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Vascular Mapping: Does It Help To Maximize Fistulae Placement?

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Abstract

The population of patients with ESRD in the United States is progressively increasing, with hemodialysis (HD) as the major mode of renal replacement therapy. The National Kidney Foundation's Dialysis Outcomes and Quality Initiative and the Fistula First Initiative recommend increasing the use of arteriovenous fistulae (AVF) in both incident and prevalent hemodialysis patients. One measure proposed is the use of pre-operative vascular mapping to assess the upper extremities for the presence of suitable vessels prior to the surgical creation of an AVF among both pre-dialysis CKD and ESRD patients on HD. This article aims to review the literature on vascular mapping, including the various techniques; their advantages and disadvantages; and whether they help to maximize the AVF creation rate as well as increase the use of AVF in the HD population.

Keywords

Venous mapping; Hemodialysis

The population of patients with ESRD in the United States is progressively increasing, with hemodialysis as the major mode of renal replacement therapy.[1] Of the 3 types of hemodialysis vascular access, arteriovenous fistulae (AVF) have higher patency rates,[2] lower infection rates,3 and lower overall costs1 than either grafts or catheters. As a result, the National Kidney Foundation's Dialysis Outcomes and Quality Initiative recommends that AVF be placed in 50% of all incident and 40% of all prevalent dialysis patients.4 The Fistula First Initiative, jointly formed by the Center for Medicare and Medicaid Services and the ESRD networks to further implement this goal, has increased the target, suggesting that 66% of prevalent hemodialysis patients use an AVF by the end of this year.[5]

Despite these recommendations, the majority of patients initiate hemodialysis with a central venous catheter as their access.1,[6] This may, in part, be attributed to the fact that AVF have a high rate (20%-50%) of primary failure that precludes their successful use for dialysis.[7] In addition, surgeon selection may have a significant impact on the rate of placement and maturation of an AVF.8 Frequent phlebotomies, peripherally inserted central catheters lines,

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9 and a high prevalence of comorbid conditions including diabetes, obesity, and vascular disease10 in this high-risk population may negatively impact the vasculature and contribute to early AVF dysfunction. Consequently, the selection of suitable vessels by preoperative vascular mapping is recommended before AVF creation for both predialysis CKD and ESRD patients on hemodialysis. This article aims to review the literature regarding preoperative vascular mapping and whether it promotes AVF creation and increases AVF use.

The Techniques

Vascular mapping involves evaluation of both arterial and venous upper-extremity systems before access placement. One of 3 techniques may be used: physical examination, ultrasonography, and angiography.

Physical Examination

A simple bedside assessment may be performed to evaluate the patency of the arterial and the venous systems. A tourniquet is placed at the upper extremity, and the veins are inspected to assess the caliber, the length of a straight venous segment suitable for cannulation, and the distance of the vein from the skin surface.[11] Arterial evaluation includes the documentation of equally strong pulses and differential blood pressure measurements in both extremities. The Allen test should be performed before the creation of any forearm AVF to assess the patency of the palmar arch. Although an upper-extremity physical examination can be valuable, when used alone, it may be inadequate to identify suitable vasculature, particularly in obese patients or those with a history of prior vascular access, and is often supplemented with additional techniques, such as ultrasonography.[12]

Ulrasound Examination

Ultrasonography provides a noninvasive and objective assessment of the arterial and venous systems before AVF creation. The preoperative criteria currently thought to promote successful AVF maturation include a minimal arterial diameter of 2.0 mm and a minimal venous diameter of 2.5 mm identified in either upper extremity.[13] The technique for vessel ultrasonographic imaging is well detailed in prior publications and the salient points are as follows.[7,14,15] The forearm is evaluated first, with the patient's arm comfortably positioned approximately 45° from the body. Evaluation of the upper-extremity arteries includes the measurement of internal diameter, wall thickness, arterial flow, and the presence of calcifications and/or other abnormalities. Both radial and ulnar arterial diameters are evaluated and if neither is 2.0 mm or larger, and the arteries are not suitable for forearm AVF creation, the brachial artery is then assessed with similar measurements. Additional ultrasono-graphic parameters that may aid the surgeon include measurement of vessel depth and Doppler flow through the vessel.

