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Chapter 27

A Holistic Approach to Vascular Access in Hemodialysis

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Additional information is available at the end of the chapter

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1. Introduction

Vascular access for haemodialysis (HD) and other forms of renal replacement therapy where access to blood is required (such as haemofiltration) is a broad area that encompasses a variety of specialties including nephrology, intensive care, interventional radiology and surgery. Within the acute setting, vascular access via catheter placement can be performed in an emergency. However, longer-term access in the form of an arteriovenous fistula (AVF) or graft requires considerable pre-procedural planning and often involves multidisciplinary input throughout the patient's "dialysis lifetime". In this chapter, we aim to discuss the common types of access and provide a holistic approach from a UK perspective, whilst also focussing on some practical aspects that have been noted from our personal experience and evidence-base.

1.1. Identification of patients who require vascular access

In the setting of acute kidney injury (AKI), a vascular catheter is the commonest access route for HD. There has to be a clear indication for insertion and this may include satisfying stage 3 of the Acute Kidney Injury Network classification, life-threatening hyperkaemia refractory to medical therapy, acidosis, uraemia and fluid overload resistant to diuretic therapy [1]. Nonetheless, there may be other specific indications considered on a "case-by-case" basis. Such instances include anticipation of non-recovery from AKI or those with chronic kidney disease (CKD) who receive debulking chemotherapy for haematological malignancies and may not cope with rapid rises in urate and potassium from cell lysis [2].

In CKD, it is generally recommended that plans to establish any form of dialysis access should be discussed with the patient between stages 4 to 5 (estimated glomerular filtration rate of 30 ml.min.1.73m$^{2\text{-}1}$ or less) and an informed decision documented [3]. In HD,

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this often involves surgery for an autogenous AVF or graft. Vascular catheters are not recommended as a first-line approach given their complications. Timely preparation will ensure the smoothest transition towards renal replacement therapy. Patients who referred late for consideration have poorer outcomes compared to those who have been established with nephrology services for longer: they are consistently shown to have increased mortality, reduced treatment choices, access to transplantation, increased morbidity and hospitalisation [4].

One fundamental difference between vascular access types is blood flow and this will determine dialysis adequacy (defined as a Kt/V of ≥1.2) [5]. Sometimes, flows are not as optimal in catheters compared to AVFs or grafts. Regardless, the need for vascular catheters in patients with end-stage renal disease is becoming increasingly commonplace in 4/5 patients who suddenly deteriorate, when AVF or graft is not possible or maturation has failed [6]. Their convenience of insertion and immediate painless use makes them popular with patients. Temporary vascular catheters (VC) are generally used for no more than two weeks (shorter duration for femoral vein catheters), whereas tunnelled cuffed vascular catheters (TCVC) are indicated for short to long-term venous access. If maintained correctly, such devices can last for a few years. Although traditionally inserted by an interventional radiologist, in many UK centres a nephrologist will now perform the majority of procedures as a day case. A more recent development within the UK has been the creation of specialist nurse-led services dedicated to this area [7].

Establishing vascular access will remain the key rate-limiting component for HD. The vascular access nurse plays a crucial role in prioritising patients and contributes to a multidisciplinary approach involving specialist nurses, surgeons, radiologists and nephrologists. Deciding on when to start dialysis once access is created in CKD is an area of intense debate but has to be determined on an individual basis. Factors may include rapidity of estimated glomerular filtration rate (eGFR) decline, symptoms of uraemia, failure to thrive or poor quality of life. However, the recent Initiating Dialysis Early and Late (IDEAL) trial definitively demonstrated that elective earlier initiation of dialysis (based on eGFR 10-14 ml.min. $1.73m^{2-1}$ vs. 5-7 ml.min.$1.73m^{2-1}$) was not associated with improved clinical outcomes or quality of life [8].

2. Types of vascular access

2.1. Arteriovenous fistulae and grafts

2.1.1. Requirements

Preferably, patients should receive counselling on the requirements of HD before referring for *any* access procedure. It is useful for them to visit a dialysis unit to experience how treatment is administered and gain familiarity with environment. This may help to adjust patients to a potentially lifelong routine.

A vascular surgeon at our centre performs AVF and graft surgery. In the UK, both renal transplant and vascular surgeons provide this service based upon local arrangements. On considering referral for access surgery, the renal physicians and vascular access nurse assess both the patient and the upper limb vessels for ease of AVF formation. This is an invaluable adjunct to the process, as priming both the patient and surgeon regarding potential difficulties provides for a more effective service.

Once referred, a vascular assessment of the patient is performed with particular focus on both upper limbs. Clearly, the successful creation of AVF or graft is dependent upon optimising its location, arterial inflow and venous outflow. In particular, the veins in both upper limbs should be examined for size, location, and patency whilst simultaneously checking for the character of radial, ulna and brachial pulses and vessels. The non-dominant limb is usually used for access surgery. Where there is a suspicion of arterial disease, we perform upper limb brachial and radial systolic blood pressure and qualitative Doppler waveform analysis at the same clinic visit.

Although clinical assessment of the patient is key to the formation of an AVF, ultrasound duplex scanning can be valuable to assess vessels and quantify flow rates. Surgeons may use duplex scanning routinely or selectively prior to surgery. Patients with diabetes frequently represent a greater challenge due to a higher incidence of arterial calcification particularly more distally at the forearm and wrist: studies demonstrate they are more likely to need a proximal AVF with their inherent risk of the steal syndrome (see below) [9].

We have seen an increasing trend in more elderly and frail patients being referred for access surgery. The increased incidence of co-morbidities including cardiac disease, loss of tissue quality and atherosclerosis in the elderly means that they represent a greater challenge both in terms of creating a fistula and avoiding associated complications [10]. If a reduction of inflow is identified in the limb being considered for surgery, then magnetic resonance arteriography (MRA) is requested to detail arterial disease. MR or venograms can be performed if there is suspicion of venous disease particularly in patients with a history of multiple central vascular catheter use: subclavian catheters being well-recognised to predispose to central vein stenosis [11]. Patients with central vein stenoses and occlusions present a significant obstacle, but can be managed by interventions such as venoplasty and stenting, and carefully selecting the site of venous anastomosis.

Informed consent for access surgery should include detail not only on the reasons for surgery and explanation of the procedure, but also information on the immediate and longer term complications that may occur. This should be based on the individual surgeons practice and observations [12]. The type and frequency of complications that we include in discussion, comprises of failure to achieve a usable fistula, haemorrhage, ischaemia, damage to surrounding structures including nerves and wound complications. Over 90% of our access surgery is performed as a day-case under local anaesthesia.

Given the burden of cardiovascular disease, it is common to find patients on antiplatelet and anticoagulant medication. Aspirin is not stopped prior to surgery. Clopidogrel and antiplatelet combinations are modified based on an assessment of risk [13]. Typically, we ask pa-

tients to omit clopidogrel for five days prior to surgery. Warfarin is omitted typically four days before surgery to achieve an International Normalised Ratio (INR) of 1.5 or less, although there is no definitive evidence for this practice [14]. Regarding the provision of regional anaesthesia for access surgery, an INR of 1.3 or less is required. If warfarin cannot be stopped for an interval of several days (e.g. in patients with prosthetic heart valves), then we typically admit patients for intravenous heparin infusion that is stopped approximately two hours prior to theatre and recommenced two hours following surgery. The platelet count should be 50,000.μl^{-1} or greater but guidance on the possible qualitative defects in platelet function due to uraemia in stage 5 CKD is not well defined [15-16].

AVF formation should ideally be timed so that patients who are deemed likely to need access have a mature fistula when dialysis is required. Clearly, access surgery should be performed as soon as is possible. However, this should not preclude optimisation of patients in terms of co-morbidities and the investigation and treatment of arterial or venous disease that will improve the likelihood of a successful outcome. Hastily performed access surgery in a sub-optimised patient is more likely result in the loss of a potentially precious AVF. Of course, it is possible that a patient will require dialysis during the period of investigation, interventions or fistula maturation and a vascular catheter with their inherent risks becomes vital.

2.1.2. Autogenous arterio-venous fistula and details of procedure

This is the gold standard and should be considered in *all* patients who required vascular access [17]. It is recommended to create a fistula in the non-dominant upper limb before approaching other sites, particularly for those considering home dialysis. The lower limb should be considered only when the upper limb options are exhausted given the higher risk of infection [18]. The commonest type of autogenic AVF is radio-cephalic where the cephalic vein is anastomosed to the radial artery at the wrist. Although initially described as a side-to-side anastomosis, many surgeons perform end-to-side procedures, ligating the vein and attaching the proximal vein to an arteriotomy.

Typically, in our practice, a patient will give signed consent and have the limb marked on the day of surgery. The vein, artery and line of incision are marked approximately in parallel, with the incision mark placed closer to the artery than vein. The procedure is performed in theatre under aseptic conditions; venous cannulation is performed on the dorsum the non-surgical hand and a single bolus of a broad-spectrum antibiotic is administered, e.g. co-amoxiclav 1.2g. Unfractionated heparin is also given via the cannula just prior to application of arterial clamps. Monitoring of pulse and oxygen saturation is continuous. No sedation is used.

The limb is placed on an arm board and prepared with a topical antiseptic e.g. iodine-based. We place the unprepared hand in a clear aseptic plastic bag. Local anaesthetic, typically in the form of 1% lidocaine, is infiltrated into the marked area. The vein is identified first, as its status will influence the rest of the procedure. Once sufficient length is judged to be exposed and dissected free of surrounding tissues, the vein is marked along its length with a surgical marker pen to avoid rotation. The vein is then ligated and cut. The proximal end is initially

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flushed to check run-off, then gently occluded to assess calibre as venospasm is routinely encountered during local anaesthesia.

