Clin Kidney J (2015) 8: 278–281
doi: 10.1093/ckj/sfv022
Advance Access publication 15 April 2015

Vascular Access

CKJ Review

Preoperative assessment and planning of haemodialysis vascular access

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Abstract

Effective haemodialysis (HD) requires a reliable vascular access (VA). Clinical practice guidelines strongly recommend the arteriovenous fistula (AVF) as the preferred VA in HD patients. The creation of an AVF should be promoted in all eligible patients who choose HD, as it improves outcomes and reduces costs when compared with central venous catheters. Fistula eligibility is a 'work in progress'. Three steps in order to increase the pool of eligible patients can be individualized: (i) process of care, which includes three fundamental items: the VA team, early VA education and timely VA surgery referral; (ii) preoperative evaluation; (iii) surgical strategy. Nephrologists should be able to play a leading and coordinating role of the VA team. They should design a plan that identifies a sequence of options that can be used to provide adequate renal replacement therapy throughout the life span of every end-stage renal disease patient. The main points of this strategy are (i) early vascular education, in which a 'save the vein program' should always be implemented; (ii) timely VA surgery referral and preoperative evaluation: careful examination of arterial and venous beds is mandatory before VA placement; physical examination in addition to colour Doppler ultrasound mapping improves AVF outcomes; (iii) surgical strategy: a successful VA strategy must take into account vascular anatomy, clinical factors and prognosis.

Keywords: arteriovenous fistula; central venous catheter; haemodialysis; vascular access; vascular mapping

Introduction

Effective haemodialysis (HD) requires a reliable vascular access (VA). Criteria for the ideal VA device are to be safe; to have reliable performance and adequate blood flow rate (Qa); to have durable long-term function; to be internal; to be free from complications; to be acceptable to the patient; to be simple to create; to be inexpensive to create and maintain [1]. Clinical practice guidelines strongly recommend the arteriovenous fistula (AVF) as the preferred VA in HD patients, followed by arteriovenous grafts, with central venous catheters (CVCs) being the least preferred access, although this recommendation is not based on the top-level evidence [2–4]. The creation of an AVF should be promoted in all eligible patients who choose HD, as it improves outcomes and reduces costs when compared with CVCs [5]. However, several hurdles must be overcome successfully to ensure that a patient initiates dialysis with a mature fistula [6]. Fistula eligibility is a 'work in progress'. In fact, determinates for fistula eligibility continue to be challenging. The creation and use of a fistula require the complex integration of patient, biological and surgical factors. Selecting the appropriate person for the appropriate VA should be a key priority for HD programmes to maximize access functionality and minimize patient morbidity [7]. Three steps in order to increase the pool of eligible patients can be individualized:

1. process of care, which includes three fundamental items: the VA team, early VA education and timely VA surgery referral
2. preoperative evaluation
3. surgical strategy

Process of care

The VA team

The successful creation and use of an arteriovenous VA requires a coordinated, educated, multidisciplinary team to ensure an optimal VA for each patient [8]. The VA team must promote staff and patient education, timely surgical referral, preoperative evaluation, VA creation and subsequent follow-up. Nephrologists should be able to play a leading and coordinating role in the VA team because they bear the ultimate responsibility for the outcomes of their

patients [8]. They should also promote a patient-centred culture of VA, in which clinical parameters, such as age and multiple comorbid conditions, prognostic parameters such as renal progression and overall survival, and vascular anatomy should always guide the choice of the best VA for the patient [9]. For example, in the context of the patient-centred approach to the choice of dialysis access an important point to be stressed is that patients who start dialysis tend to be sicker and have multiple medical encounters, which may necessitate the placement of a peripherally inserted central catheter (PICC) or CVC. A discussion in the VA team about the selection of patients who might not benefit from fistula creation and thus would be less restricted in terms of PICC/CVC is fundamental for the outcomes of the patients. In conclusion, a patient-centred approach to the choice of dialysis access that incorporates a balance between recent evidence from the literature and patient preferences may be preferred to the current 'fistula first' focus in VA choice [10].