Similarly, to visualize the venous system, the entire upper extremity is evaluated, starting from the cephalic vein in the forearm to the cephalic and basilic veins in the upper arm. A tourniquet is sequentially placed at the midforearm, antecubital area, and at the upper arm, and the cephalic, basilica, and brachial vein diameters are measured throughout their course up to their insertion into the subclavian or axillary veins. The draining and central veins are assessed for stenosis or thrombosis by analysis of the waveform for changes in respiratory phasicity and transmitted cardiac pulsatility. However, it is important to note that ultrasonography offers only indirect evaluation of central venous vasculature; therefore, additional techniques may be needed, particularly among patients with a history of central venous catheter use.

Angiography

Vascular mapping can also be conducted via radiocontrast administration,[11,16] although it is primarily the veins that are evaluated with this technique. A peripheral vein on the dorsum of the hand is cannulated, and the arm is then placed in the anatomic position. Sequential tourniquets are then applied, one at the elbow and the other at the axilla. Low isoosmolar contrast diluted with normal saline is injected through the cannula, and images are obtained throughout the course of the veins using calibrated pulse fluoroscopy. The lower tourniquet may be removed once the forearm is examined to allow contrast to pass into the upper arm. The criteria used to determine suitability of veins for AVF placement are the same as those for ultrasonography[13]: vein diameters of at least 2.5 mm, a 6-cm long straight cannulation segment, and patent draining and central veins. It is useful that both the cephalic and basilic venous systems be imaged to delineate relevant anatomy.

The Evidence

Is One Technique of Vascular Mapping Better Than Another?

To date, no randomized studies have compared the various techniques for AVF vascular mapping. Nonetheless, each technique has advantages in certain clinical settings. A detailed and focused physical examination alone may suffice by using clearly defined criteria and careful clinical examination. In a retrospective comparison of 2 surgical practices, preoperative duplex ultrasonography resulted in a significant decrease in AVF creation when compared with physical examination.17 The authors speculated this to be a consequence of underestimation of cephalic vein size by ultrasonography. In a European analysis of 145 consecutive patients referred for vascular access surgery, 106 patients (73%) proceeded to vascular access surgery on the basis of clinical examination alone, with favorable (77%) subsequent patency results.[18] However, because an increasing proportion of the hemodialysis population in the United States has multiple comorbidities that may affect the vasculature as well as a high prevalence of central venous catheter use, physical examination alone may be insufficient in the vast majority of these patients. In another recent study, the authors reported that suitable veins for AVF placement were clinically visible in only 54 of 116 patients (46.5%). The remaining 62 patients then underwent ultrasonographic examination and a majority (48 patients, 77.4%) were found to have adequate veins for successful AVF creation.12 Therefore, ultra-sonography has the advantage of providing noninvasive assessment of both venous and arterial systems as well as indirect assessment of central venous patency, without exposure to radiation or potentially nephrotoxic contrast.

Angiography offers the advantage of direct imaging of the central veins and is often used in patients with a history of long-term central venous catheter use. Nevertheless, the administration of radiocontrast material does expose the patient to the risk of potential nephrotoxi-city. Recent data have shown that small doses of low iso-osmolar contrast agent for venous mapping may be safe in patients with stages 4 and 5 CKD.[19,20] However, larger studies with long-term follow-up are needed before establishing the safety of contrast in this high-risk population.

Does Vascular Mapping Help To Maximize AVF?