Once the vein is assessed as viable, the artery is then exposed sufficiently to allow an arteriotomy and placement of two paediatric non-crushing arterial clamps. The vein is cut to adjust for length and end circumference to avoid excessive tension and anastomotic disparity. Once clamped, an arteriotomy is made, typically of four to six millimetres and the end-to-side anastomosis performed using a double ended 6-0 or 7-0 polypropylene suture (Figure 1). We routinely flush all vessels just prior to completion of the anastomosis to flush out any clot that may have formed. Closure is then performed in layers with absorbable sutures. Occasionally, non-absorbable sutures are used to close the skin when the cutaneous tissue is thin and unsuited to subcuticular closure.

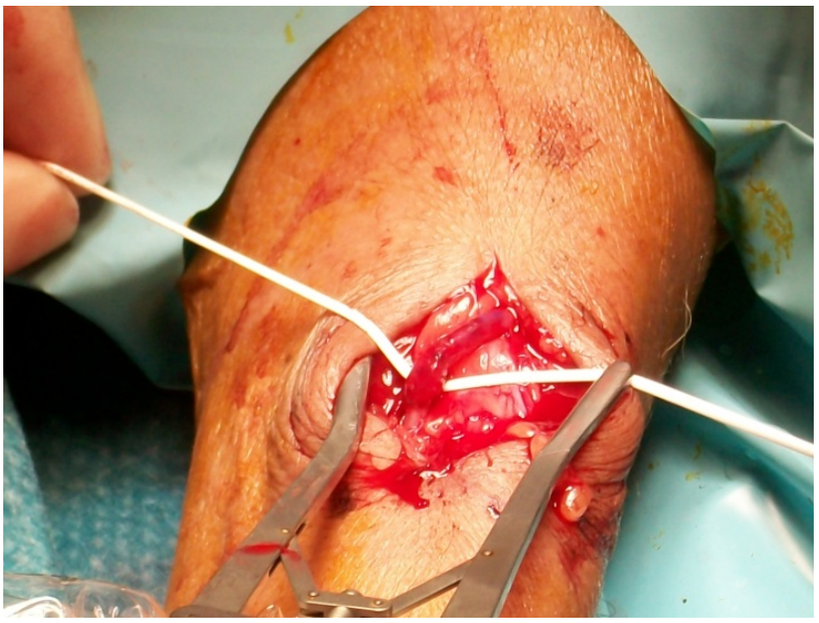


Figure 1. Completion of anastomosis in a radio-cephalic fistula.

The degree of urgency and co-morbidities are factors to consider when deciding on the location of an AVF [19]. For patients vulnerable to factors such as reduced arterial inflow due to cardiac failure, a proximal AVF may be preferable as it is more likely to develop quickly and be resilient to changes in the patient's cardiovascular status. Although more proximal AVF are likely to achieve better primary outcomes, we strive to perform distal procedures - frequently performing snuff-box AVF, distal to the wrist in the anatomical snuff box [20]. Distal AVF surgery can be more technically demanding because the vessels are of smaller calibre requiring finer sutures and instruments. Despite this, the great advantage of a distal AVF apart from ease of use for the patient and staff, is that failure will most commonly only cause local venous thrombosis and not limit venous return for any subsequent, more proximal AVFs. This approach allows for better utilisation of veins with potential for a greater

number of AVF in each limb. Thus, if a snuff-box or wrist AVF fails, then a more proximal radiocephalic or antecubital fossa AVF can be created.

An antecubital fossa AVF involves anastomosing the median cephalic vein (or local variation of this), to the brachial artery. Other approaches include distal ulnar-basilic, radio-basilic or brachio-basilic transposition, performed as a single or two separate procedures. The basilic transposition involves a basilic or median cubital vein anastomosis to the brachial artery, but requires transposition of the vein from its normal deep lying medial location to an anterior and superficial position to enable access for puncture. If the upper limbs are not suitable or fistula maturation has failed, then the lower limbs can be used. For example, a long saphenous vein proximal thigh loop or mid/distal superficial femoral or popliteal artery anastomosis. Other more unusual approaches to AVF formation have been described for patients with particular challenges for access surgeons [21].

Autogenous AVFs exhibit a long-term patency rate superior to prosthetic grafts and vascular catheters [22]. Their relative cost is reduced with thrombosis and septic complications tending to be low. However, there are also disadvantages including the prior requirement of healthy veins that have not experienced inflammation and trauma leading to fibrosis and stenoses, the commonest cause of which is repeated cannulation [23]. This is particularly relevant to the cephalic vein in the forearm, the most precious of veins for AVF formation. Vein cannulation is a common occurrence and the importance of the cephalic vein is often forgotten by clinicians in the patient approaching end-stage kidney disease. Another important drawback when comparing AVF to grafts is a maturation time of typically four to six weeks. Grafts can be used far more quickly.

2.1.3. Prosthetic graft fistula

Prosthetic grafts are derived from several materials including polytetrafluoroethylene (ePTFE) and polyurethane. Despite their relative lack of vascular compliance, ePTFE grafts have an inherent stability as their hydrophobic properties make them less likely for blood to adhere [24]. Perforations created by dialysis needles tend not to close but are instead occluded by the development of a pseudointimal lining and platelet deposition. This is opposed to polyurethane grafts, which do possess self-sealing properties. Biological grafts of bovine origin (mesenteric vein, ureter and carotid artery) are available, but seldom used in the UK. Although more expensive than prosthetic grafts, biological grafts are less prone to infection.

Our unit uses grafts only occasionally when upper limb veins are not viable. We have a small stock of ePTFE grafts readily available usually as standard wall six millimetre diameter, with external reenforcement for loop grafts to prevent kinking. Unlike AVF, grafts require subcutaneous tunnelling. The most common procedures employing grafts are the forearm loop graft with anastamoses to the brachial artery and basilic/cephalic veins and brachio-basilic bridge graft with a venous anastamosis placed proximally towards the axilla. Grafts, in common with AVF, require good inflow and outflow. Their advantage over AVF is that needling can be performed much earlier (e.g. within two weeks) and cosmetically, they may be more acceptable to patients. Where urgent dialysis is required, synthetic grafts are available that can be used within 24 or 48 hours. Grafts can also be used for more unusu-

al bridge procedures, such as the necklace axillo-axillary graft and bridge grafts extending from more central vessels in the upper and lower limbs.

2.1.4. Post-procedure follow-up

In our practice, we routinely cover wound dressings with an additional layer of soft bandage typically from the hand to mid-forearm. This acts as a deterrent to hospital staff inadvertently grasping the surgical site in the immediate post-operative period. Following return to the ward, the patient is typically observed for two hours to monitor for bleeding and any acute neurovascular compromise that requires urgent revision surgery (see below). An audible bruit and often a mild thrill should be detectable following successful surgery. The vein in an autogenous AVF should become more prominent as maturation occurs. The patient should be educated about managing the surgical wound and reminded about the avoidance of cannulation and blood pressure recording in the fistula limb. In the early post-operative period, it is imperative that maturation is assessed on a weekly basis – usually by the surgeon or the vascular access specialist nurse.

During maturation the vein proximal to the anastomosis dilates rapidly over a three-week period and then at a slower rate subsequently. Although during this period, forearm exercises are advocated by the Kidney Foundation Disease Outcomes Quality Initiative, the evidence so far for this is patchy with little randomized-controlled trial data. Our unit recently conducted a pilot randomized-controlled trial of the effects of progressive handgrip training on autogenous AVFs. There was a small but sustained effect upon the change of venous diameter and accelerated arterial remodelling in the exercise group in the first four weeks of study [25]. These findings, although taken from a small sample size, suggest larger studies should be undertaken to clarify the significance of this intervention [26]. ePTFE grafts on the contrary do not change in size. Another, not uncommon cause of poor maturation in our population is vein branching causing flow reduction in the main draining vein. This may be related to stenoses secondary to cannula trauma. Prompt ligation of branches usually remedies this, occasionally combined with surgical or percutaneous management of associated stenoses.

Significant flow changes occur at the fistula anastomosis with normal laminar arterial blood flow becoming turbulent as blood flows abruptly from a high pressure/low volume vessel into a low pressure/high volume system with changes in wall sheer stresses. This is associated with variable degrees of intimal hyperplasia and venous stenosis. Vein ischaemia following sometimes extensive dissection, is also likely to influence wall fibrosis and stenosis. Our experience also suggests that the presence of vein valves in close proximity to the anastamosis is also associated with hyperplasia. Timely intervention using percutaneous angioplasty or surgical revision to improve vessel calibre can preserve fistula development [27]. Grafts can be affected by neointimal hyperplasia causing a gradual narrowing, particularly at the venous anastomosis and can lead to significant pre-and post-stenotic stasis and thrombosis. Flow monitoring has been advocated to detect these changes earlier, but the evidence is mixed and good trial data is desperately needed.

2.1.5. Long-term complications

The greatest risk universal to all fistulae and grafts is thrombosis. This may occur as an early or late complication. Interventions for complete occlusion of AVF are very time dependent, as unless it is immediate (typically within 24 hours of the event), the resulting phlebitis induces thrombosis and precludes a successful outcome [28]. Grafts are not subject to inflammation, although the adjacent vein will be susceptible. Thrombosed grafts can undergo thrombectomy or thrombolysis several days following occlusion.

There is limited evidence for use of antiplatetlet agents or warfarin to maintain fistula patency [29,30]. Further, any benefits may be offset by an increased risk of bleeding episodes. Fish oil has also been tried, but large trials are still awaited [31]. Nonetheless, in our experience, such measures should be considered in patients who have required multiple fistulae or when further attempts at any form of vascular access will be extremely challenging. In our unit, reducing flow rates are initially imaged using duplex scanning. The management of vein or anastomotic stenoses is influenced by whether the patient is dialysis dependent. Our preference is for surgical correction, most commonly more proximal re-implantation, over fistulogram and fistuloplasty in patients not requiring dialysis because of the nephrotoxic profile of the majority of contrast agents. Anecdotally and possibly related to a more elderly population, we are encountering more 'blow-outs' of autogenous veins, occasionally causing large haematoma formation and subsequent stenosis. Thinner, more fragile veins may be a contributing factor.

