AVGs than AVFs in long run.

2.5 Complications in established VA

VA-related morbidity represents a tremendous burden for patient (pain, anxiety and depression) and healthcare system (hospitalisation, technical procedures and interventions and cost). VA-related problems represent a common cause of hospitalisation in dialysis patients accounting for 10–15% of cases [5].

VA complications vary according to VA type [52]. Arteriovenous accesses (AVF and AVG) are associated with less complications and risks as compared to tCVC [53]. AVF is still the "standard" for VA presenting significant less complications and longer survival patency than AVG [54].

Most common complications of recently created AVFs and AVGs are inadequate flow, failure to mature and thrombosis [55]. This aspect is further developed in the next section.

VA dysfunction in mature access requires further exploration and imaging (e.g., Doppler US, contrast media phlebography or arteriography and digital VA imaging) to identify the cause of poor flow or insufficient development. Based on the root cause analysis of the VA dysfunction, specific interventional procedures may be proposed. Usually they consist in percutaneous angioplasty with or without stenting. In the worst cases, surgical VA revision or new VA creation might be preferred.

Thrombosis occurs rarely as an unexpected event but usually follows and/or complicates an underlying stenosis of the distal or proximal vein or proximal artery [56]. This well-established fact reinforces the need for regular VA monitoring to correct pre-emptively this causal factor. Treatment of thrombosis requires urgent action by VA interventional expert consisting usually in a combination of thrombolytics and thrombectomy techniques [57–59]. After successful declotting, it is important to treat underlying stenosis by percutaneous balloon angioplasty to prevent thrombosis recurrence [60].

Aneurysms or more frequently false aneurysms may have developed on the vein segment of the VA either with AVFs or AVGs [61]. They result from repeated cannulation in the same area and high venous pressure. False aneurysms should be resected since they are exposed to further complications (e.g., infection and bleeding), and cause of high venous pressure (e.g., stenosis) should also be treated by balloon angioplasty.

Steal syndrome is a rare but painful and severe condition that needs to be treated adequately [62]. Steal syndrome results from retrograde blood flow after AV access creation, and a condition that diverts blood flow to proximal segment creates functional ischaemia in distal arm segment. It is more likely to be observed in severely arteriopathic and vascular calcified patients. Severity of steal syndrome is graded from minor (pale, blue and cold hand) to major (ischaemic pain, ulceration and necrosis of digits or hand). Treatment of steal syndrome consists usually in venous banding (high flow steal syndrome) or distal revascularisation and interval ligation (DRIL procedure) (normal flow steal syndrome). In worst cases, closing AVF or AVG would be considered as a safer option.

Infection of VA is not common in AVFs but more common in AVGs (2–3 times) and much more common (5–7 times) with tCVCs [63]. Infection results from specific risk of VA and chronic dialysis patient profile, but more likely from VA handling practices and hygienic rules of the dialysis facility [64].

Complications are associated with CVC placement (puncture of the associated artery, bleeding, major venous laceration, atrial perforation, pneumothorax and air embolism) and use (malfunction and limitation of dialysis performances, central vein stenosis or thrombosis and catheter infection) [65–67]. For patients who are treated with HD, the risks of major cardiovascular events, fatal and non-fatal infections and overall mortality are far greater with catheters than with AVF.

The NKF/DOQI guidelines define CVC dysfunction as the failure to attain a sufficient extracorporeal blood flow rate of ≥300 ml/min with a pre-pump arterial pressure lower than −250 mmHg [68]. Catheter dysfunction can lead to catheter thrombosis in the extreme. Early CVC dysfunction is defined as a catheter that never functioned adequately after placement and is mainly consequent to technical problems. Later, CVC dysfunction is related to partial or total catheter occlusions induced by intrinsic thrombus within the CVC, external fibrin sheath or extrinsic thrombus around the catheter in the vein leading to catheter adherence to the vessel wall or to the cardiac atrium. The majority of thrombi associated with CVC are asymptomatic. If the dialysis staff notices a decreasing Kt/V, an increasing level of serum potassium, phosphate, urea and creatinine and an increase of both negative arterial pressure and positive venous pressure during consecutive dialysis sessions, a CVC dysfunction could be suspected. If thrombosis involves the catheter tip, it may not be possible to withdraw blood and/or to infuse fluids and there may be leaking at the access site. In general, symptoms vary from local tenderness or pain at the site of entry to obstructive symptoms with swelling of the ipsilateral extremity, neck or face. Atrial thrombi may become symptomatic, with pulmonary or systemic (paradoxical) embolism or catheter dysfunction, or may be incidentally found as an atrial mass. In the experience of the authors of various studies, many patients who undergo an echocardiogram bring equivocal reports describing valve vegetation vs. tip catheters thrombi [69–71].

3. Vascular access creation and maintenance

3.1 Vascular access choice: selection bias

Whenever a native AVF can be created and is able to mature in no more than 12 weeks, it is considered the first and best choice as a VA [72]. Higher long-term longevity, less thrombotic or infectious morbidity, needs less procedure for maintenance. Overall a native AVF is big life and money saver.

The optimal VA is one that enables an adequate dialysis treatment, for as long as needed, keeping in mind that ultimately the natural history of a VA is failure. Its characteristics are a good blood inflow through the feeding artery, and an access flow (Qa) > 600 ml/min, without recirculation. It must be superficial (<0.6 cm skin deep), have a thick wall, a long straight segment to allow two needle punctures 2.5 cm away, a diameter > 0.6 cm, a good venous outflow, without causing distal ischemia in that limb.

That perception lead health authorities, some agencies and big provider chains to influence access choice through incentives and performance indicators, as if it was a black & white issue. In fact, AVF should not be always first and CVC are not always last. VA type comprises two of the nine quality metrics in the US CMS's five star rating of dialysis facilities a Quality Incentives Program (QIP) that rewards high AVF prevalence and penalises CVCs, without regard to patient case-mix.

There has never been a RCT comparing different VA choices regarding mortality or other hard outcomes. All large observational trials compared accesses achieved as opposed to the accesses that were intended (as in intention to treat). As 30–60% of all AVFs created either fail or need several procedures to mature and the CVC group in most studies were people in whom AVF failed, or CVC was chosen because of a predictable bad prognosis (old age, congestive heart failure, short life expectancy...), then we really cannot answer the question on which VA is the best or correlate it with hard outcomes [73]. If we exclude patients that begin HD urgently, mortality between AVF and CVC patients become identical [73].

VA is only one example of the paradox between patient-centred care and the tyranny of quality metrics based on population studies. Reconciling this paradox is what clinical judgement is all about and why physicians cannot be replaced by algorithms, care paths or protocol-driven medicine [74].

The native AVF comes with its own set of disadvantages. There is a higher risk of primary failure (non-maturation), up to 60% failing prior to ever being cannulated, angiographic procedures frequently required to assist maturation. Attempt to maximise fistula use by increasing creation rates has led to the unintended consequence of higher primary failure rate and longer dependency on catheters [75, 76].

Studies have shown that the primary failure rate is two times greater for fistulas (40%) than AVG (19%), with similar cumulative patency, in addition, the number of catheter days before AV access use was more than double in those having a fistula (81 days) compared with AVGs (38 days). However, grafts require more angioplasties (1.4 vs. 3.2 events) and thrombolysis (0.05 vs. 0.98 events) interventions per 1000 patient-days [76, 77]. The risk of primary fistula failure is much higher for lower arm fistula (28%) than with upper arm fistula (20%) [75].

