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ORIGINAL ARTICLE

Preoperative assessment for percutaneous and open surgical arteriovenous fistula creation in patients for haemodialysis

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ABSTRACT

Preoperative assessment prior to surgical arteriovenous fistulas (AVFs) including ultrasound-guided mapping has been shown to have beneficial effects on their immediate success as well as early outcomes. This has led to their wide acceptance and adoption however clinical practice criteria is variable and is reflected in variabilities in practice. When transposing this to percutaneously created endovascular AVFs (endoAVFs), variable preoperative assessment criteria could equally result in variable practice and potentially subsequent and expectant outcomes. We aimed to review literature on reported validated methodologies and workflows of preoperative assessment for surgical AVF creation as reported in highest levels of available evidence, specifically randomized controlled trials. Published practice recommendations and guidelines on best clinical practice as well as systematic reviews and meta-analyses of published studies were also reviewed. Data on practice methodology from identified trial publications and protocols was collated and a summative narrative synthesis was carried out which compared these methodologies to additional assessments that may be required when targeting assessment for percutaneous endoAVF formation, based on our units experience as part of an international multicentre trial. In this review we present a brief overview of published literature and guidelines and propose a unified and uniform workflow for preoperative assessment for surgical AVFs and endoAVFs to aide clinical and imaging practice.

Keywords: arteriovenous fistula, dialysis access, end stage kidney disease, physical examination, ultrasonography

BACKGROUND

The incidence of end-stage renal disease (ESRD) in patients requiring renal replacement therapy (RRT) continues to see an increasing trend globally [1, 2]. With an ageing population with increasing comorbidities, the majority of these ESRD patients will likely not be able to manage their RRT independently at home and would opt for haemodialysis in hospital or at satellite dialysis units as their preferred or recommended RRT modality and setting [3, 4]. Surgically created native arteriovenous fistulae (AVFs) or subcutaneously implanted prosthetic arteriovenous grafts are the recommended permanent form of vascular access (VA) for dialysis, as compared with

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tunnelled central venous catheters (TCVCs) [5–12]. Surgically created AVFs, since their inception over half a century ago, have seen limited progression in terms of their modality of creation. Not all AVFs created will develop or mature to be subsequently useable for dialysis. Delays to use for dialysis as a result of failed maturation or complete failure (primary failure or occlusion) have been reported to be up to 50% [13]. Once in use, these can then develop dysfunction due to development of steno-occlusive disease. Their ongoing surveillance and maintenance following development of dialysis dysfunction continues to be debated, with conflicting but often underpowered evidence only being available [14–18]. Neointimal hyperplasia is well recognized as a frequent contributor to these outcomes, be it following surgical AVF creation at the level of the anastomosis or following repeated cannulation across a single venous outflow conduit that is exposed to high vessel wall shear stress [19–22].

Percutaneously created endovascular AVFs (endoAVFs) for dialysis access now over five years since their first reports, is one of the most innovative and significant steps forward in native dialysis vascular access (VA) creation [23–25]. The percutaneous suture-less AVF anastomosis is a single communication created between the forearm deep arterial and venous system and has multiple outflow venous conduits across the upper arm deep and superficial venous systems. Evidence of the functional usage of endoAVFs for dialysis VA continues to accumulate from both controlled clinical trials and real-world settings. Improved anastomotic level outcomes as compared to standard surgical methodology are postulated as being the result of reduced vessel manipulation and trauma at the time of surgical creation [26]. Better outcomes along the lines of subsequent steno-occlusive disease also continues to populate reported literature, and may be due to sharing of vessel wall shear stress load as the outflow from an endoAVF is distributed across multiple vessels [27–30]. Understandably, the core outcome for any dialysis access is functional outcome of dialysis or usability by end users, that is, the patient and their haemodialysis cannulator. With shared outflow from endoAVFs, functional outcome is dependent on sufficient flow being available in a vein that is easily accessible for cannulation. Following guidance from previously published literature on usability, this should be easy to feel and superficial to cannulate, and have sufficient flow rates to sustain prescribed dialysis flows, which, in turn, should equate to dialysis adequacy and quality [5, 31]. Appropriate vessel selective at preoperative evaluation involving clinical and ultrasound (US) based assessments has been shown to have beneficial effects on their immediate success as well as early outcomes. This has led to their wide acceptance and adoption. However, clinical practice criteria is variable and is reflected in variabilities in reported practice in literature. When transposing this to percutaneously created arteriovenous fistula (endoAVF), variable preoperative assessment criteria could equally result in variable practice and subsequent outcomes.