Early VA education

Patient education programmes on VA are associated with increased arteriovenous VA use at dialysis initiation. Education should be tailored to patient goals and preferences with the understanding that experiential education from patient to patient is far more influential than that provided by the healthcare professional. VA education for the nephrologists should focus on the systematic and patient-level barriers in achieving a functional VA, with specific components relating to VA creation, maturation, and cannulation that consider patient goals and preferences. As far as the nursing staff is concerned, a deficit in nursing skills in the area of assessment and cannulation can have devastating consequences for HD patients [11]. As said, the education programme should be continuous, multidisciplinary, structured, and tailored to patient goals and preferences [11]. However, it may happen that the nephrologist and/or dialysis staff preferences could contribute to a facility 'VA culture' that influences patient preference for the type of VA [12]. Finally, it must not be forgotten that the placement of a PICC and/or CVC contributes to venous sclerosis and reduces the suitability of the patient's vasculature for fistula placement. Clinical practice guidelines have recommended against placement of PICCs and subclavian catheters to minimize central venous stenosis and other complications that may otherwise forbid or complicate future fistula placement [2, 13]. Notably, guideline 1.2 of the Kidney Disease Outcomes Quality Initiative (KDOQI) advises not to use forearm and upper-arm veins in patients with chronic kidney disease (CKD) stage 4 or 5 for venipuncture or for placement of intravenous catheters, subclavian catheters or PICCs (evidence level B) [2]. Several nephrology practices have recommended that patients with an estimated glomerular filtration rate (eGFR) <30 mL/min wear a 'medic-alert bracelet' that signifies to health professionals to save the veins in the arm and avoid PICC lines or other indwelling catheters [14].

Timely VA surgery referral

Existing guidelines for AVF referral are inconsistent and based on expert opinion [15]. During the past decade, the KDOQI recommendations have varied from referral for AVF creation when HD is anticipated within 12 months (2000) [16], within 6 months [2], or when eGFR decreases to <30 mL/min/1.73 m^2 (2002) [17]. In 2006, the Canadian Society of Nephrology guidelines suggested referral at an eGFR of 15–20 mL/min/1.73 m^2 in patients with progressive CKD [3]. A decision analysis on when to create the VA is not easy, even if it is evident that appropriate predialysis care and timely VA placement reduces complications, morbidity and mortality [18]. However, HD initiation is unplanned in up to 50% of patients, primarily because of late end-stage renal disease (ESRD) diagnosis or referral, urgent medical indications, or acute intercurrent illnesses in a patient with CKD [19]. Unplanned dialysis starts are associated with higher catheter use. Among incident US HD patients, AVF use remains low, with ∼70% initiating HD therapy with a catheter (60% starting with catheter when having ≥4 months of predialysis nephrology care) [20]. A recent multicentre cohort study tried to identify the perceived barriers to a timely AVF creation [21]. They included lack of formal policies for patient referral, long wait times for surgical review and access placement, and lack of a patient database for management purposes. First assessment by a nephrologists <12 months before dialysis therapy start was an independent predictor of catheter use (OR, 8.71; $P < 0.0001$). Characteristics of the best performing centres included the presence of a formalized predialysis pathway with a centralized patient database and low nephrologist and surgeon to patient ratios [21]. Recent published registry data suggest that barriers to adopting a fistula-first policy in Europe are suboptimal access to surgical resources, the lack of dedicated training, a limited routine use of preoperative diagnostic imaging and finally the patient characteristics [22].

Preoperative evaluation

The preoperative evaluation is the cornerstone of VA planning. The goal of preoperative evaluation is to design a sequence of surgical options for providing VA throughout the life span of an ESRD patients [23]. History and clinical examination should be performed before placement of a permanent VA. VA history, prior central venous access, central lines and cardiac devices should be considered. Previous VA, comorbidities, as diabetes mellitus, peripheral vascular disease and congestive heart failure play a crucial role in the surgical strategy, as these factors could influence proper functioning of the inflow, outflow, or the conduit of AVF. Coagulation disorders and thrombophilia should also be ruled out. Careful examination of arterial and venous beds is mandatory before VA placement. Arterial evaluation for AVF should consider pulse examination, differential pressure, palmar arch patency and arterial size. The axillary, brachial, radial and ulnar pulses should be examined in both upper extremities. The quality of these pulses should be scored as either normal, diminished or absent. Differences in systolic blood pressure between the two arms should be reported and graded. A difference of 20 mmHg or greater in systolic blood pressure is suggestive of subclavian artery stenosis in the low pressure arm. The modified Allen test is used to determine competence of the palmar arch. In order to complete the arterial evaluation, the arterial anatomy must be imaged in order to determine if it is suitable. Physical examination of the venous system should be carried out in a warm room with outflow obstruction so as to dilate the veins of the arm adequately for evaluation. A luminal diameter of 2.5 mm or greater at the anastomosis point, absence of obstruction, a straight segment for cannulation, to be