According to the EDTA Registry, there is a trend for decreasing AVF in incident patients from 42% in 2005 to 32% in 2009, while there was an increment in CVCs from 58 to 68% (80% in the USA), with large international variation. In prevalent patients, AVFs went from 66 to 62% and CVCs from 28 to 32% [23, 78]. In a recent meta-analysis, CVCs (compared with AVF) have a higher risk of all-cause mortality (RR 1.53), fatal infection (RR 2.1), and cardiovascular events (RR 1.48) [18]. Grafts need twice as many angioplasties (1.4 vs. 3.2 events/1000 acc. days) than AVF, more thrombolysis (0.06 vs. 0.98 events/1000 acc. days). Although they need more procedures, their cumulative patency is the same when primary AVF failure is factored in [79].

Applying a proportional hazard model to examine mortality in incident HD pts aged 65–90 years old in association with the type of VA, but accounting for case-mix and health status, the RR of AVF is 1.0, graft 1.18, CVC transformed in AVF 1.2, CVC transformed in a Graft 1.38 and CVC permanently 1.54 (both adjustments reduce RR in CVCs of 44%) [80].

Using a decision analysis model (fed with data extracted from DOPPS 2, the REDUCE FTM study, the DAC study and CMS data) of the best option for patients initiating HD with a CVC, an AVF attempt strategy is associated with better survival and lower annual cost, but that advantage is progressively lost in patients above 60 years or diabetics [81]. The advantages of an AVF attempt strategy lessened considerably among older patients, particularly women with diabetes, reflecting the lower fistula success rates and lower life expectancy.

Although upper-arm fistulas have a greater chance of maturation, the loss of multiple lower-arm possibilities will sooner exhaust VA sites. Also, the upper-arm option exposes patients to higher frequency of steal syndrome, potential adverse long-term complications of high-flow AVF on cardiac function and an incidence of cephalic arch stenosis that is dramatically higher when compared with the forearm choice [82].

According to data from CMS, the first year cost in the common scenario of patients initiating haemodialysis with a CVC, the annual cost of access-related procedures and complications is higher in patients who initially receive an AVF vs. an AVG. In their first year, the average annual cost of an AVF is $10,642 vs. $6810 in an AVG. The CVC group had the highest median annual access-related cost of $28,709 largely attributed to high frequency hospitalisations due to bacteraemia, repeated use of thrombolytics, and frequent catheter replacement [83].

3.2 Timing of referral for vascular access surgery

It is consensual that once established, a native AVF is the preferred HD access, and all guidelines recommend placement of an AV access before dialysis initiation; however, that desideratum is achieved only in less than one third of all incident patients [84]. If we create it too early, the access may need extra procedures to keep its patency until dialysis initiation and many more CKD stages 4 and 5 patients will die of cardiovascular events than those who will progress to end-stage renal failure needing dialysis, and on the other hand, if we do it too late more than 60% of all patients will begin their treatment through CVC, without time for full maturation of their AV access [85].

Hod examined the optimal timing of incident fistula placement in a population of elderly patients above 66 years old, showing that the odds ratio for successful fistula use was maximised when surgery was performed 6–9 months before dialysis was needed, with worst results in obese females, in diabetics and patients with congestive heart failure [86]. Unfortunately, even when a patient is being monitored in clinic by a nephrologist, the rate of progression of CKD to ESRF is not constant, the need for dialysis can be precipitated by random, unexpected clinical events and the correlation between measurements of renal function and uraemic clinical symptoms are poor; therefore, it may be quite difficult to plan the best timing. The best strategy would be to develop techniques that speed fistula maturation below 2 months' time after surgical creation, what would make planning much easier and accurate [87]. Despite the tremendous heterogeneity in the decline of kidney function in stage 5 CKD patients, factoring in the presence of diabetes, the degree of proteinuria and the eGFR trajectory in the preceding year, significantly improved our prediction capability of dialysis commencement [88].

3.3 Access creation and early complications

Access malfunction is a source of tremendous emotional and physical suffering, dialysis treatments loss, low treatment adequacy, urgent need for a central catheter as a substitution access and referral for new angiography or surgical procedures.

The most common first VA complications include haemorrhage, usually at the sutures level, infection, revealed in the first 15 days, local pain/inflammation, failure to mature producing poor dialysis adequacy and early thrombosis. Non-maturation and thrombosis, both have as an underlying mechanism the development of early stenosis along the arterial inflow, in the VA itself or in the access outflow.

Stenosis is necessary for thrombosis, but it is not enough. Only 30% of stenosis above 50% of lumen compromise will cause thrombosis in the next 6 months, we just do not know which ones [89], and on the other hand, stenosis treatment based on morphology, percutaneous angioplasty, induces accelerated neointimal hyperplasia with recurrent stenosis [90]. In 20% of all cases, recurrent stenosis occurs in 1-week post-procedure and 40% in 1 month [51].

We define VA maturation by our capability to cannulate it with two needles and deliver a minimum blood flow to the extracorporeal circuit of 350 ml/min for the whole dialysis, 4 months after its creation, for a minimum of eight dialysis in 1 month [91].

Immediately after fistula creation, the blood flow increases from an average of approximately 20 ml/min in the radial artery to as much as 300 ml/min in a radio-cephalic fistula, 1 week later the mean blood flow rate increases further to an average of 540 ml/min and the mean shear stress from 5 to 10 dyne/cm^2 to 24.5 dyne/cm^2. Ultimately, the increase in flow in a well-developed fistula can reach 600–1200 ml/min [2].

The functional ability of the artery and vein to dilate and achieve a rapid increase in blood flow are the most important determinants of fistula maturation [92] and declared that success correlated much better with Qa one day after surgery than with preoperative vessel diameter [91]. Increased shear stress sensed by the endothelium, related directly with flow rate and inversely with vessel radius, initiates the vascular response and secretion of vasodilators and anti-inflammatory mediators, to reduce neointimal hyperplasia and lower shear stress back toward baseline levels.

At the pathogenic level, the stenosis seems to be caused by a combination of neointimal hyperplasia and an inadequate outward or positive remodelling [93]. The abundant presence of myofibroblasts within the neointima is consistent with a role for the adventitia as a source of cells for neointimal proliferation. New biologic interventions, delivered periadventitial during surgery may old promise in preventing fistula maturation failure [92, 94].

3.4 Prevention of early complications

The process of care to maximise AVF includes: (a) early referral to a nephrologist; (b) patient and hospital staff education to save peripheral veins, avoiding peripheral as well as central I.V. lines (in our experience, 75% of all patients in a renal ward have an I.V. line in the cephalic vein), as well as transvenous implantation of pace-makers to be substituted by epicardial leads; and (c) timely referral to the right surgeon (well trained and experienced in obtaining VAs), that will probably order, or preferably will do it himself a pre-operative vascular mapping. Remind him to avoid grafts, but, if no other choice, do not save in their length and that an AVF do not always have to be distal [95].

Preoperative physical examination provides essential information in patients needing AVF construction but is rarely sufficient nowadays because an increasing proportion of HD patients has a compromised vasculature, the result of age, diabetes, many years of dialysis therapy and prior HD catheters. Non-invasive assessment by duplex sonography is very helpful in locating veins that are not clinically visible and also provides information about their functional characteristics, including venous outflow. Duplex sonography is the method of choice for evaluation of arteries. A calcified artery with a small lumen and thickened wall will never provide adequate fistula function [96].

Vascular mapping (**Figure 3**) is a technique that leads to information on patient's inflow and outflow anatomy as they relate to arteriovenous access creation. It can be done by using US evaluation, or angiographic mapping, both have pros and cons, the choice depends on local expertise and availability.

The US scanner should allow examination with B-mode and Doppler mode, using linear array probes with a frequency of 7 MHz for B-mode and 5 MHz for Doppler. Patients more likely to benefit from pre-operative US evaluation are those with: (a) difficult clinical examination (obese, absent pulses and multiple previous access surgery); (b) possible arterial disease (older age, diabetics and cardiovascular disease); and (c) venous disease (previous cannulation) [97]. Doppler US has a distinct advantage of being a non-invasive modality that can evaluate both structural and functional aspects of vessels that play a key role in access maturation [98].