Objectives

Anatomical variants or indeed availability (or lack) of vessels identified at individual patient's preoperative assessment (clinical assessment and ultrasound (US) guided mapping and assessment), can highlight if not dictate suitability to undergo surgical AVF creation. A limited, but growing, supporting evidence base has led to the development of best practice suggestions, recommendations and guidelines for such preoperative assessments. However, clinical practice in this regard can be variable. When considering preoperative assessments for endoAVF creation, similar assessment principles apply, as well as additional considerations for the percutaneous AVF creation procedure and follow-up planning for cannulation, to achieve the desired functional outcomes [25, 26, 28, 32]. The aim of this study was to review literature for validated assessment methodologies and work flow patterns utilized in the preoperative evaluation for surgical arteriovenous fistula creation, and compare to additional aspects required with planning percutaneous AVF creation.

MATERIALS AND METHODS

Methodology applied for this review of literature and narrative summation followed published recommended framework [33–37]. Reported validated methodologies on preoperative evaluation for an arteriovenous dialysis access formation were sought. These were defined as those utilized in higher levels of evidence, specifically seeking published validated methodologies from randomized controlled clinical trials. An electronic database search strategy was developed and deployed with specific keywords, MeSH terms and text words to be deployed across relevant electronic databases (PubMed/Medline, EMBASE/OVID SP, Cochrane CENTRAL and ClinicalTrials.gov). The following terms were utilised to develop this search strategy following a Boolean strategy: Ultrasonography, physical examination, veins, diagnostic imaging, arteriovenous fistula, Surgical, renal dialysis, end stage kidney disease, chronic kidney failure and randomised controlled trial as publication type (see an example of a search strategy applied in Table S1 in Supplementary data). Published evidence summaries in the form of systematic reviews on the subject were also identified with a similar strategy. These were screened to confirm identification of relevant literature and review of reported findings from respective meta-analyses. Relevant published guidelines and best practice recommendations on the subject were reviewed as well as their most recent updates, where available. Search strategy was designed with advice from a research librarian and spanned a search period from 1990 to present with last search up to date June 2019.

Abstracts were screened following predefined criteria as randomised controlled trials with defined assessment methodology relevant to the scope of this review. Full-text articles were reviewed and additionally underwent 'backward' bibliography searches, as well as 'forward citation reviews' to identify any studies not found in the initial searches. Published studies reporting on percutaneous endoAVF formation were also collated along with available study protocol methodology for preoperative assessment criteria.

Data were collated for narrative synthesis and included: assessing operator's reported experience and specialty; clinical examination details; and US technology, mapping and assessment characteristics. These outcomes were categorized as relating to 'inflow' arterial assessment, 'outflow' central venous assessment and venous 'conduit' for cannulation assessment. Summative narrative synthesis was then carried out which compared these methodologies to additional assessments that may be required when targeting assessment for percutaneous endoAVF formation based on published evidence.

RESULTS

A total of three randomised controlled trials were identified with the highest level of methodological rigour, reporting on preoperative assessment for arteriovenous access formation in chronic kidney disease patients who were planned for haemodialysis [38–40]. Two further studies were identified with limited

methodological rigour [41, 42]. Three systematic reviews and meta-analyses were identified reporting on the summation of study outcomes, including a Cochrane systematic review by Kosa *et al.* [43–45]. A further systematic review evaluated cohort studies, which reported on preoperative US mapping and assessment however review of these primary cohort studies was beyond the scope of this review [46].