Infection is a dreaded complication, particularly when using grafts and is associated with false aneurysm formation. Local signs of inflammation such as warmth, erythema, oedema and tenderness should raise a high index of suspicion. Cultures should be taken to target antimicrobial therapy, although *Staphylococcal*-targeted antimicrobials are commonly used. Excision of the entire graft with arterial repair is not uncommon. Infection is not exclusive to grafts: following the advent of the buttonhole needling technique for autogenous AVFs there have been outbreaks of infection leading to *staphylococcus aureus* septicaemia [32]. Autogenous vein infection should be treated with conventional antibiotics and if possible alternative dialysis access sought on a temporary basis. Patient and staff education is an essential part of management and involves meticulous and repeated assessment of correct needling technique without the introduction of healing scabs into circulation.

Neurovascular compromise to a limb following access surgery may present as the steal syndrome and is characterised by classic signs of acute or worsening chronic ischaemia [33]. It can present hyperacutely with complete anaesthesiae of the hand, pain, loss of motor function or culminate in a more chronic form as severe ulceration and gangrene (Grade IV steal syndrome). Acutely, this represents a surgical emergency and necessitates immediate management to improve perfusion including revision surgery such as the distal revascularisation and interval ligation (Dril) procedure or reversal of the fistula to prevent permanent injury [34].

After a long period of AVF maturation, high output cardiac failure can occasionally develop. Given the burden of cardiovascular disease in the dialysis population this should not be

forgotten as a potential cause of worsening congestive cardiac failure. This develops due to left to right shunting of large volumes of blood via the fistula. The resulting increase in preload leads to higher cardiac output, and over time, the rise in overall cardiac workload leads to a progressive cardiomyopathy [35]. Access flow monitoring can demonstrate massive blood flows over the fistula (e.g. 2 litres.min^{-1}) and echocardiography reveals variable ejection fractions. Treatment with conventional therapies (e.g. angiotensin blockage, beta-antagonists, diuretics and fluid restriction) can improve the condition, but often banding or ligation of the AVF is needed which may create a dilemma over future vascular access.

Cosmetically, fistulae can be unappealing to some given the possible progression to aneurysmal dilation and venous collaterals from venous hypertension. The latter can be exacerbated by central vein stenosis from multiple catheter usage. Central vein angioplasty with possible stenting may be attempted to settle this but such intervention should be avoided if dialysis is adequate. Advances in buttonhole needling techniques have seen a reduction in the frequency of aneurysmal dilation. [36]. Occasionally, aneurysms and pseudoaneurysms (in grafts) need to be surgically removed as they carry a high risk of bleeding and infection.

2.2. Vascular catheters

2.2.1. Requirements

Similar to AVF creation, anatomical planning is crucial to ensure a successful outcome and reduction in complications. Deciding upon the site of catheter insertion depends upon several factors. Generally, haemodialysis catheters are inserted into either one of the internal jugular veins. Commonly the right side is approached given: 1) larger lumen than its counterpart and 2) its direct path into the superior vena cava and right atrium. The course of the left internal jugular vein is less straightforward as it makes a turn at the junction with the left brachiocephalic vein and a second turn at the superior vena cava. If a left-sided approach is being contemplated, it is recommended to perform this under fluoroscopic guidance so any tortuosity is safely traversed.

Although anatomical landmarks continue be used to guide insertion, current NICE guidance in the UK recommends the use of ultrasound scanning (USS) pre- and/or intra-procedure [37]. This enables the operator to accurately determine site of entry, trajectory, proximity of the artery relative to the vein and assess vessel calibre. Compressibility of the vein is a defining feature distinguishing it from the neighbouring artery (usually in a slightly posterior-medial position with an internal jugular approach; Figure 2). This may however be reduced if thrombus is present. Arterial pulsation detected on USS can also act as a discriminating feature, but caution is advised in the face of a critically ill patient who is hypotensive. From our personal experience, an entry point of approximately two centimetres above the clavicle is satisfactory. A higher approach may be less comfortable as the external portion of the catheter may protrude into the neck and restrict movement. Moreover, a lower approach facilitates conversion of a VC to a TCVC if desired at a later stage.

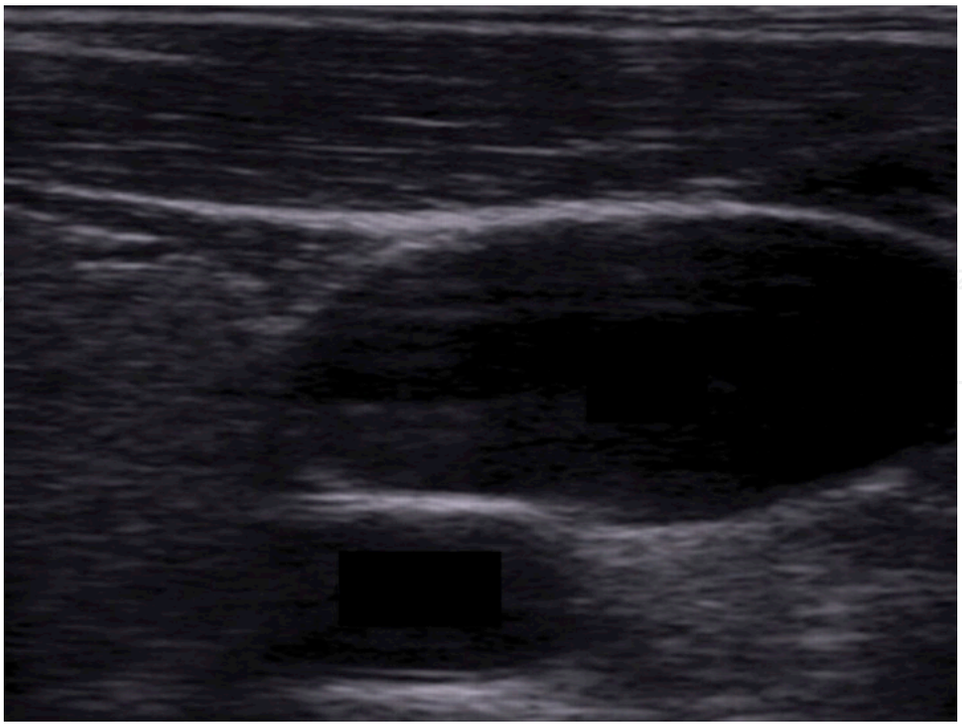


Figure 2. Transverse ultrasound image of internal jugular vein with the common carotid artery in a posterio-medial position.

Occasionally, alternative sites are sometimes sought, as patients may not be able to lie supine for a prolonged period due to dyspnoea or cervical osteoarthritis. In addition, it is common for dialysis patients to have multiple catheters inserted during their lifetime and this can result in thrombosis and stenosis making future insertions difficult: attenuated internal jugular veins with multiple collaterals is suggestive of a central occlusion [11]. Therefore, subclavian and femoral veins can also be considered. However, the latter is thought to be undesirable given the increased risk of infection despite evidence for the contrary [38]. Subclavian insertions are not recommended given their propensity to subsequent stenosis or thrombosis by inducing endothelial damage and may compromise future AVF formation. Thus, the remaining discussion will focus on the internal jugular approach as it is the most widely used.

Written informed consent is advisable. The entire procedure should be explained in detail and complications outlined. In the emergency setting, where the patient lacks capacity to give consent, this may not be required and the procedure can be performed under the auspices of Common Law in the UK. Common complications include arterial puncture, bleeding and risk of infection. In our experience, pneumothorax is overstated and is rarely seen in internal jugular insertions. However, in a subclavian approach, there is a higher risk of pneumothorax and pleural injury given proximity of the lung apex.

Those with active septicaemia should not have a TCVC inserted where possible, but should be postponed until negative blood cultures are obtained. Patients should also have a satisfactory coagulation system and similar precautions should be taken as outlined in the previous section.

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2.2.2. Details of insertion procedure

For *any* insertion, an aseptic technique is essential and can be achieved readily in a pre-designated area for catheter placement (Figure 3). Ideally, an assistant should be present who can provide material to the operator and reassure the patient. The operator should don sterile mask, gown, gloves and a lead-protective apron if fluoroscopy is being utilised. Moreover, a sterile drape should be placed over the patient with a window exposed over the proposed site of catheter entry (Figure 4). Electrocardiogram monitoring can be useful to detect any ventricular arrhythmias encountered during the procedure.

The patient should be placed in the supine position with the neck turned opposite the site of entry. If possible, the chin should also be slightly elevated. We have found that elderly patients find this particularly uncomfortable. Pillows placed under the head and tilting the head-end of the bed to a Trendelenberg position may resolve such difficulties (vertical head tilt of -15 or -30°). The latter manoeuvre assists in venous filling and thus aids in identification and venepuncture. Otherwise, an alternative entry site should be sought.



Figure 3. The operator needs to ensure asepsis at all times throughout the procedure.



Figure 4. Fenestrated drapes are readily available that can be placed over the procedure site. Care must be taken to minimise patient discomfort, as this will inevitably cover their face.

Once landmarks have been identified and the exposed areas have been cleaned (iodine or chlorhexidine 2%), adequate anaesthesia should be applied with 1% lidocaine through a 25-gauge needle or equivalent. This should be applied generously - initially with a skin wheal or bleb at the entry point and then subcutaneously with USS guidance down to the superior wall of the vein (Figure 5). Visual guidance and intermittent negative suction will reduce the risk of inadvertent intravenous or intraarterial injection. However, if this does occur, the needle should be gently withdrawn until blood is no longer aspirated. From our experience, this is a satisfactory approach and sedation is rarely required. Maintaining visual contact and reassurance during the procedure can avoid the need for sedatives. However, if high levels of anxiety are anticipated, pre-medication with a short-acting benzodiazepine may suffice.