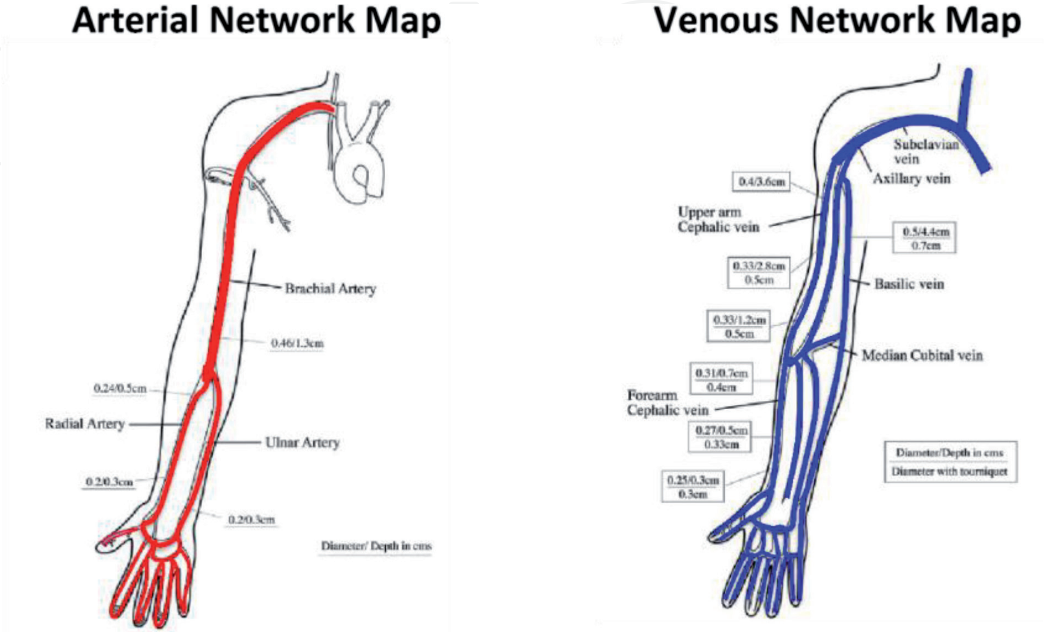

Figure 3.
Vascular network mapping: arterial map and venous map.

Preoperative mapping in some settings leads to marked increase in placement of AVF and a reduction in the use of catheters [24, 99]. Comparing pre-op US Doppler with physical examination, there was a dramatic increase in AVF creation 64 vs. 34% [24], reduction in graft placement from 62 to 30% and in tunnelled catheters insertion 24–7% [99]. Those were not universal findings, though.

The success rate of fistula formation does not correlate with vessel diameter but with flow, mainly in the day after [92], and in some series, a preoperative Doppler US achieved 80% successful constructed AVFs. Average parameters in this success cases: artery internal diameter 2.6 mm (vs. 1.6), Qa 54.5 ml/min (vs. 24.1), and resistive index 0.5 (vs. 0.7). Risk of primary failure is much higher for lower arm fistula, and long-term patency is not better, increase in vein ID after compression 59% (vs. 12.4) and Qa increased to 300 ml/min in 1 week (vs. 4–8 weeks) [100].

There is no systematic evidence that preoperative US mapping will induce an increase in the proportion of fistulas ultimately used for dialysis or a reduction in catheter use. It appears that the results from vessel mapping only influenced the decision as to the type or location of the AV access in surgeons with less than 15 years of experience [101]. In patients with pre-operative vascular mapping, on multiple variable logistic regression, factors associated with failure to mature were female gender, age > 65 years and forearm location (up to 78% if the three criteria were met), and the extracted mapping hemodynamic measurements could not differentiate patients with mature or immature forearm fistulas [102].

There is clearly more to maturation than vessel diameter, non-anatomic factors likely to contribute to maturation failure include the underlying vascular pathology and impaired endothelial function associated with CKD, vein trauma from surgical manipulation and the haemodynamic stresses resulting from the creation of an AV anastomosis [94]. Preoperative duplex US scanning and venography increased first fistula creation rate from 66 to 83%, but maturation rates actually declined from 73 to 57%, probably due to basing decision mostly on the vessels diameter [103].

4. Best VA outcome: role of a vascular access centre: quality assurance process

Dialysis VA outcome relies on three main components: support of a referent vascular access centre (VAC) providing expertise and service 24/7/365 per year; implementation of a quality assurance process optimising use of VA; commitment and skills of trained nursing staff ensuring best use and management of VA. This last part will be addressed more specifically in the nurse perspective section.

4.1 The vascular access centre in a dialysis network

A VAC is a dedicated department specifically designed and equipped to deal with VA dysfunction. Its goals are to provide easy access in less than 24 hours to an experienced VA surgeon or interventional nephrologist, to increase the prevalent number of patients dialysed through native arteriovenous fistulas (AV fistulas) and above all to reduce the number of patients requiring a catheter as a transient or permanent VA. Place and role of VAC are summarised in **Figure 4**.

The structure of a VAC is very similar to an ambulatory surgical unit, with continuous service from 9:00 am to 9:00 pm, 5 days a week, with a standard operating room and angiography suit functioning side by side, staffed by VA expert surgeons and interventional nephrologists. The perfect setup for a multidisciplinary approach to VA care is in a constant dialogue between surgeons and nephrologists.

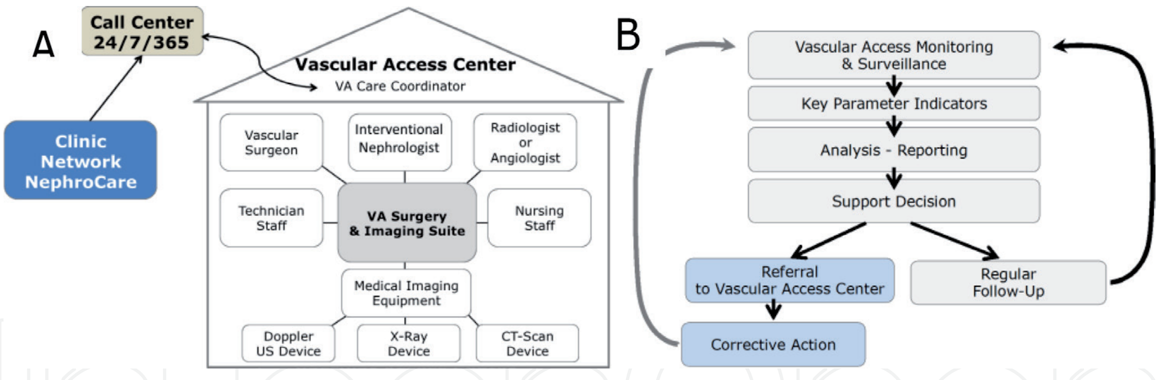

Figure 4.
(A) Place of VAC in clinic network organisation; (B) role of VAC in coordinating VA care.

The equipment should include a portable C-arm with capability for digital subtraction and road mapping, US equipment for central vein access localisation and puncture, pre-procedure patients´ triage and procedure planning, sterilisation facilities and a common recovery room for both disciplines. Supplies are tailored to operator preferences, within economic considerations [31, 32]. The VAC must be licenced by the health authorities, and their physicians credentialed to perform the needed techniques.