Study characteristics and validated assessment methodologies from these selected studies were extracted. A summary of results from the identified RCTs and systematic reviews and meta-analyses, including their methodological quality assessments, are given in Tables 1 and 2, respectively. Summated results of additional assessment criteria from reported studies of percutaneously created native AVFs are provided in Table 3.

Table 1. Summary of studies identified for narrative summation, including their study design, reporting clinical examiners and US operators and US equipment used

References	Country	Study design	Synthesis inclusion	Clinical examiner/s	US operator/s	US equipment	Methodology protocol
Smith *et al.* [40]	UK	Two-arm, open-label RCT Parallel assignment Crossover design	Yes	Specialist consultant surgeon and trainee	Vascular scientist	SonoSite[a] MicroMaxx© 10–5 MHz linear transducer	Detailed in study
Ferring *et al.* [38]	UK	Two-arm RCT Sealed-envelope randomization	Yes	Specialist consultant, three trainees	Nephrologist, VA CNS	Sonosite[a] 180+ © portable 10–5 MHz linear	Cited as: Ferring *et al.* [47]
Nursal *et al.* [39]	Turkey	Two-arm RCT Block randomization	Yes	Assumed specialist radiologist	Not specified	Siemens[b] Antares© 7.5 MHz linear	Cited as: Mihmanli *et al.* [42]
Mihmanli *et al.* [42]	Turkey	Random assignment Prospective study	No	–	–	Acuson[b] 128×P/4© 7 MHz linear	Detailed in study
Zhen *et al.* [41][c]	China	Random allocation Prospective study	No	–	–	NA	NA

[a]Sonosite is a trademark of Fujifilm Corp., Bothell, WA, USA.
[b]Siemens Antares, and now Acuson, part of Siemens Healthcare LLC., Camberley, Surrey, UK.
[c]Only online abstract available.
CNS, clinical nurse specialist; NA, not available/applicable.

Table 2. Reviews and meta-analysis of literature reporting on preoperative US mapping and assessment for arteriovenous access formation in chronic kidney disease patients, their respective methodological quality assessment and reported significant outcomes

References	Quality assessment of studies included	Results of methodology quality assessment	Significant factors assessed and reported, with respective 95% CI
Kosa *et al.* [43]	Cochrane Risk of Bias tool Four RCTs included	One study low risk Two studies unclear One study high risk	Fistula creation: RR = 1.02 (0.94–1.12) Maturation: RR = 1.11 (0.98–1.25) Use for dialysis: RR = 1.12 (0.99–1.28) All studies favouring US mapping, except rate of intervention [mean difference 14.7 (7.51–36.91)]
Georgiadis *et al.* [48]	Oxford Jadad Scale Five RCTs included[a]	Three studies scored 3 One study scored 2 One study scored 1	Immediate failure pooled: OR = 0.32 (0.17–0.60; P < 0.01) Early/mid-term adequacy: OR = 0.66 (0.42–1.03; P = 0.06) Clinical examination alone versus combined with US assessment: OR = 0.56 (0.33–0.95; P = 0.03) All trends favouring US mapping
Wong *et al.* [45]	Oxford Jadad Scale Three RCTs included	Two studies scored 2 One study scored 3	Successful start on dialysis post-US mapping Pooled OR = 1.96 (0.85–4.5; P = 0.11)
Voormolen *et al.* [46]	Critical appraisal checklist, Dutch Cochrane collaboration Seven observational studies included	Mean quality score 51%	Multiple factors to evaluate preoperative HRS[b] RA size: RR = 1.5 (0.9–2.5) CV: RR = 1.9 (1.5–2.3) Preoperative imaging risk factors: RR = 1.7 (1.4–2) All trends favouring US mapping

CI, confidence interval; OR, odds ratio; RR, risk ratio; RA, radial artery; CV, cephalic vein; HRS, haemodynamic risk stratification.
[a]Zhang *et al.* a prospective study with random allocation.
[b]This was carried out in radiocephalic AVFs only.