Following this step, a wider-bore 21-gauge needle is attached to a small syringe (five or ten millilitres). The needle should be wide enough to accept a straightened J-curve microwire through its lumen. Ideally, the USS image should incorporate a transverse view with the internal jugular vein centred. The operator should limit the amount of pressure applied on the skin as too much may obliterate a satisfactory image and result in transection of the vein. Aiming for a similar trajectory as during anaesthetic infiltration, the needle is inserted through the skin adjacent to the centre of the USS probe whilst applying negative suction. Entry into the vessel is indicated by free aspiration of blood (Figure 6).

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Figure 5. The operator should use real-time USS guidance for both anaesthetic infiltration and cannulation of the internal jugular vein. The needle in both cases should be placed adjacent to the probe.



Figure 6. Entry into the internal jugular vein will be indicated by free aspiration of blood. If blood fills the syringe in a pulsatile fashion then arterial puncture should be suspected.

Some authorities advocate visualisation of the needle tip in the lumen of the vessel. However this is not always possible, and in our collective opinion aspiration of blood is a more reassuring sign of vessel entry. Carotid artery puncture will result in pulsatile filling of the syringe and the access attempt should be abandoned temporarily and gentle pressure applied over the puncture site for five to ten minutes. A resulting haematoma may compress the vein and reduce visibility.

When aspiration is achieved, the operator should carefully keep the needle in position whilst removing the syringe from the bevel. At this point, the microwire should be introduced through the bevel and passed through freely to enter the vessel (Figure 7). Occasionally, the guidewire may enter into the right ventricle and irritation may result in short bursts of ventricular tachycardia. Simply withdrawing the wire slowly into the right atrium can resolve this. If resistance is encountered then gently withdrawing around one centimetre and twisting the guidewire before reintroducing may help, as the wire may be deflected superiorly within the vein. Otherwise, the syringe should be reapplied and checked to see if blood is freely aspirating. If not, the needle should be completely withdrawn and puncture reattempted. The wire should not be pulled through the needle, as there is a theoretical risk that the sharp bevelled needle can sheer off the tip of the microwire – particularly if a kink had developed [39]. Kinked wires may restrict passage of the catheter and should therefore be replaced with a fresh wire. If despite clearly entering the vessel and obtaining good aspiration flow, guidewire passage fails, then possibilities include stenosis or a collapsing vessel. Such circumstances may be remedied by asking the patient to perform a Valsalva manoeuvre to aid venous filling or using a thinner guidewire coupled with real-time fluoroscopic screening [40].

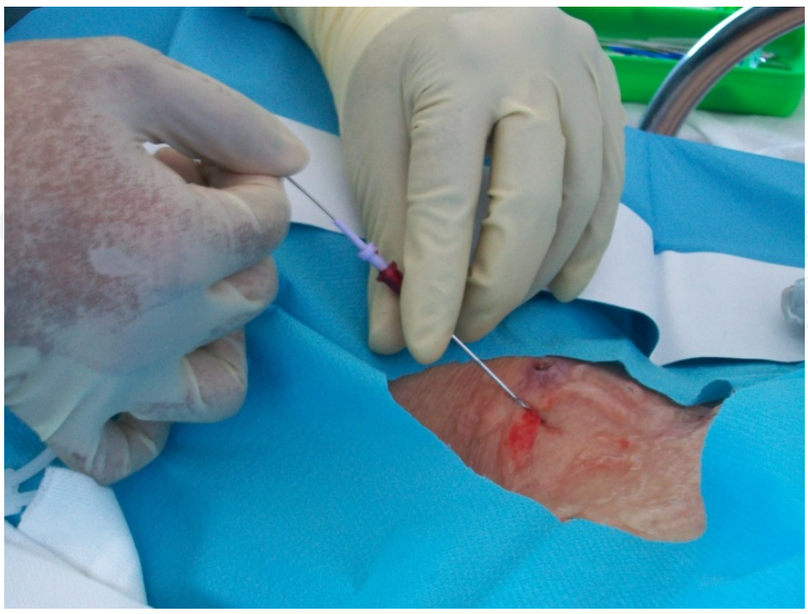


Figure 7. The microwire usually has to be straightened at the J-tip to permit smooth entry through the wide-bore needle.

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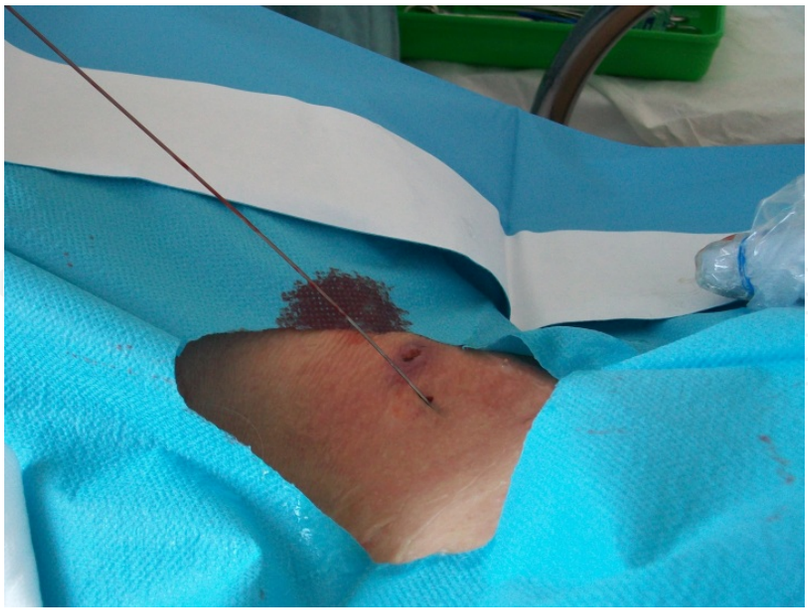


Figure 8. Once in place the needle should be removed over the wire whilst ensuring the wire is stabilised.

If a guidewire has been successfully introduced, the wide-bore needle should be removed over the wire (Figure 8). At this point, fluoroscopy should be used to image the path of the wire, which should lie in the right atrium. A 0.5-1 centimetre horizontal incision is made over the superior end of the wire's exit point and widened with mosquito forceps (Figure 9). Care should be taken that there are no skin tags and the wire freely moves across the incision. A smaller incision can lead to considerable resistance when introducing dilators or a catheter and may result in the guidewire kinking.

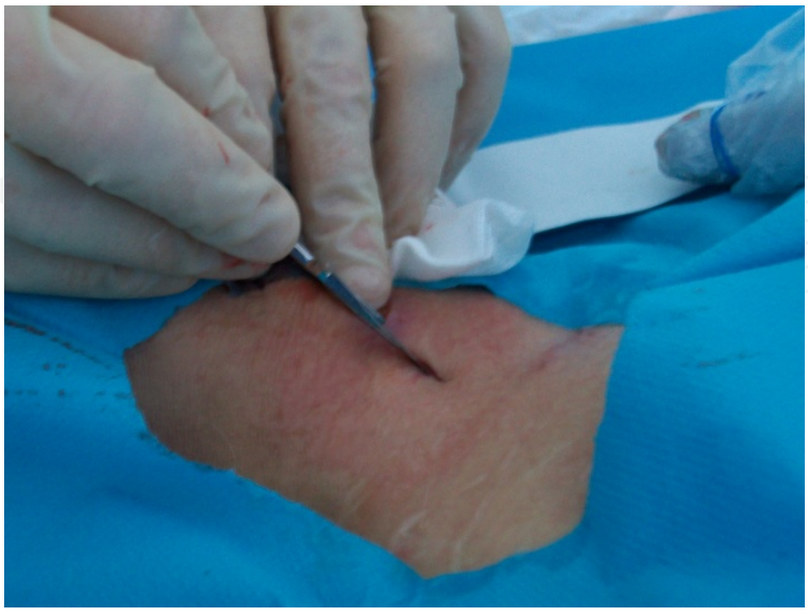


Figure 9. The scalpel blade should be inserted over the superior aspect of the guidewire.

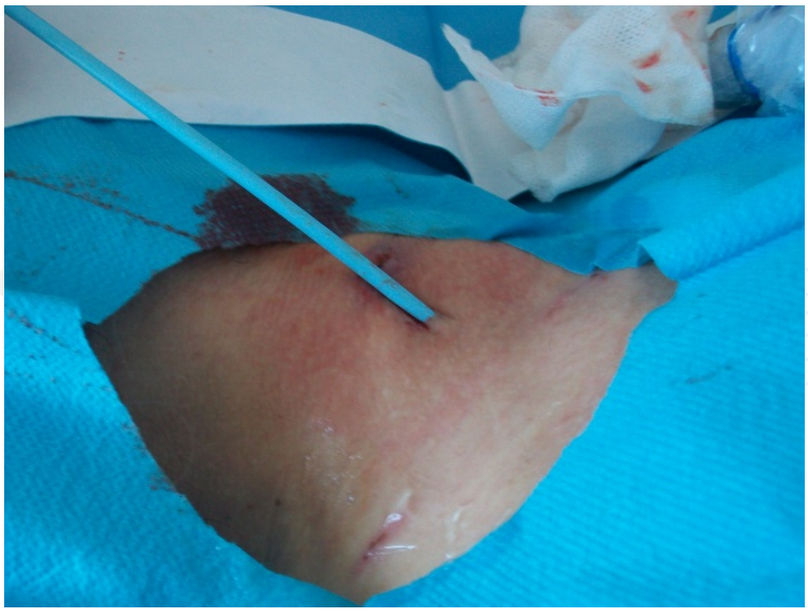


Figure 10. A stiff flexible dilator is placed over the wire to puncture the vein and form a tunnel that will permit smooth passage of the catheter. Knowing how far the dilator needs to be pushed in can be estimated from the distance of the internal jugular vein to the skin using ultrasound.