In our network, we manage around 5000 HD patients, treated in 37 dialysis units evenly covering the whole country, serviced by two freestanding ambulatory VACs and connected by a paperless dedicated software (VAonline©), a computerised database that handles dialysis unit referrals, reporting from the VAC back to the units and a permanent registry of our clinical activity used for research and administrative purposes. It connects and extracts data from the main network database (EuCliD).

Referrals to the VA are decided at the discretion of the attending nephrologist in the dialysis unit, and on arrival to the VAC patients are assessed to confirm referral correctness. Referral indications to the surgical pole of our VAC include: (a) construction and revision of AV fistulas or grafts; (b) exudative infection of the VA; (c) distal ischaemia of the access limb; (d) actively growing aneurysms; (e) haemorrhage or rupture of the VA; and (f) native AF thrombosis.

Referral indications to the angiography suite include: (a) graft thrombosis; (b) growing oedema of the access limb; (c) pain in the access limb during treatment; (d) unexplained reduction of dialysis adequacy (Kt/V) and/or VA flow (Qa drop < 600 ml/min in a graft, or < 400 ml/min in a native AV fistula confirmed in a second measurement); (e) SVC syndrome; and (f) native AV fistula non-maturation. Local bylaws require that all central venous catheters be implanted in hospitals.

Techniques performed in the operating room include: (a) construction or revision of native AV fistulas and grafts; (b) basilic vein transposition; (c) surgical treatment of VA infection; and (d) surgical treatment of ischemia or aneurysms of the VA limb. Techniques performed in the angiography suite include: (a) diagnostic angiography (mapping not achieved with ultrasound); (b) stenosis A=angioplasty; (c) pharmacomechanic thrombolysis; and (d) VA stenting.

In our series, with around 3000 interventions per year in both VACs, the most common referral cause is by far a drop in Qa in 61.2% of all causes, meaning that a VA surveillance program like ours, using daily physical examination by trained dialysis nurses and monthly measurement of Qa in the dialysis unit, although of controversial benefit, will have a major impact in the workload of the VAC and in the costs of the whole operation.

The most common site of stenosis, requiring intervention, was in the access itself in 31% of all cases, graft venous anastomosis in 29%, in the cephalic arch with

9.9% and the swing segment of the native AV fistula (the proximal segment immediately after the AV anastomosis) in 9.1%.

The most common procedures in the angiography suite were isolated balloon angioplasty in 67.5% of all cases, thrombolysis + angioplasty in 14.3% (depending on the graft prevalence in each region) and 10.1% did not need any endovascular intervention (false positive referrals). We decrease the implantation of stents, extremely expensive and not suitable for reintervention once suffering a stenosis recurrence, to less than 0.5% of all procedures, substituted in the same indications by drug eluting balloons. We were not successful accomplishing needed endovascular treatment in 7.1% of all cases.

Like the experience of others [104], in our centres, the procedures profile changed in the last years from a majority of interventions in grafts (angioplasties and thrombectomies) to one characterised primarily by angioplasties performed on AV fistulas. The number of interventional procedures did not decrease, and it was just the referral pattern and the percutaneous intervention required that changed in parallel with the increasing AV fistulas utilisation in prevalent patients.

A VAC needs a quality assurance program, to continuously monitor its performance. In our network, we use: (a) in first accesses an AVF construction in 80% of all cases; (b) in subsequent VAs 60% of AVF; (c) primary AVF failure at 3 months in less than 40% of all cases; (d) percentage of function VAs 7 days post-thrombolysis > 75% and at 3 months > 50%; and (e) absence of VA infection 15 days post-intervention. We also monitor the dialysis unit, requiring less than 1 referral to the VAC per patient year. We closely follow our success and complication rate according to international standards [105, 106].

In our experience, the major achievements of a VAC in our network are a substantial reduction in the waiting time for urgent procedures (28% of all referrals) to the same day response (elective referrals 4–6 days), the clear improvement of training and education of physicians and nurses in the dialysis units, now generating 0.3 surgeries/pt.Year, 0.37 angiographies/pt.Year, a precipitously drop of prevalent patients being dialysed through a tunnelled catheter from 24 to 14% and the total disappearance from our units of transient catheters. VA-related hospital admissions went from 1.3 to 0.6 episodes/pt.Year and they were 20% of all admissions and are now less than 10%. Our numbers compare favourably with the experience of others [107].

So, the question is, do we need a VAC for our dialysis patients? It depends on how good and how prompt is VA care offered in your region, if you are working in a capitated system, as in our case, is VA management included in the care bundle, are you mainly serving your own patients, raising the quality and coordination of care they previously received, or is there a market for you to sell a service outside your network. Do dialysis units in your area implemented a VA surveillance program, and in that case, do we intend to act pre-emptively to correct apparent malfunction?

To turn it into a success, it is important to monitor and influence the process of care delivered in our VAC, avoiding futile procedures such as AV fistulas that will never mature, diagnostic angiographies not needing therapeutic intervention (false positive referrals), useless angioplasties that will only accelerate more severe recurrences, or short-lived thrombolysis. It is imperative that we reach a consensus on how to define success and reward it (is it Δ Qa, Kt/V improvement, recurrence rate?). It is also of utmost importance to establish an accredited program for training young surgeons and nephrologists in VA care to guarantee future expertise in this field [108].

If we manage to be responsible for the full cycle of VA care, without sharing responsibilities with other providers, we may expect to keep costs control below the reimbursement rate, reduce the hospitalisation rate due to VA morbidity and limit the number of dialysis treatments lost. Reducing the number of patients with catheters we will avoid morbidity due inadequate dialysis, and the extra costs of supplies for in-treatment catheter handling as well the cost of thrombolytics to treat recurrent catheter obstruction and antibiotics to treat frequent catheter infections.

In the U.S. to break even a VAC in their current reimbursement environment, requires at least 800 patients, I suspect we would need a larger patient base in Europe; however, the feasibility of a VAC is quite variable and depends on unique payment structure in different geographic locations, specific needs of the patient population being covered and the availability of trained operators.

4.2 Quality assurance process

Patients with ESKD are fragile and vulnerable. For those who depend on HD, the ongoing success requires access to blood vessels capable of providing high volume extracorporeal blood flow to execute efficient HD treatments. Indeed, a properly functioning and reliable VA is one of the key successes of the HD adequacy. Unfortunately, the vascular access for HD continues to be referred to as the "Achilles Heel" of the HD procedure. Complications have a negative effect on the quality of life and continue to be a leading cause for morbidity and mortality of ESKD patients, with dysfunction being a major cause of morbidity and mortality in HD patients [109, 110].

VA options for HD include the placement of endogenous AVF, AVG and tCVC. The AVF is the preferred choice for chronic HD VA, rather than AVG and CVC, due the better outcomes (morbidity and mortality) and lower need for interventions and complications that could reduce both efficiency and efficacy of HD treatments which also increase the overall HD costs [111–114]. The selection of access should be individualised based on life expectancy and comorbidities and in consultation with a vascular surgeon with experience in the creation of HD VA. However, AVF is not always the ideal VA choice for certain ESKD patient categories such as the elderly: for those patients, the selection of VA should be individualised based on life expectancy and comorbidities. AVF, AVG and CVC are all used in older patients for permanent VA.

The HD VA long patency depends on several factors and minimises its complications, and failure has high priority in dialysis therapy and is a significant challenge for nephrologist, nurse and surgeon. The multidisciplinary team approach with agreement on a common set of targets [115], the surgeon experience [116] and adopting specific prevention measures such as, time referral for surgery with preliminary vascular mapping, specific VA surveillance strategies, AVF and AVG cannulation techniques with specific hygiene procedures are mandatory measures to prevent the VA both early and late failure or complications such as stenosis, thrombosis and infection.