within 1 cm of skin surface and to have continuity with proximal central veins are venous requirements for AVF [24]. Preoperative colour Doppler ultrasound (CD-US) should be performed where there are no obvious veins on clinical examination, or concerns about size or patency exist [25]. Vessel mapping has been highly encouraged and current international guidelines support the routine use of CD-US before AVF surgery [4]. The goal is to achieve satisfactory arterial inflow and a compliant outflow vein by selecting the optimal location of the arteriovenous anastomosis, especially in patients with diabetes mellitus, obesity, in the elderly and in patients with compromised vasculature. Several anatomic parameters, including feeding artery internal diameter, resistance index, arterial blood flow before and after reactive hyperaemia test and internal diameter of the vein before and after proximal vein compression have been proposed to evaluate vessel suitability [26]. Although vessel mapping has many potential benefits, there is still no evidence that pre-surgical evaluation leads to an increase in the primary patency of AVFs. Our opinion is that the gap between the value of preoperative evaluation and the missing maturation mainly depends on the experience of the VA surgeon [27]. A very recent randomized controlled trial (RCT), comparing a selective and a routine policy of CD-US before AVF surgery, found no significant differences in primary patency and complication rates [28]. On the contrary, another RCT supported the use of CD-US over physical examination alone [29]. In an ideal setting the evaluator and the surgeon are the same individual, but this is not mandatory as long as the information is shared [30]. Finally, CD-US parameters may be relevant in the construction of a patient-specific haemodynamic computational model. This innovative approach may help the VA surgeon to plan the most appropriate fistula configuration to optimize access Qa for HD, potentially reducing the incidence of VA dysfunctions [31]. Venography or another imaging modality such as computed tomography or magnetic resonance imaging should be used when there is a risk of central venous stenosis. The effects of radiographic contrast on renal function should also be taken into account.

Surgical strategy

The elderly and patients with limited life expectancy may be less likely to benefit from an AVF first approach. These patients may be more likely to die before benefiting from an AVF and are more likely to experience primary failure of an AVF [32]. This is the reason why elderly patients with CKD could be referred later to reduce the risk of creating an AVF that is never used [33]. If these factors are considered, arteriovenous grafts, and in some cases CVCs, become a valid alternative form of VA [32]. Patients may have strong opinions about each type of VA, leading to a preference for alternative forms of access [10]. A non-selective 'fistula first' approach among certain populations, such as elderly patients, may be particularly ill advised given low fistula functionality and high patient mortality in this group [32]. Physicians need to determine the ideal location for fistula creation as this may influence the maturation and patency of the fistula. Several authors have highlighted the problem of early failure, which may span from 20 to 60% [34]; in promoting fistula placement and use, it would be ideal to predict which patients would benefit from a fistula that would mature successfully. A scoring system has been derived with the ability to predict the likelihood of failure to mature dependent on the patient's clinical profile including factors such as age (>65 years), coronary artery disease, peripheral vascular disease, and race [35]. Recently, the Hemodialysis Fistula Maturation Group designed a study to elucidate clinical and biological factors associated with fistula maturation outcomes [36]. The majority of CKD patients have an anatomy suitable for AVF creation [37], although the aging incident ESRD population might require different strategies in order to minimize risk of failure and number of surgical procedures. A decision-making tree based on patient characteristics and suitable vessels with a sequence of options to provide durable access in a timely manner should be pursued. In this case, the bend of the elbow area is of great strategic interest for VA surgery. In this region, arteries of adequate size and less affected by atherosclerotic processes, the venous network connecting the forearm and the arm and presence of a patent perforating vein of the elbow allow the surgeon great flexibility in the type of AVF to construct [38]. However, a VA conundrum does exist, as the distal VA more likely results in lower Qa and high incidence of early non-function, whereas the proximal VA more likely results in very high Qa, increasing the risk of steal syndrome and congestive heart failure [39]. It seems to be the art of access surgery to place a fistula in the proximal forearm/elbow region by creation of a small arteriovenous anastomosis in the presence of vessels with larger diameters to try to reduce the rate of high-flow phenomena.

Conclusions

Effective HD requires a reliable VA. Clinical practice guidelines strongly recommend the AVF as the preferred VA in HD patients. The creation of an AVF should be promoted in all eligible patients who choose HD, as it improves outcomes and reduces costs when compared with CVCs [5, 40]. Fistula eligibility is a 'work in progress'. Nephrologists should be able to play a leading and coordinating role of the VA team [8]. They should design a plan that identifies a sequence of options that can be used to provide adequate renal replacement therapy throughout the life span of every ESRD patient [11]. The main points of this strategy are (i) early vascular education, in which a 'save the vein programme' should always be implemented; (ii) timely VA surgery referral and preoperative evaluation: careful examination of arterial and venous beds is mandatory before VA placement; physical examination in addition to CD-US mapping improves AVF outcomes; (iii) surgical strategy: a successful VA strategy must take into account vascular anatomy, clinical factors and prognosis. We do not have the old patient, the female patient, the diabetic patient. The by far best VA will result from respecting the individual conditions of the patient in front of us.

Conflict of interest statement. None declared.

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Received for publication: 19.2.15; Accepted in revised form: 19.3.15