A stiff dilator is then inserted over the guidewire (Figure 10). There are two aspects to take note at this point: firstly, it is advisable to forewarn the conscious patient that dilator insertion will cause pressure discomfort; secondly, the dilator should be inserted in a firm but smooth motion from the distal (tip) end so as to avoid guidewire kink. Advancing the dilator several centimetres is only required: pushing further may theoretically result in vessel damage – particularly in a left internal jugular approach owing to its tortuosity. Following removal of the dilator heavy bleeding may occur, so pressure over the exit site must be applied.

The catheter should then be placed over the guidewire until its tip is seen protruding from one of the catheter hubs. The remaining length of catheter can then be inserted to its hilt with simultaneous withdrawal of the wire (Figure 11). Free aspiration should be attempted from each hub to ensure smooth flow in and out. If there is resistance, it may indicate that suction of the distal tip against the atrial wall. The catheter should be flushed with saline through each port and a heparin lock solution applied. This may take the form of 5000 iu of heparin diluted 1:5 or a preformed solution with anticoagulant and antimicrobial properties (e.g. Taurolock™). There is evidence that filling the hubs after dialysis with antibiotic solution prevents the formation of a biofilm inside the catheter lumen: biofilms can form within 24 hours after placement and create an opportune environment for bacterial colonisation [41]. The final stages of the procedure should include applying sutures to the entry site and to secure the line (Figure 12). The neck should be cleaned thoroughly and dried before applying adhesive dressing. Sutures should remain in-situ for the duration of catheter use, but be inspected regularly for evidence of infection or suture abscess.

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Figure 11. Once the catheter has been fully inserted to its hilt, flow should be immediately checked and be smooth with little effort required. Any resistance may complicate subsequent dialysis. Testing should be followed with liberal saline flushes.

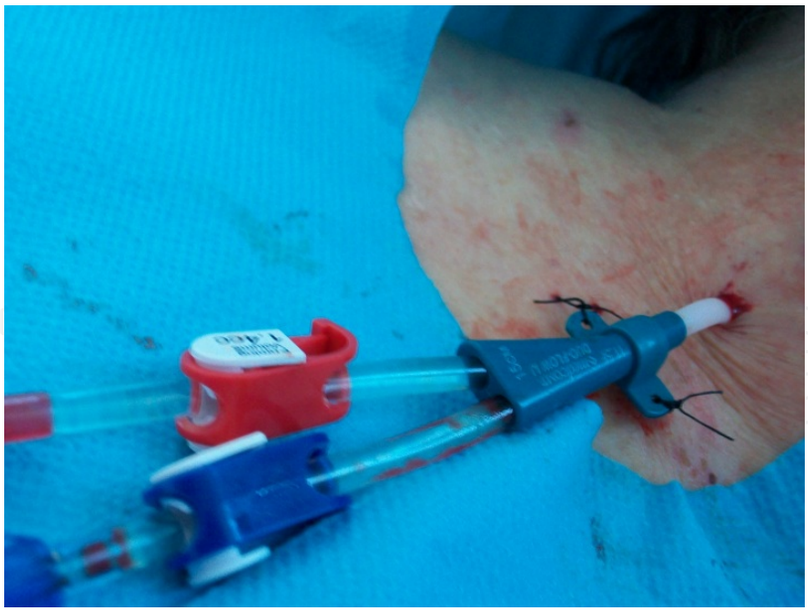


Figure 12. Two sutures should be applied at the butterfly wing as shown to anchor the catheter and avoid displacement.

2.2.3. Tunnelled catheter insertion

Most TCVCs are derived from polyurethane or silicone. This provides good elasticity and enough rigidity to permit high flow rates required during renal replacement therapy. Numerous designs are available but no one specific design shows significant superiority over another [42]. It is useful to have a non-sterile TCVC to assess the length required and location of the intended exit site prior to the actual procedure. Clearly, owing to the tortuous course of the left internal jugular vein, a longer catheter is usually required. Body habitus is also another factor to consider with smaller individuals probably requiring shorter catheter lengths. Additionally, predicting whether the tip will suck against the atrial wall after placement is important as this can influence flow rates.

Essentially, most of the above applies to insertion of TCVCs, though several additional steps during the procedure should be noted. Firstly, once the guidewire has been inserted into the internal jugular vein, the horizontal incision made superior to the wire should be followed by generous widening with a mosquito forceps - prising apart subcutaneous tissue bridges (Figure 13). This is thought to reduce the risk of intractable kinking at the turning point of the catheter.

Secondly, a subcutaneous tunnel has to be created for the entry point for this is usually on the chest wall, and this is best achieved by using a lumbar puncture needle to inject anaesthetic up to the entry point of the internal jugular vein. The catheter is then tunnelled through with gentle pressure using a pliable metal introducer (attached to the catheter tip) out through the entry point incision, adjacent to the guidewire. The tunneller is then disconnected from the catheter. Sometimes, it is preferable to perform a two-stage tunnelling process to form a smooth curved entry into the internal jugular vein, which may reduce chances of kink formation and thus sluggish flow. If a kink is encountered following the procedure, occasionally a gentle pull of the catheter from the proximal (hub) end may resolve this. Once tunnelled, the polyester (Dacron) cuff should lie subcutaneously within the formed tract. Over time, a fibrotic reaction between the cuff and the subcutaneous tissue occurs and thus provides effective stabilisation and a mechanical barrier to infection. If a cuff does not adhere sufficiently, the catheter may become displaced and "fall out". In such cases, no attempt should be made to reintroduce any exposed catheter back into the tract but it should be removed and replaced when convenient.

Finally, TCVC kits usually include several dilators of differing diameter. All should be used to create a satisfactory puncture within internal jugular vein to facilitate insertion. Of note, the catheter tip is inserted into the vein by means of a "pull-apart" introducer/dilator. This is inserted last in a similar fashion to a dilator device, but has a central lumen capable of accommodating the dialysis catheter through into the vein once its central stiff portion has been removed. Sutures (2-0 Prolene) should be applied to the entry point to the internal jugular and proximally at the butterfly wing. The latter sutures can be typically removed after ten days.

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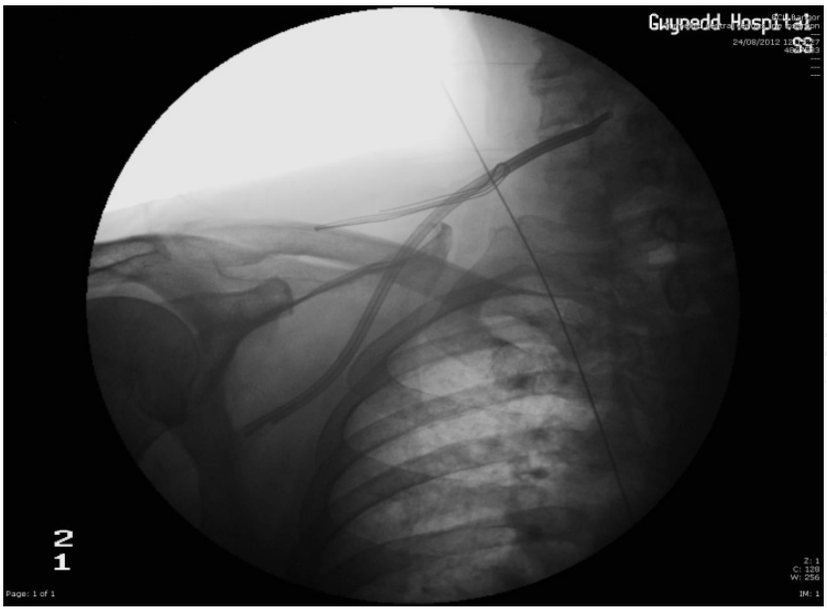


Figure 13. Successful insertion of guidewire into right internal jugular vein. Tunnelled catheter can be seen adjacent, ready for final placement.

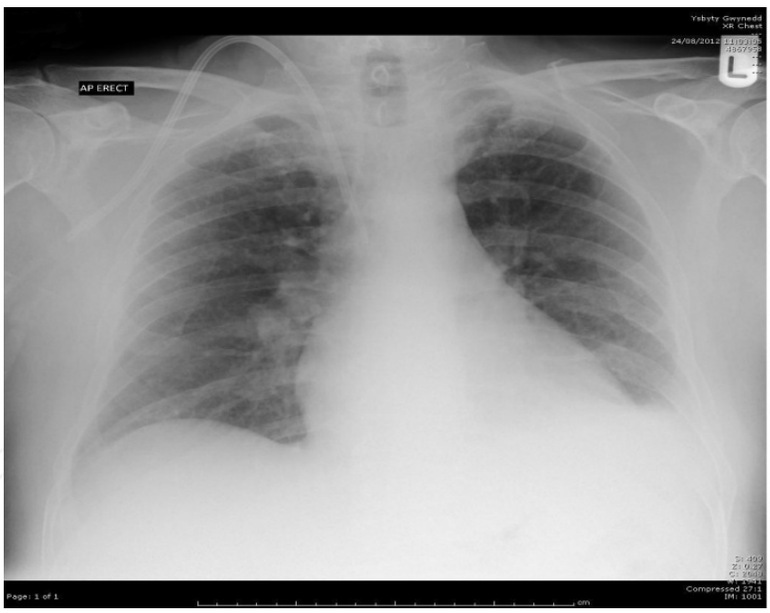


Figure 14. Post-procedure chest radiograph with the tip of the tunnelled catheter within the right atrium.