It is important to differentiate an increase in AVF creation from an increase in mature, usable fistulae. In a key report showing the benefit of preoperative ultrasonography, the authors conducted a historic cohort study, comparing primary failure rates and patency rates of AVF before and after the institution of ultrasonographic assessment of the upper extremity vasculature.[13] The protocol resulted in a significant increase in the creation and use of AVF, with a reduction in early AVF failure rates and an increase in cumulative AVF patency. Other researchers have observed similar results after the implementation of the

various techniques for preoperative evaluation, including physical examination, ultrasonography, angiography, or a combination thereof as well as institution of a comprehensive multipronged approach to maximize AVF placement.[14,21–26]

One would assume that a preoperative strategy to identify suitable vessels for AVF creation would translate into decreased early failure rates and an increased proportion of prevalent patients dialyzing with an AVF, but this may not always be the case. In a recent study, routine preoperative vascular mapping resulted in a marked increase in AVF creation and an increased maturation rate for forearm AVF; however, it did not improve the maturation of upper arm AVF.[22] In a different study, the implementation of preoperative ultrasonography and angiography to aggressively increase AVF creation resulted in a greater number of AVFs, but had the unintended consequence of reducing the AVF maturation rate from 73% to 57%.[27] The authors attributed the decline to a change in practice patterns, with more complex surgeries being performed in the study group as compared with historic controls. Furthermore, they did not routinely perform ultrasonography in all patients and reserved the technique for those patients in whom physical examination was inadequate to identify suitable vessels for AVF placement. A synopsis of the evidence in this field is summarized in Table 1. In most cases, the primary outcome of previous studies has been AVF creation, rather than AVF maturation or usability, and only 2 of the 12 previous studies report favorable outcomes related to venous mapping and AVF maturation. It must also be noted that the studies showing a benefit of preoperative mapping are not randomized and were published in parallel with the promotion of AVF creation by major national initiatives.[4,5]

Conclusions and Future Directions

Preoperative vessel mapping increases AVF creation,[13,14,21,23–26] although there is limited and conflicting evidence regarding the effect of vessel mapping on AVF maturation.[22,27] Currently, there is no evidence to support one vessel mapping technique over another; therefore, we believe that the technique used should be individualized to the patient, with careful consideration of the advantages and disadvantages of each method. Selective, rather than the routine use of ultrasonography, in patients with poorly defined vessels on physical examination may limit costs and at the same time expedite placement of fistulae by early referral for surgery.[18] Although minimal vessel diameter criteria have been established for ultrasonography,[13] these clearly have limitations, as evidenced by the poor AVF maturation rates reported in the DAC study; therefore, variables including resistive indices, internal vessel diameter, and blood flow before and after reactive hyperemia might be considered in order to maximize AVF placement and maturation.[15,28,29] Prospective studies are needed to further delineate the impact of these measures on the creation of mature, functional AVF. Future research should focus on prospective, randomized controlled trials to evaluate the efficacy of preoperative mapping techniques on the creation, maturation, and patency of AVF.

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Table 1

Effect of Preoperative Vascular Mapping on Vascular Access Outcomes

Author	Technique	AVF Creation rate	Percentage of Usable AVF
Silva (1998)	USS	14% (pre) to 63% (post)	8% (pre) to 64% (post)
Robbin (2000)	USS	32% (pre) to 58% (post)	Not reported
Ascher (2000)	USS + DOQI	5% (pre) to 68% (post)	Not reported
Allon (2001)	USS	34% (pre) to 64% (post)	16% (pre) to 34% (post)
Gibson (2001)	USS + institutional policy change	11% (pre) to 95% (post)	Not reported
Dalman (2002)	USS	35% (pre) to 85% (post)	Not reported
Fullerton (2002)	USS + DOQI in group 1	23% (group 1) to 39% (group 2)	79% (group 1) to 71% (group 2)
Huber (2002)	USS + angiography	90%	71%
Patel (2003)	Physical examination + USS + angiography	61% (pre) to 73% (post)	73% (pre) to 57% (post)
Wells (2005)	Physical examination (73%); USS (27%)	100% (physical examination) to 76.5% (USS)	Not reported
Asif (2005)	USS	77%	All functional at follow-up
Elsharawy (2006)	Physical examination (26%); angiography (74%)	95%	Not reported

Abbreviations: USS, ultrasonography; DOQI, Dialysis Outcomes and Quality Initiative.