The first challenge is the time referral to the vascular surgeon allowing to the AVF to mature adequately (1–6 months) and to be used for HD, remaining useable for many years with minimal intervention. Early referral of patients with CKD is strongly recommended. This approach helps to preserve access sites and provides adequate time for planning the creation and allowing maturation of the VA [68]. The most experienced surgeon of the HD vascular access team should be responsible, or supervise the AVF creation. Fassiadis [117] demonstrated that the primary success and primary and secondary patency rates of a series of consecutive radio-cephalic fistulae were affected by the experience of the surgeon. The risk of AVF primary failure related to ESKD patient increasing age, gender (female) and comorbidities (cardiac disease, pulmonary disease, peripheral arterial disease, diabetes and obesity) should be improved by careful patient evaluation and vascular mapping prior AVF creation. Patient evaluation (medical history and physical examination) and preoperative mapping of arm vessels allow a higher percentage AVF placements as well as an increased fistula success rate [24, 118]. Physical and US examination are intended to evaluate both the arterial and the venous system: vascular lesions, classified as inflow or outflow problems, should be identified allowing the surgeon the best AVF option protecting as much possible the arm vessel paucity for native AVF. The goals of the arterial evaluation are to find an artery capable of delivering the blood flow at rate to allow the HD treatment correctly. The axillary, brachial, radial and ulnar pulses should be examined as well as the blood pressure between the two arms to assure that the vessels are patent. By modified duplex Allen test is evaluated the hand arterial blood circulation if the radial or the ulnar arteries will be utilised in the AVF creation. The artery used must be of sufficient size (diameter > 2 mm) [119]. A forearm cephalic vein AVF (radial artery–cephalic vein) (brachial artery–cephalic vein) is preferred. The entire extent of the vein, its drainage, the diameter, depth and assessment of the ability to dilate should be assessed. The upper arm cephalic vein AVF (brachial artery–cephalic vein) is evaluated in case no suitable vein is found in the forearm. The non-dominant forearm is preferable for dialysis access placement, and the first choice used is the radio-cephalic AVF [111]. In case the first choice is not available, the other options from the most to least desirable are the following [113]: (a) dominant forearm radio-cephalic AVF; (b) non-dominant, or dominant upper arm brachiocephalic AVF; (c) non-dominant or dominant upper arm Brachiobasilic vein transposition AVF; (d) forearm loop graft rate; (e) upper arm straight graft; and (f) upper arm loop graft (axillary artery to axillary vein).

After AVF creation immediate thrombosis, failing to mature, or early fistula failure, may develop [120], and after the maturation late failure and other complications can occur [120]. VA monitoring and surveillance are crucial to ensure best outcome of VA and success to renal replacement program [121–123]. The AVF monitoring and the early identification of complications contribute to maintain the long-term patency of the AVF. Once the HD treatment is started, skilled nurses should evaluate the VA at each dialysis session. VA monitoring is performed on a regular basis synchronised with dialysis sessions to detect early dysfunction or complication. A routinely weekly physical examination of mature AVF is recommended by 2006 National Kidney Foundation Kidney Disease Outcomes Quality Initiative (NKF-KDOQI) guidelines and 2008 Society for Vascular Surgery [68, 119]. The nurse should inform the nephrologist in case of abnormal noise intensity [12], oedema, redness, swelling, bruising, haematoma, rash or break in skin, bleeding, other exudate, aneurysm or pseudo-aneurysm. The AVF blood flow is in the range of 800–2000 mL, and the thrill is associated with a blood flow >450 ml/min: in case the patient notices that the pulse or the thrill is reduced or it cannot be felt he/she should immediately inform the clinical staff. Patients should be instructed to keep the access extremity clean and to avoid wearing any cloths or wristwatches that restrict flow.

VA surveillance is intended to assess objectively and to follow over time VA performance and dialysis treatment delivery efficacy. It requires specific non-invasive tests and special instruments. Three main key parameter indicators are usually monitored: effective dialysis dose delivered, recirculation of VA [124, 125] and VA flow.

Time trend behaviour monitoring of VA performance based on selected indicators is crucial to detect early VA dysfunction (e.g., stenosis). Pre-emptive intervention has been shown very effective in correcting stenosis (percutaneous angioplasty) and preventing further risk of thrombosis and dysfunction. Precise knowledge of individual VA performances, threshold values (e.g., access flow

500–600 ml/min) and time trend analyses are required to optimise and personalise VA maintenance strategy [126, 127].

Time of first use or first cannulation varies according to VA type, maturation degree and local expertise: native AVF may be cannulated within 4–8 weeks after creation; AVG may be cannulated earlier 2–6 weeks; tunnelled CVC may be used immediately after insertion. Timing of VA cannulation (early <2 weeks or late >3–4 weeks) does not seem to impact VA outcome, and this is a particular feature of dialysis policy units [128].

The correct cannulation technique is mandatory for preventing AVF injury that might cause infiltration/haematoma or intimal damage with subsequent stenosis that might lead AVF thrombosis. Recommendations for the AVF cannulation procedures are few and mainly focused on needle size, angle of needle insertion and direction of needle bevel. Experienced dialysis staff only should be allowed to cannulate a newly created fistula. For first cannulations, local anaesthesia performed with topic anaesthetic cream or patch (Emla) is recommended [129].

In FMC EMEA NC clinics, the following cannulation procedures are applied [43]. The arterial needle should be placed in the direction of the blood flow and bevel down, but in case of anatomical restrictions, the needle is placed against blood flow and bevel up. The venous needle is always placed in the direction of the blood flow. The needle should be inserted at an angle of 20–35°, and when flashback is observed, the needle should be lowered and advanced into the centre of the vessel. Sites on the AVF which display evidence of aneurysm formation should be avoided. In mature AVF, 15- or 14-G needles are needed to support a blood flow rate of >350 ml/min needed for high efficiency dialysis or convective treatments. In 2006, NKF KDOQI guidelines recommended the use of arterial needles with a back-eye, to reduce the need for flipping or twisting the needle [68]. Parisotto showed in a cohort of 7058 patients from nine countries, that area cannulation technique (repeated cannulations concentrated over a small vessel area (2–3 cm)) was associated with a significantly higher risk of access failure than rope-ladder or buttonhole. Retrograde direction of the arterial needle with bevel down was also associated with an increased failure risk [130]. Moreover, patient application of pressure during cannulation appeared more favourable for VA longevity than not applying pressure or using a tourniquet [130].

The buttonhole needling is postulated to be associated with a reduction in haematoma and might increase long-term survival of AVF with less complication. The buttonhole technique is a cannulation method where the AVF is cannulated in the exact same spot, at the same angle and depth of penetration every time [131–134]. By using the exact same spot, a scar tissue tunnel track will be created. The procedure should be performed by the same cannulator until the track tunnel has been created. After track creation, this technique should always be performed by highly experienced staff. Using a sharp needle, it takes approximately 6–12 cannulations (depending on the individual patient) to create a track at a given site. The creation of a scar tissue tunnel track allows the use of a blunt needle [43].

The needle removal procedure is as important as the cannulation. Needle withdrawal must be done carefully in order to prevent tearing of the vessel, to minimise access trauma and to achieve optimal haemostasis. Each needle should be withdrawn slowly, keeping the same angle as that of insertion, until the entire needle has been removed. Digital pressure should be applied only after the needle is completely removed to prevent damage to the vessel wall and should be sufficient to stop bleeding but not so great as to stop the flow of blood through the VA [43, 135].

Cannulation and needle removal techniques are similar in patients with either AVF or AVG with the exception of the buttonhole technique that cannot be utilised to cannulate the AVG. It is suggested to avoid "flip" or rotate the bevel of the needle 180°. Flipping can lead to stretching of the needle insertion site, which can cause bleeding from the needle site and oozing, during dialysis treatment and can damage the graft [135].