2.2.4. Post-procedure

A post-procedure chest radiograph is essential to assess the position of the catheter tip and check for any complications (e.g. pneumothorax or inadvertent insertion into azygous vein). Position of the catheter tip is a point of contention: most operators believe the ideal location is the junction of the superior vena cava and right atrium (Figure 14). If the tip is lower it

may induce ectopic beats and possibly occlude if it is opposed against the vessel / atrial wall. If the tip is not in satisfactory position, gentle catheter withdrawal and re-imaging may be attempted. Pneumothorax should be treated by conventional means.

2.2.5. Complications

Bleeding is common early complication that usually responds to firm compression over the exit site for up to 30 minutes. This can be followed by application of a pressure dressing and/or haemostatic wound dressing [43]. If these measures fail, then a purse-string suture can be performed. This should be left for a period of no more than 24 hours. However, in the rare event of persistent bleeding, thrombin can be injected into the tunnel or the catheter should be removed altogether [44]. Additionally, if there has been considerable bleeding during the procedure it is common practice to administer a single dose of vancomycin (1g IV) post-procedure to reduce the possibility of bacteraemia. Although this is widely practised, the evidence-base for this is currently lacking [45].

After each dialysis session, both hubs should be locked with an anticoagulant and/or antimicrobial solution. Various types are available and there is some evidence that citrate-based solution may offer distinct advantages to heparin [46]. If poor access flow occurs, then trial with an infusion of a thrombotic agent (e.g. tissue plasminogen activator 1mg.ml^{-1} or urokinase 5000 IU.ml^{-1}) may be helpful in removing thrombosis within the lumens. Recurrent blockages may respond to low dose warfarin to maintain patency (aiming for an INR of 1.4 – 1.9), but again the evidence for this is very limited at best [47]. Occasionally, poor flow may also result from catheter kink and repositioning the patient during dialysis can be tried. When all these measures fail, catheter removal and replacement is indicated.

Infection is a widely recognised problem with indwelling dialysis catheters – especially long-term tunnelled lines. The prosthetic nature of the catheter promotes formation of biofilms within the lumen and can result in exit site infections or bacteraemia [40]. *Staphyloccoci*, *corynebacterium* and *enterobacter* are common culprits and dialysis units should have protocols in place to treat such infections. In our unit, exit site infection is swabbed for microscopy, culture and sensitivity. If fever is present, peripheral and catheter blood cultures must be taken. Methicillin-resistant *staphylococcus aureus* (MRSA) remains a serious problem in UK dialysis unit [48]. Pending results, appropriate empirical *staphylococcal* antibiotic in the form of vancomycin should be administered as this will cover MRSA and methicillin-sensitive (MSSA) strains. If MRSA is confirmed then intravenous vancomycin should be continued for a minimum of two weeks for exit site infections. Gram-negative cover can also be considered, but this depends upon local microbiological epidemiology. Given that vancomycin is renally excreted, dosing schedules should be based on trough levels every four to seven days, aiming for a therapeutic concentration between 10 to 15 mg.l^{-1}. For MSSA, an oral course of flucloxacillin should suffice for a local exit site infection.

If infection is more severe (e.g. the presence bacteraemia, systemic features of illness or tunnel track infection), lengthy intravenous treatment is recommended. Patients should also be thoroughly examined and appropriately investigated for evidence of bacterial seeding e.g. endocarditis and septic arthritis. Management of other organisms should be discussed with

microbiology services. If despite these measures there is a lack of response and the catheter cannot be salvaged, the removal is the most effective form of treatment [49]. Nonetheless, this often is a last resort option, especially in patients whom achieving any form of vascular access is historically very difficult. There is no benefit in attempting to salvage temporary devices and these should be removed and replaced if required.

Following insertion of all catheter devices, patient education is of paramount importance to ensure longevity and to reduce infection. Keeping the catheter dry is important and ensuring aseptic technique whenever handled – particularly in patients who perform home dialysis. There is limited evidence that *staphylococcal* screening and decolonisation may reduce the incidence of catheter-associated infection, but large trials are lacking to assess the cost-effectiveness of this approach [50]. In general, in-house quality assurance programs should be implemented to ensure best clinical practice with lowest infection rates possible and will require a multidisciplinary approach.

2.3. The role of the vascular access nurse

In 2004, the Department of Health in England and Wales launched The National Service Framework for Renal Services. In this document one of recommendations as a marker of good practice is that all patients with established renal failure receive '*timely preparation for renal replacement therapy*' as well as '*timely and appropriate surgery*' for permanent vascular access which is '*monitored and maintained to achieve it maximum longevity'* [51]. Later, when reviewing the provision of vascular access services and the volume of the workload, a joint report with the Renal Association UK recommended that units providing vascular access for patients appoint a dedicated vascular access co-ordinator to ensure smooth progression throughout the patient pathway [52]. Today, an extensive network of vascular access nurse specialists exist working within UK renal units to improve service delivery with an particular emphasis on minimizing the use of dialysis catheters.

2.3.1. Identification of patients

One of the broad roles of the vascular access nurse is to work closely with other members of the renal team to identify the most suitable type of renal replacement therapy for patients, whilst taking into account the patient's wishes and preferences. Current best practice is that 65% of patients starting HD do so with a fully functioning AVF and that planning should take place when the patient has reached CKD Stage 4 or an eGFR of 30 ml.min.1.73m$^{2\text{-}1}$ or less [53,54]. Through liaising closely with the patient, family and renal team during the early stages of planning allows one to identify potential problems that may contribute to creating access and permit timely, appropriate referral to the surgical and radiological teams. It is suggested that vascular access is created six months prior to the anticipated start of HD or even earlier [55-57]. This period accounts for planning, creation and maturation of the access and any further procedures that may be necessary to ensure functionality [58]. Overall, this strategy enables the delivery of an individualized plan of care.

2.3.2. Information provision

The vascular access nurse can be a valuable source of information and advice. The importance of preserving veins for dialysis access cannot be emphasized enough (Figure 15). As discussed above, patients with CKD undergo frequent blood sampling that damages veins rendering them unsuitable for access creation, and a plan to preserve vessels should be made early on [59,60]. Moreover, following fistula creation, patients and caregivers should be constantly reminded of vascular preservation for future access and inappropriate use of a fistula (Figure 16).



Figure 15. Custom armbands can help warn patients and healthcare staff about vascular preservation for access creation and therefore avoiding venepuncture.



Figure 16. Sadly, this is still a common site where even after fistula creation, vascular access for dialysis is abused. Education of staff is of paramount importance to prevent this potentially catastrophic occurrence.

Patients with CKD often attend multiple hospital clinics and careful planning of appointments by the vascular access nurse to coincide with each other may reduce the number of visits to hospital. One-stop access clinics, whereby the patient is reviewed by the vascular nurse and surgeon, receives Doppler scans of both arms as well an pre-operative assessment, have been shown to greatly reduce the number of hospital appointments [61]. Following AVF creation, studies indicate that there is developmental change from two to four weeks, and that skilled physical assessment can accurately predict its maturity for cannulation [62]. Early follow-up and assessment of the patient by the access nurse is critical to ensure that prompt action and re-referral to the surgeon can be taken should the fistula fail for the initiation of dialysis.

2.3.3. Assessment pre- and post-access creation

By becoming familiar with the patient in the early stages of assessment enables the access nurse to manage the referral process efficiently and to prioritise the surgical waiting list according to the rate of decline in eGFR and patient symptoms. This helps expedite surgery, investigations and revisions according to clinical need, as well as providing a 'familiar face' and a point of contact for the patient.

2.3.4. Access monitoring

Another essential but labour-intensive role of the access nurse is monitoring, surveillance and co-ordination access salvaging procedures within the entire HD population. The use of advanced surveillance techniques are recommended by the Renal Association in addition to systematic observation of access [53]. Although it is accepted that monitoring and surveillance of vascular access is an integral part of HD patient care, evidence in the form of randomized controlled studies is lacking as to the most effective method of access surveillance [59]. Nonetheless, it is accepted that measuring access flow is an accurate predictor of AVF or graft dysfunction and all surveillance methods are directly or indirectly linked to this [53,57]. Many units now use flow-based methods of measuring access flow (QA) and recirculation (such as the Transonic™ ultrasound flow dilution system), that has the advantage of being performed during HD and thus limits patient inconvenience. Access flows of < 400 $ml.min^{-1}$ or < 600 $ml.min^{-1}$ in grafts can indicate stenosis and therefore a high risk of thrombosis. This also can limit blood pump flows (QB) and lead to recirculation – both impacting upon kT/v.

It is important note that access flow readings only represent one aspect of monitoring and that a compete clinical picture is established in conjunction with other information, including: physical examination of the fistula, the presence of cannulation problems, dialysis clearance and the patient's general physical condition. Further investigation is often necessary - initially in the form of USS and then contrast-based fistulograms to establish the presence of a lesion affecting the flow (e.g. stenosis or aberrant tributaries). Indeed, the access nurse has a pivotal role in coordinating these investigations and arranging interventional radiology or surgery if necessary [61].

The success of monitoring and surveillance depends on a team approach with good communication between all members of the renal team and the dialysis nurses who manipulate access on a daily basis [59]. Depending on patient numbers and workload of individual units, the access nurse can be directly responsible or can coordinate with designated dialysis "link" nurses to conduct surveillance. Finally, the patient should be encouraged to familiarize themselves with their vascular access and alert staff to any unexpected changes.

2.3.5. Education

Regular education of staff and patients on access-related issues is essential for preservation, as poor needling techniques can cause damage to fistulas, stenosis and subsequent risk of failure. Written protocols for cannulation of fistulas, handling central venous catheters and physical examination of the fistula prior to cannulation should exist and be managed by the access nurse with clinical competency assessments performed periodically to ensure standards are maintained. The access nurse can also assist with cannulation care planning, difficult cannulations and advising on the most suitable technique for individual patients. For example, it is important to ensure that the fistula is not 'area needled', which can result weakening of the vessel wall and subsequent aneurysm formation [63]. Although the buttonhole technique is currently the favoured cannulation technique preferred by staff and patients, the risk of infection is higher than the more traditional site rotation method [64,65]. Patients should be therefore risk profiled before using buttonholes, and if selected, educated to minimize the risk of sepsis. Notwithstanding, the buttonhole technique does contribute to preservation of the fistula for patients with a limited needling area and is aesthetically more pleasing when body image is an important consideration (Figures 17 and 18). It has also proven to be an integral part of care for our patients on daily home dialysis.

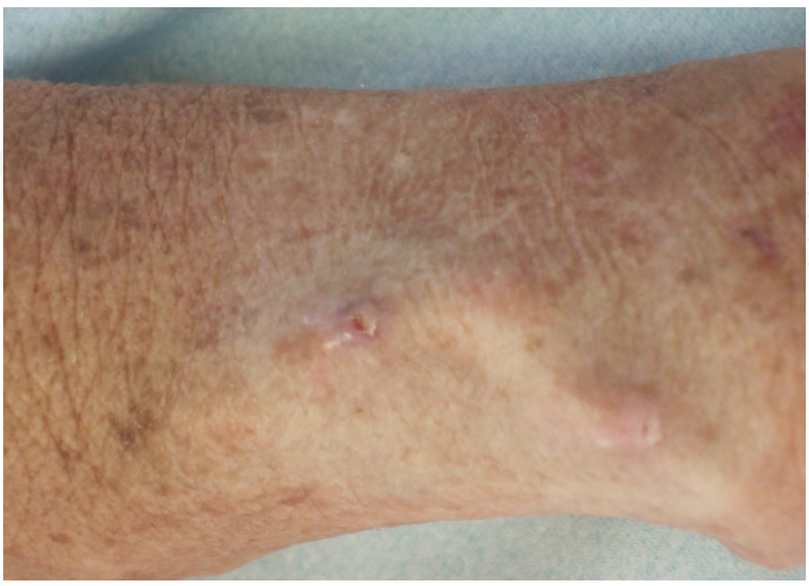


Figure 17. Buttonholes in a 78 year old female patient.

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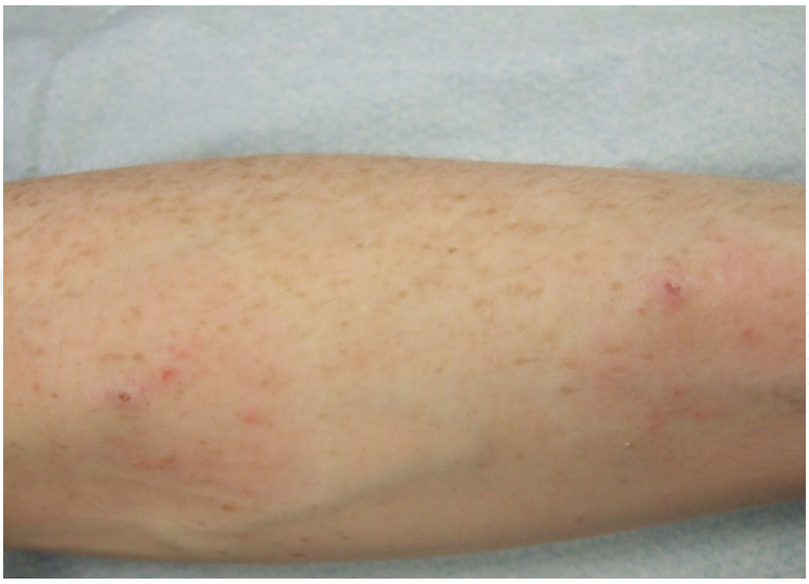


Figure 18. Buttonhole sites after 6 months in 21 year old, needle phobic male patient. Both patients had major issues regarding body image prior to fistula creation.

2.3.6. Vascular catheter care

While it is accepted that vascular catheters should not be actively encouraged as first-line HD access, often the vascular access nurse plays a pivotal role in catheter care. Many of the above principles apply to central venous catheters usage. The main issues concerning the access nurse involve minimizing infections and promptly treating poorly functioning catheters - a relatively common event for HD patients [53]. Regular assessment of catheters can detect failing flow and ensure that prompt action is taken to avoid further dysfunction or complete failure. Similar to AVFs and grafts, protocols should be in place for catheter maintenance and dysfunction as well as for rapid treatment of sepsis - suspected or proven. Increasingly, there has also been development of a more "hands-on" approach encompassing catheter insertion and removal. Within the UK, this has been extended in some units to involve vascular access nurses independently inserting catheters after undergoing a comprehensive training programme, and has the distinct advantage of reducing waiting times and burden on clinical staff [7,66].

2.3.7. Audit and research

Monitoring of access outcomes and documentation allows for future planning and clinical audit. This and research are essential to evaluate outcomes and provide up-to-date, evidence-based care. In an area of dialysis care that is continually evolving, the access nurse needs to be flexible with the role according to the ever-changing needs of the patient and the requirements of the service.

The target of 85% prevalent HD patients dialysing with an autogenous AVF has been a challenge to achieve by many renal units in the UK as indicated by data collected by the national Renal Registry [53,67]. There is now increasing evidence that appointing a vascular access nurse reduces catheter use in favour of autogenous AVFs [68]. In our unit, AVF prevalence has risen from 60% to 82% since appointment in 2009, and statistical analysis of our outcomes indicate that a regular programme of monitoring and surveillance has helped to achieve this and improving dialysis adequacy above the Renal Association standard. This is not only due to the increase in fistula prevalence, but an improvement in the quality and survival of existing fistulae through emphasis on prompt referral for investigation and intervention for poorly functioning ones.

3. Concluding remarks

Vascular access in haemodialysis is crucial step to maintain quality of life once native renal function ceases. The acute setting differs markedly from chronic disease where the patient will encounter numerous specialties and procedures on multiple occasions. The procedures involved are complex and require detailed planning to ensure good outcomes and reduce short- and long-term complications. A multidisciplinary approach is commonplace and roles within the context of vascular access are constantly evolving to optimise care. Implementation of a vascular access nurse ensures that the patient's journey into haemodialysis is a timely one and follow-up care is likewise.

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References

[1] Ricci Z, Cruz DN, Ronco C. Classification and staging of acute kidney injury: beyond the RIFLE and AKIN criteria. Nat Rev Nephrol. 2011;7(4) 201-208.

[2] Lameire N, Van Biesen W, Vanholder R. Electrolyte disturbances and acute kidney injury in patients with cancer. Semin Nephrol. 2010;30(6) 534-547.

[3] Davidson I, Gallieni M, Saxena R, Dolmatch B. A patient centered decision-making dialysis access algorithm. J Vasc Access. 2007;8(2) 59-68.

[4] Smart NA, Titus TT. Outcomes of early versus late nephrology referral in chronic kidney disease: a systematic review. Am J Med. 2011;124(11) 1073-1080.

[5] Eknoyan G, Beck GJ, Cheung AK et al. Effect of dialysis dose and flux on mortality and morbidity in maintenance hemodialysis patients: Primary results of the HEMO study. N Engl J Med 2002;347 2010-2019

[6] Chan MR, Yevzlin AS. Tunneled dialysis catheters: recent trends and future directions. Adv Chronic Kidney Dis. 2009;16(5) 386-395.

[7] Kelly LJ, Buchan E, Brown A, Tehrani Y, Cowan D. Exploring how the development of a nurse-led vascular access service has benefited patients. Nurs Times. 2009;105(24) 16-18.

[8] Cooper BA, Branley P, Bulfone L et al.; IDEAL Study. A randomized, controlled trial of early versus late initiation of dialysis. N Engl J Med. 2010;363(7) 609-619.

[9] Gefen JY, Fox D, Giangola G, Ewing DR, Meisels IS. The transposed forearm loop arteriovenous fistula: a valuable option for primary hemodialysis access in diabetic patients. Ann Vasc Surg. 2002;16(1) 89-94.

[10] Lazarides MK, Georgiadis GS, Antoniou GA, Staramos DN. A meta-analysis of dialysis access outcome in elderly patients. J Vasc Surg. 2007;45(2) 420-426.

[11] Agarwal AK, Patel BM, Haddad NJ. Central vein stenosis: a nephrologist's perspective. Semin Dial. 2007;20(1): 53-62.

[12] Achneck HE, Sileshi B, Li M, Partington EJ, Peterson DA, Lawson JH. Surgical aspects and biological considerations of arteriovenous fistula placement. Semin Dial. 2010;23(1) 25-33.

[13] Palmer SC, Di Micco L, Razavian M et al. Effects of antiplatelet therapy on mortality and cardiovascular and bleeding outcomes in persons with chronic kidney disease: a systematic review and meta-analysis. Ann Intern Med. 2012;156(6) 445-459.

[14] Chung HY, Beheshti MV. Principles of non-tunneled central venous access. Tech Vasc Interv Radiol. 2011;14(4) 186-191.

[15] Jalal DI, Chonchol M, Targher G. Disorders of hemostasis associated with chronic kidney disease. Semin Thromb Hemost. 2010;36(1) 34-40.

[16] Hedges SJ, Dehoney SB, Hooper JS, Amanzadeh J, Busti AJ. Evidence-based treatment recommendations for uremic bleeding. Nat Clin Pract Nephrol. 2007;3(3) 138-153

[17] Santoro A, Canova C, Freyrie A, Mancini E. Vascular access for hemodialysis. J Nephrol. 2006;19(3) 259-264.

[18] Antoniou GA, Lazarides MK, Georgiadis GS, Sfyroeras GS, Nikolopoulos ES, Giannoukas AD. Lower-extremity arteriovenous access for haemodialysis: a systematic review. Eur J Vasc Endovasc Surg. 2009;38(3) 365-372.

[19] Ekbal NJ, Swift PA, Chalisey A, Steele M, Makanjuola D, Chemla E. Hemodialysis access-related survival and morbidity in an elderly population in South West Thames, UK. Hemodial Int. 2008;12(2) S15-9.