Some medications, including statins, antiplatelet agents, anticoagulants, and dipyridamole have been reported to potentially affect VA outcome. Saran evaluated the association between VA failure and the use of specific drugs [136]. Calcium channel blockers improved the primary graft patency (relative risk [RR] for failure, 0.86; $P = 0.034$). Aspirin therapy was associated with better secondary graft patency (RR, 0.70; $P < 0.001$). Treatment with angiotensin-converting enzyme inhibitors was associated with significantly better secondary fistula patency (RR, 0.56; $P = 0.010$). Patients administered warfarin showed worse primary graft patency (RR, 1.33; $P = 0.037$). Statin treatment could be associated with reduced neointimal proliferation, vascular inflammation, and improved AVF dysfunction [137–139]. A Cochrane review reported that antiplatelet treatment can improve the 1-month patency rates of AVFs and AVGs [140]. Dipyridamole demonstrated to reduce ePTFE graft occlusion reducing the vascular smooth muscle proliferation and the neointimal hyperplasia [141].

Infection is the second most common cause of AVF-AVG loss after stenosis/thrombosis [9]. An effective hygiene and infection control policy is essential, and healthcare staff must be trained appropriately. Standard precautions prevent healthcare-associated transmission of infectious agents among patients and healthcare workers, and they must be applied to all patients. Appropriate sterile technique should be used [43]. The patient's skin must be disinfected with an appropriate solution (before needle insertion for approximately 30–60s) starting at the chosen cannulation site and moving outward in a circular rubbing motion. If the skin is touched by the patient or staff after the skin prep has been applied but the cannulation has not been completed, repeat the preparation.

The CVC exit-site infection can be defined as a culture-positive inflammation external to the cuff of the catheter and localised to the exit site and not extending beyond the cuff. It is characterised by local redness, crusting and a variable amount of exudate. In most of these cases, the patients respond well with local measures, like topical antibiotic application (without fever). The CVC tunnel infection is defined as a culture-positive inflammation within the catheter tunnel but beyond the catheter cuff, with negative blood culture. Usually it is characterised by erythema, tenderness and induration in tissues overlying the catheter and > 2 cm from the exit site. CVC-related bloodstream infection (CRBSI) is defined as the presence of bacteraemia originating from an intravenous catheter. The diagnosis of CRBSI is often suspected clinically in a patient using a CVC who presents fever or chills, unexplained hypotension, and no other local sign. Severe sepsis and metastatic infectious complications, such as infective endocarditis, septic arthritis, osteomyelitis, spinal epidural abscess and septic emboli, can prolong the course of CRBSI and should be considered in patients who do not respond appropriately to treatment. Specific connection and disconnection procedures to prevent the CVC infections are applied in FMC EMEA NC [69].

5. Patient perspective

5.1 Patient information and education

Patient information and education are powerful means for keeping VA functional and safe and to guarantee successful dialysis therapy. These needs extend to patient's family and relatives. Awareness and learning processes should start as soon as the patient is diagnosed with chronic kidney disease. VA creation is a significant milestone in the life cycle of CKD patient that marks almost the final step of kidney disease progression and announce the start of replacement therapy. VA planning and creation are usually associated with a severe psychological trauma in renal patient that needs to be adequately prepared. Therefore, regarding VA education, it is important to differentiate in the life cycle of CKD patient two stages: before and after VA construction.

Preservation of vessels is an essential message and task that should be given to any CKD patients and relatives [11]. It is of utmost importance that CKD patients are aware of how they can preserve their vessels in both arms. They need to realise very early that vessels are essential for VA creation as a line to life-sustaining therapy and superficial vein resources are not endless. Patient education should include information to avoid and/or to refrain using major vessels located in the forearm for blood sampling, intravenous (IV) injections and infusions or invasive arterial procedures and to avoid the use of upper arms veins for catheterisation (e.g., angiography) or radio-logical procedures (e.g., contrast media imaging). Such message should be repeated at each hospital or clinical admission. Instead the use of superficial veins of the hand and minor vessels of upper arm should be preferred for exploration or imaging.

Patient education means more than providing information, CKD patients will benefit from counselling to actively participate in the choice of their treatment modality, to act on their own care and in successfully self-managing certain tasks needed by their treatment [11]. Patient education is needed to increase patients' skills and confidence in managing their own disease. Education should be part of CKD management program during outpatient clinic consultation as a continuous training process. Long-term follow-up of renal patient gives caregivers and patient a better understanding of the choice regarding the type of renal replacement therapy and VA option. Obviously, patient education does not mean simply handing over information. Appropriate materials and personalised education (e.g., adapted to age, educational level, cultural and language barriers), that consist both in providing written documents, pictures, movies, social media and discussions, but also in regular checking of patient understanding and knowledge. This regular interaction between patient and care giver is one of the most efficient components of the educational and training process.

When the creation of VA is planned or performed, the patient must be informed about and what to be expected after the surgery. Also, he must be asked to report immediately to the VA reference centre if side effects or important changes occur. Important and practical advices after VA surgery include for example: to keep the arm warm and dry; to monitor the surgical wound for changes; to elevate the arm slightly to prevent swelling; to use the other hand to feel VA thrill; to avoid sleeping on the fistula arm, wearing tight sleeve, carrying heavy weights, violent sports or activity that may cause a trauma to the AVF; to avoid blood pressure measurements, blood sampling and IV injections on the VA; to ask dialysis nurse to check AV patency if patient is already on dialysis via a CVC.

Maturation of AV access is an important period for long-term VA outcome corresponding to the non-use of the VA. This time may last 4–8 weeks dependent on the VA type, medical patient profile and vascular network characteristics. After wound healing, patient needs to start appropriate exercise program for enhancing flow in the VA arm (e.g., open and close hand, squeeze soft ball and touch finger-tips with thumb) that will foster VA maturation. Long-term monitoring of VA is needed for dialysis patient. In the patient's life, VA patency and local skin aspect should be checked at least daily. The easiest way is to put their hand or fingers on the fistula to feel a buzzing sensation (thrill) and to detect abnormal pain or temperature.

Patients with a dysfunctioning VA may require at some points imaging and/or interventional procedures. It is necessary to explain planned procedures or examinations to the patient. Patients should be informed about the contrast media use for the examination and be aware of allergy or other potential side effects. Expected results of investigation and potential required intervention should be carefully explained to the patient.

Hygienic rules should be applied any time on the VA arm to prevent skin colonisation and migration of bacteria from the skin to the blood circulation system at the time of needling (e.g., AVF or AVG) or VA connection (e.g., CVC). General recommendations consist in washing access arm with water and soap every day, before and after each dialysis session, avoid coughing or sneezing on the VA, keep the haemostatic and adhesive dressing for up to 3–4 hours after VA disconnection. Teach patients of the importance of preserving VA from special risky practices (e.g., sauna and steam bath, swimming, extreme sport and gardening with gloves).

5.2 Pain management of VA cannulation

Pain and discomfort caused by VA cannulation and needling are of major concern for dialysis patient. Pain assessment is a primary task and responsibility of nursing staff when caring dialysis patient [142]. Dialysis patients are exposed to pain with VA cannulation more than 300 times per year. Such repetitive exposure to pain and discomfort causes anxiety and depression, reduces quality of life, and interferes with daily life enjoyment.

Pain is an unpleasant emotional and sensory experience due to an actual or potential tissue injury that is tremendously enhanced by anxiety. This is a quite stressful condition that can lead to severe and uncontrollable fear of needles known as "needle phobia" or "trypanophobia" leading eventually to "dialysis phobia." In this sense, the pain control during VA cannulation by nursing staff should be considered as a top priority in dialysis units. Pain intensity during VA cannulation may benefit from regular monitoring relying either on subjective assessment (nurse feeling) or better and more objective assessment using visual analogue scale (VAS).

To prevent fear of needles and pain caused by the VA cannulation, dialysis nursing team should be adequately trained in pain management. Effective pain control improves patient satisfaction with dialysis nursing care, helps patient to accept haemodialysis and enhances their quality of life. Effective and personalised plans are needed to manage VA needling pain in dialysis patients. There are different pharmacological and non-pharmacological pain management strategies for VA needling. General approaches include topical heat or cold therapy, rhythmic breathing, distraction, transcutaneous electrical nerve stimulation, aromatherapy, acupressure, massage, active listening and music therapy. Topical treatment approaches aiming to reduce pain via local anaesthesia that include Emla (cream or patch) and lidocaine (cream or intradermic injection) or local analgesia such as Arnica topical cream or diclofenac sodium topical gel are now more frequently proposed. Other approaches may be advised such as hypnosis or gas anaesthesia with inhalation of nitrous oxide depending on the psychological component and on the local setting.

6. A value-based approach relying on best nursing practices learned from NephroCare

6.1 VA cannulation

VA cannulation method is still an "art" and procedure that reflects local unit practices and personal nursing skills [130]. Interestingly, despite the impact needling has on VA survival and patient outcome, there is no universal or standardised method proposed for proper cannulation [143].

There are three cannulation methods used by nursing staff: rope-ladder, area cannulation and buttonhole [144]. The rope-ladder (site-rotation) method appears to be the most used worldwide being considered as the safest one. It consists of alternating puncture sites at a defined distance from the previous one along the VA vessel as an attempt to prevent aneurysm formation, stenosis and repeated trauma by multiple punctures. The area (one-site-itis) puncture is the insertion of the needles in the same general area of 2–3 cm, session after session [145]. This method exposes to weakness VA wall with progressive dilation leading to false aneurysm. The buttonhole (constant-site) method is less used in centre but seems of great interest for patient self-cannulating their own VA. It consists in creating a track by cannulating repeatedly the same spot and angle with sharp needle over 6–9 weeks. Once the track is formed, then a blunt needle can be used for subsequent cannulation. Buttonhole cannulation appears to be less painful and create less anxiety than rope-ladder but exposes to a more risk of infection. Nursing vascular access procedures are detailed in a separate document accessible and downloadable from the website: https://www.edtnaerca.org/academy/publications.

6.2 Patients bearing chronic tunnelled central venous catheter (tCVC)

Despite strong recommendations from best clinical practice guidelines, the use of tCVC is very common and tends to increase over time in almost all countries either in incident (10–80%) and prevalent (2–48%) dialysis patients [20]. Such trend most likely reflects change in medical profile of dialysis patients (e.g., advanced age, comorbidities, short life expectancy and repeated failures of VA creation), change in medical practices (e.g., easy access to CVC and shortage of motivated vascular surgeon) and poor or fragmented management of CKD patients (e.g., late referral). Interestingly, prevalence of tCVC in prevalent patients varies from 20 to 40% in Europe.

6.3 Nurse perspective: skills, training and responsibilities

Nurses play a crucial role in the management of all VAs. VA assessment, cannulation and care are mandatory skills for dialysis nurses: failure to correctly perform this operation may result in serious complications for the patients [145].

6.3.1 Competencies and responsibilities

A highly-skilled dialysis nurse is required to ensure that each cannulation/connection procedure is carried out with minimal or no complications. At every dialysis session, and before each cannulation/connection, ensure that the patient's VA is functional and has no problems in obtaining the optimal blood flow ensuring an adequate dialysis [43]. The competencies and responsibilities to achieve this are as follows:

- The nurses should have competence in:
    - AVF/AVG and CVC assessment
    - AVF/AVG cannulation techniques and care
    - CVC connection and care
    - Management of complications
    - Patient education related to VA care
- The nurses should have responsibility for:
    - Ensuring patient comfort and safety
    - Reporting and documenting all complications relating to VA
    - Liaising with the dialysis medical team to early identify and manage complications

Before starting the cannulation procedure for AVF/AVG or the connection of the CVC, the Registered Nurse (RN) must assure the preparation of the environment, material and patient following strictly the hygienic rules.

6.3.2 Hand hygiene

The impact of health care-associated infections implies prolonged hospital stay, long-term disability, increased resistance of microorganisms to antimicrobials, massive additional financial burden, high costs for patients and their families and excess deaths [146]. In accordance with the WHO hand hygiene should routinely be performed.

6.3.3 Personal protective equipment (PPE) and work uniform

PPE (hand and face protection, aprons and gowns) serves to protect HCW from hazards and preventable injuries in the workplace. Some PPE items, such as gloves and masks, protect HCWs and patients.

Uniforms are not considered as PPE. Nonetheless they provide the HCW with professional attire that supports the HCW in carrying out her or his work in the dialysis unit, while at the same time preventing cross-contamination between the workplace and the home.

6.3.4 Patients general condition assessment

Prior to any HD treatment, assessment of patient's general condition to identify potential problems that may arise during the treatment should be performed: temperature (as a routine, only for CVC), diet, loss of appetite, vomiting, diarrhoea and any other intercurrences between treatments like cramps, bleeding or some other signs or symptoms of complications.

The nurse needs to weigh the patient and compare the value with the last post dialysis weight and to the prescribed dry weight. Blood pressure and pulse must be evaluated and all treatment parameters should be validated. When using a CVC, the catheter exit site must be examined thoroughly for the presence of any signs of infection. A physical assessment of the VA must be carried out before every treatment.

6.3.5 AVF/AVG assessment

Using the eyes, ears and fingertips, AVF/AVG are assessed for complications. Inspection (observe and look for):

- Signs and symptoms of inflammation/infection: redness, drainage, abscess, warmth, oedema and rash over the fistula.
- Infiltration/haematoma: needle infiltration of new AVF is a relatively frequent complication, and haematoma can develop easily in patients on chronic anticoagulation therapy.
- Pseudo-aneurysms are frequently seen on the fistula arm: pseudo-aneurysms develop because of trauma from cannulating the same site or due to a significant proximal stenosis in the outflow tract.
- Skin colour: changes in the skin colour could point to stenosis of infection, discoloured or cyanotic fingers could be an early sign of steal syndrome.

Palpation (touch and feel):

- Thrill: normally a very prominent thrill is present at the anastomosis and the fistula is soft and easily compressible, the thrill diminishes evenly along access length.
- Skin temperature: warmth could be a sign of infection; cold could be a sign of decreased blood supply (possible steal syndrome).

Auscultation (listen to the fistula):

- Listen for bruit: listen to entire access every treatment and note changes in sound characteristics.

AVF/AVG physical examination is crucial to evaluate the proper function and to detect possible signs of complications. If any sign of complication is present, the VA should not be used and the patients should be evaluated by the nephrologist [43].

6.3.6 CVC assessment

CVC, despite being considered the worst HD VA, is used in a considerable number of patients, up to 80%, either due to the need to start HD following emergency catheter placement or due to lack of native vessel to create an AVF or place an AVG. The goal of performing a HD treatment via a CVC should be the achievement of the best patient outcome as possible, while keeping all possible complications under control. For this purpose, it is fundamental that all team members are familiar with the principles of CVC care, which include assessment, usage, surveillance and maintenance.

6.3.6.1 Exit site

The exit site of the CVC must always be inspected at each HD treatment for any signs of irritation, infection or development of allergy to dress or disinfectant solution, including tenderness, skin peeling, rash, swelling, exudate and redness. European Renal Best Practice (ERBP) recommends to always ensure the area being cleansed around the exit site is slightly larger than the final dressing and include the section of the catheter that will be underneath the dressing [147].