[20] Dixon BS, Novak L, Fangman J. Hemodialysis vascular access survival: upper-arm native arteriovenous fistula. Am J Kidney Dis. 2002;39(1) 92-101.

[21] Niyyar VD. Anterior chest wall arteriovenous grafts: an underutilized form of hemodialysis access. Semin Dial. 2008;21(6) 578-580.

[22] Huber TS, Buhler AG, Seeger JM. Evidence-based data for the hemodialysis access surgeon. Semin Dial. 2004;17(3) 217

[23] Allen AW, Megargell JL, Brown DB et al. Venous thrombosis associated with the placement of peripherally inserted central catheters. J Vasc Interv Radiol. 2000; 11(10) 1309-1314.

[24] Marois Y, Sigot-Luizard MF, Guidoin R. Endothelial cell behavior on vascular prosthetic grafts: effect of polymer chemistry, surface structure, and surface treatment. ASAIO J. 1999;45(4) 272-280.

[25] Junglee N, Law B, Bigwood B, Williams D, Jibani M, Macdonald J. The effects of progressive handgrip training on arteriovenous fistula maturation in chronic kidney disease – a pilot randomised controlled trial [abstract]. In: Proceedings of the British Renal Society Conference; 2009 May 2-5; Birmingham, UK.

[26] Rus RR, Ponikvar R, Kenda RB, Buturović-Ponikvar J. Effect of local physical training on the forearm arteries and veins in patients with end-stage renal disease. Blood Purif. 2003;21(6) 389-94.

[27] Nassar GM. Endovascular management of the "failing to mature" arteriovenous fistula. Tech Vasc Interv Radiol. 2008;11(3): 175-180.

[28] Palmer RM, Cull DL, Kalbaugh C et al. Is surgical thrombectomy to salvage failed autogenous arteriovenous fistulae worthwhile? Am Surg. 2006;72(12) 1231-1233.

[29] Saran R, Dykstra DM, Wolfe RA, Gillespie B, Held PJ, Young EW. Dialysis Outcomes and Practice Patterns Study Association between vascular access failure and the use of specific drugs: the Dialysis Outcomes and Practice Patterns Study (DOPPS). Am J Kidney Dis. 2002;40(6) 1255-1263.

[30] Osborn G, Escofet X, Da Silva A. Medical adjuvant treatment to increase patency of arteriovenous fistulae and grafts. Cochrane Database Syst Rev. 2008;(4) CD002786.

[31] Irish A, Dogra G, Mori T et al. Preventing AVF thrombosis: the rationale and design of the Omega-3 fatty acids (Fish Oils) and Aspirin in Vascular access OUtcomes in REnal Disease (FAVOURED) study. BMC Nephrol. 2009;21(10) 1.

[32] Chow J, Rayment G, San Miguel S, Gilbert MJ. A randomised controlled trial of buttonhole cannulation for the prevention of fistula access complications. Ren Care. 2011;37(2) 85-93

[33] Malik J, Tuka V, Kasalova Z et al. Understanding the dialysis access steal syndrome. A review of the etiologies, diagnosis, prevention and treatment strategies. J Vasc Access. 2008;9(3) 155-166.

[34] Field M, Blackwell J, Jaipersad A et al. Distal revascularisation with interval ligation (DRIL): an experience. Ann R Coll Surg Engl. 2009;91(5) 394-398.

[35] Isoda S, Kajiwara H, Kondo J, Matsumoto A. Banding a hemodialysis arteriovenous fistula to decrease blood flow and resolve high output cardiac failure: report of a case. Surg Today. 1994;24(8) 734-736.

[36] Ball LK. The buttonhole technique for arteriovenous fistula cannulation. Nephrol Nurs J. 2006;33(3) 299-304.

[37] NICE. Technology Appraisal 49: Guidance on the use of ultrasound locating devices for placing central venous catheters. http://guidance.nice.org.uk/TA49 (accessed 17 August 2012)

[38] Parienti JJ, Thirion M, Mégarbane B et al; Members of the Cathedia Study Group. Femoral vs jugular venous catheterization and risk of nosocomial events in adults requiring acute renal replacement therapy: a randomized controlled trial. JAMA; 299(20) 2413-2422.

[39] Atkinson JB, Chamberlin KL, de Csepel J, Srikanth M. Overcoming a kinked peel-away sheath during central line implantation. J Pediatr Surg. 1994;29(3) 379-380.

[40] Schnabel KJ, Simons ME, Zevallos GF et al. Image-guided insertion of the Uldall tunneled hemodialysis catheter: technical success and clinical follow-up. J Vasc Interv Radiol. 1997;8(4) 579-586.

[41] Tapia G, Yee J. Biofilm: its relevance in kidney disease. Adv Chronic Kidney Dis. 2006;13(3) 215-224.

[42] Tal MG, Ni N. Selecting optimal hemodialysis catheters: material, design, advanced features, and preferences. Tech Vasc Interv Radiol. 2008;11(3) 186-191.

[43] Schwarz T, Rastan A, Pochert V et al. Mechanical compression versus haemostatic wound dressing after femoral artery sheath removal: a prospective, randomized study. Vasa. 2009;38(1) 53-59.

[44] Damm C, Degen H, Stoepel C, Haude M. Management of a catheter-induced rupture of a pulmonary artery]. Dtsch Med Wochenschr. 2010;135(39) 1914-1917.

[45] Salman L, Asif A. Antibiotic prophylaxis: is it needed for dialysis access procedures? Semin Dial. 2009;22(3) 297-299.

[46] Moran JE, Ash SR; ASDIN Clinical Practice Committee. Locking solutions for hemodialysis catheters; heparin and citrate--a position paper by ASDIN. Semin Dial. 2008;21(5) 490-492.

[47] Wilkieson TJ, Ingram AJ, Crowther MA et al. Low-intensity adjusted-dose warfarin for the prevention of hemodialysis catheter failure: a randomized, controlled trial. Clin J Am Soc Nephrol. 2011;6(5) 1018-1024.

[48] Fluck R, Wilson J, Tomson CR. UK Renal Registry 12th Annual Report (December 2009): chapter 12: epidemiology of methicillin resistant Staphylococcus aureus bacteraemia amongst patients receiving dialysis for established renal failure in England in 2008: a joint report from the UK Renal Registry and the Health Protection Agency. Nephron Clin Pract. 2010;115 Suppl 1 c261-270.

[49] Sychev D, Maya ID, Allon M. Clinical management of dialysis catheter-related bacteremia with concurrent exit-site infection. Semin Dial. 2011;24(2) 239-241.

[50] Simor AE. Staphylococcal decolonisation: an effective strategy for prevention of infection? Lancet Infect Dis. 2011;11(12) 952-962.

[51] Department of Health. The National Service Framework for Renal Services; part one dialysis and transplantation. http://www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/DH_4070359 (accessed 17 August 2012).

[52] The Renal Association. The organization and delivery of the vascular access service for maintenance haemodialysis patients: Report of a joint working party of the Renal Association, Vascular Society of Great Britain and Ireland and the British Society of Interventional Radiology. http://www.vascularsociety.org.uk/library/vascular-society-publications.html (accessed 17 August 2012).

[53] Renal Association. Vascular Access for Haemodialysis: 2011 Guidelines. http://www.renal.org/Clinical/GuidelinesSection/VascularAccess.aspx (accessed 17 August 2012).

[54] National Kidney Foundation. KDOQI GUIDELINES: Clinical Practice Guidelines and Clinical Practice Recommendations 2006 Updates: Haemodialysis Adequacy. http://www.kidney.org/professionals/KDOQI/guideline_upHD_PD_VA/ index.htm (accessed 17 August 2012)

[55] Malorvrh M. Approach to patients with end–stage renal disease who need an arteriovenous fistula. Nephrol Dial Transplant,. 2003;18(suppl 5) v50-52

[56] Tordoir J, Canaud B, Haage P et al. EBPG on Vascular Access. Nephrol Dial Transplant. 2007;22(Suppl 2) ii88-117.

[57] Grieve R. Developing a dialysis access service: the role of the dialysis access nurse. Journal of renal nursing. 4(3).

[58] Ball L. Practical assessment of new arteriovenous fistulae. http://www.touchbriefings.com/pdf/2598/ball.pdf (accessed 17 August 2012)

[59] Kumbar L, Karim J, Besarab A. Surveillance and monitoring of dialysis access. Int J Nephrol. 2012;2012: 649735. Epub 2011 Nov 22 (accessed 17 August 2012)

[60] Gelbfish GA. Clinical surveillance and monitoring of arteriovenous access for hemodialysis. Tech Vasc Interv Radiol. 2008;11(3) 156-166.

[61] Cornall A, Thomas P. The role of the vascular access nurse specialist', Journal of renal nursing. 1(1).

[62] Whittier WL. Surveillance of hemodialysis vascular access.Semin Intervent Radiol. 2009;26(2) 130-138.

[63] Ball LK. Improving arteriovenous fistula cannulation skills. Nephrol Nurs J. 2005;32(6) 611-617.

[64] Doss S, Schiller B, Moran J. Buttonhole cannulation – an unexpected outcome. Nephrol Nurs J. 2008;35(4) 417-419.

[65] Ball L, Mott S. How do you prevent indented buttonhole sites? Nephrol Nurs J. 2010;37(4) 427-431.

[66] Kelly L. Crossing professional boundaries: nurse-led catheter insertion. Nursing Management. 2010;16(6).

[67] UK Renal Registry. UK Renal Registry Report 2011. http://www.renalreg.com/Reports/2011.html (accessed 17 August 2012).

[68] Polkinghorne KR, Seneviratne M, Kerr PG. Effect of a vascular access nurse coordinator to reduce central venous catheter use in incident hemodialysis patients: a quality improvement report. Am J Kidney Dis. 2009;53(1) 99-106.

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