6.3.6.2 Type of dressing

There is a wide variety of different types of products for dressing and securing CVCs, but the superiority of one over another has not yet been demonstrated. According to ERBP, for long-term catheters sterile gauze is preferable, for enabling maximal natural airing of the exit site.

6.3.6.3 Patency

Before starting the HD treatment, the patency of the catheter should be evaluated. The locking solution use in the previous treatment should be removed by withdrawing 3–5 ml, locking solution mixed with blood. Using a 10 ml syringe filled with 0.9% NaCl, a small amount of blood should be aspirate into the syringe and observed for clots containment. If yes, flush should not be done. If unable to flush the physician should be alerted to assess and, if necessary, provide intervention.

6.3.6.4 Patient's skin preparation for cannulation

Before needle insertion in an AVF/AVG, proper needle-site preparation should be done to reduce infection rates. Site selection should be done prior to the final skin preparation.

6.3.6.5 Cannulation

The most important procedure is the cannulation of an AVF/AVG, and over the course of a day, it is carried out on numerous occasions by the dialysis nurse. Choice of the correct cannulation site and technique are fundamental factors for an optimal dialysis session (more information at Section 6.1).

6.3.6.6 Needle taping

Tape the needle in place on completion of insertion, secure it using a minimum of three strips of tape: one to fix the wings, a second on top of it to secure the needle and a third one to secure the needle tubing.

6.3.6.7 Needle removal and haemostasis (HS)

The procedure of needle removal by the nurse is as important as the cannulation of the AVF. Needle withdrawal must be done carefully to prevent tearing of the vessel, to minimise access trauma and to achieve optimal HS. The needle should be removed using the same inclination as the insertion angle. Appropriate pressure should be applied after complete needle removal (thrill should be felt above and below the site of pressure). The pressure must be hold for 8–12 min without checking.

6.3.6.8 Haemostasis

HS of the first cannulation must always be performed by skilled nursing staff, since the vessel wall is fragile and there is an increased risk of haematoma formation. Manual compression applied by the nurse, health care assistant, or patient is the standard of care following withdrawal of HD needles. For the patients who cannot or are unwilling to hold pressure for sufficient time for HS the use of a HS clamp or band is required.

6.3.6.9 Patient education to care for VA

One of the most important responsibilities of the nurses is patient education. To achieve shared decision making, improve understanding and adherence, motivate, and encourage self-management, effective patient education is crucial [20] (more information at Section 5).

A good knowledge on VA management is necessary to enable the nurse to assess, plan, implement and evaluate the care given to patients before, during and after cannulation (AVF/AVG) or connection (CVC) and to deal with complications. The first use of a VA is an important opportunity for the expert nurse to demonstrate and transfer her/his knowledge and expertise to novice HD nurse. This will ensure the continuing education of healthcare staff engaged in patient care within the HD unit.

7. VA future outlook

As stated in the background section, VA is an essential component of a life-sustaining therapy in ESKD patients with a significant effect on both patient outcomes and associated costs [3, 8]. Therefore, taking a value-based approach and identifying opportunities for VA that would provide the right balance between optimal patient outcomes and total spending would be the ultimate goal [148].

The clinical/medical evidence basis clearly shows from a value-based perspective that it is obvious that native arteriovenous fistula is still the best VA option providing the highest survival expectation and the lowest complication risk [149]. However, patient profiles have become more complex including an increase of co-morbidities that affect the success rates of AVF [150]. Therefore, several attempts have been made to substitute failing native AVF by new VA devices including vascular graft (synthetic and biomaterial), implantable devices (graft, venous catheter and port catheter) or hybrid system (graft port or venous port catheter) with limited success [151, 152].

What are the new VA perspectives to improve outcome and/or to expand VA possibilities in difficult cases. Several opportunities are currently under clinical investigation:

First, better management and use of existing VA from installation (VA network mapping) to maintenance permitted by use of non-invasive imaging (US-based) including monitoring technologies (online monitoring HD) [149, 153, 154] or connected technologies offering 24/7 continuous monitoring of VA patency [155]. The idea behind is to facilitate maturation of newly created AVF and/or to intervene earlier on failing VA to permit percutaneous interventional procedures for restoring patency [156].

Second, make better use and improve outcome of tCVC or implanted venous access port devices by implementing strict rules of handling and generalisation of catheter locking solutions [157].

Third, assess clinical value of minimally invasive procedures such as percutaneous creation of VA [158, 159].

Fourth, use medication either with systemic or local action to prevent thrombosis, to reduce neointimal proliferation leading to stenosis [160–162].

Fifth, evaluate performance and outcome of bioengineered VA conduit based on vascular matrix formation and autologous cell seeding as part of regenerative medicine [19, 163].

Next to the medical future outlook, the economic perspective should also be considered, reviewing the bottom part of the value-based healthcare equation where value "is defined as the health outcomes achieved per dollar spent" [148]. Two systematic reviews (one focused on VA creation and the other on VA maintenance) identified a total of ~15 economic evaluations and/or cost and resource use analyses. As from a medical perspective, AVF is concluded to be the most cost-effective VA type for HD patients [164]. Nevertheless, the number of studies identified, and the level of evidence currently available shows a clear gap in knowledge to come to a solid conclusion from a health economic point of view. Especially, the total patient life cycle with regards to costs is not clearly mapped including the identification of: downstream costs, costs of adverse events, associated costs of patency rates and long-term consequences in effectiveness of the HD treatment.

Finally, there is one additional component that would need to be tackled which is the health system set up in general around transition management for CKD patients including VA placement and maintenance. According to Porter, healthcare needs to be structured based on meaningful outcomes to patients to maximise the value that is delivered in the end [165]. As part of this structure, episodic treatment should be transferred to bundling therapies under the responsibility of one provider [165]. Translating this to renal care would entail to include VA placement and management in the dialysis reimbursement bundle, which is already the case in, for example, USA, Portugal and Spain.

The reason for this reorganisation is especially needed as currently approximately 32–73% of the CKD patient population experiences an unplanned start of dialysis [166–169]. This unplanned start leads to the use of the least optimal VA type (CVC) rather than AVF as this requires a 6-month maturity phase. This suboptimal start is caused by a lack of screening and diagnosis of CKD patients in time, as these patients are first seen by a general practitioner (GP) rather than a nephrologist [170]. Hence, awareness/educational measures toward GPs could also be one of the future outlooks from a health policy perspective to improve VA practice and consequently the lifecycle of HD patients.

In conclusion, the outlook for the future for VA practice is promising and has potential to improve significantly from multiple perspectives (medical, economic, health system, etc.). A collaboration and partnership between these disciplines would create an understanding and clear roadmap for next steps to put these into practice.

8. Conclusion

VA is an essential component of renal replacement therapy in ESKD patients. VA is currently referred to the life line of dialysis-dependent patient. Dialysis access relies on two main options: arteriovenous shunt (autologous AVF and AV graft); veno-venous access (tunnelled catheter and venous port device). AVFs are still the preferred VA option associated with best outcomes, higher performances and lower morbidity. Various innovative and quite interesting options, including minimally invasive percutaneous creation of AVFs and implantation of bioengineered vascular conduit deserve further clinical studies to enter in the VA armamentarium. VA performance is a key factor to drive success of extracorporeal renal replacement treatment. Furthermore, VA dysfunction and/or morbidity (stenosis, thrombosis and infection) are a source of frequent hospitalisation and corrective procedures. VA management in CKD patient is of tremendous importance in the overall quality care of dialysis patients. VA care and outcome are greatly improved in a large dialysis care provider network by means of a referent VAC and continuous quality improvement program [171].

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Conflict of interest

All authors are employees of Fresenius Medical Care.

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