Table 3. Summary of assessment of target vessels from studies on percutaneous creation of AVFs as reported in the study methodology and study inclusion/exclusion criteria

References	EndoAVF device	Arterial/venous diameter for access	Arterial/venous diameter at creation site	Deep perforator vein size	Distance between vessels for creation
Rajan *et al.*, FLEX study [23]	6-Fr two-catheter system	To accommodate 6/7 Fr sheath	≥2 mm	NS	≤2 mm
Lok *et al.*, NEAT study [26]	6-Fr two-catheter system	To accommodate 6/7 Fr sheath	≥2 mm	NS	NS
Radosa *et al.*, single-centre cohort study [29]	6-Fr two-catheter system	≥2.5 mm	≥2 mm	NS	Run parallel >2 cm
Berland *et al.*, EASE study [49]	4-Fr two-catheter system	To accommodate 5 Fr sheath	2 mm or able to accommodate 4-Fr device	NS	To allow sufficient alignment
Hull *et al.*, TRAD study [50]	6-Fr single-catheter system	Cephalic vein to accommodate 6 Fr sheath	>2 mm	NS	≤1.5 mm
Hull *et al.*, Pivotal study [25]	6-Fr single-catheter system	≥2 mm cephalic vein to accommodate 6 Fr sheath	≥2 mm	NS	≤1.5 mm
Mallios *et al.*, single-centre cohort study [32]	6-Fr single-catheter system	Cephalic vein to accommodate 6 Fr sheath	>2 mm	>3 mm	≤1.5 mm

Based on a narrative synthesis methodology, a unified assessment workflow with comments comparing these assessment methodologies and any required additional steps for endoAVF formation is provided. Published guidelines and suggestions for best clinical practice are described in Table S2 in supplementary data.

Inflow arterial assessment

Inflow arterial assessment should follow qualitative evaluation for any indications of pre-existing upstream or downstream steno-occlusive disease within the ipsilateral arterial tree. The following factors should ideally be considered during an inflow arterial assessment in preoperative evaluation and mapping for both surgical and endoAVF creation:

- the presence and quality of a palpable arterial pulse for the radial artery ± ulnar artery at the wrist, and the brachial artery in the antecubital fossa—pulsatility score has been described as a quantification method [39];
- confirmation of a complete palmar arch is recommended with Allen's test, although this has been argued to be subjective [51]. Others include modified Allen's or Barbeau's test [52, 53];
- the calibre of arteries reported for US-based selection have ranged from >1.6 mm at the wrist to 3 mm in the upper arm. Arterial diameters of 2–2.5 mm, measured as the maximal anteroposterior diameter, have been previously suggested as a suitable cut-off [47, 51, 54];
- consideration of the level of bifurcation of the brachial artery, aberrant branches or anatomical variations with clear documentation of the size, level and accessibility of each respective target artery in relation to topographical anatomical boundaries is recommended. This has been reported in up to 14% of cases [55];
- it has been proposed that pre-existing disease, such as atherosclerosis, can potentially impact access maturation and the development of distal extremity hypoperfusion/steal. This can also impact possibility to clamp/inability to clamp the target artery and potential for clamp related injury during surgery. Reported methodologies included B mode assessment, adequate vessel colour filling and spectral waveform assessment at distal forearm and mid-arm levels only; additional assessments included further analysis with measurements of peak systolic/end-diastolic velocities and vessel flow [38–40]. Detailed assessment has been reported as:

1. target artery waveform with or without indirect evidence of upstream inflow arterial disease, that is, dampened monophasic waveform with upstream stenosis, and potentially higher likelihood of inadequate inflow, primary failure, distal hypoperfusion or rarities of presentation, including vertebro-subclavian steal either on or off dialysis [56];
2. target artery waveform with or without indirect evidence of downstream normal outflow arterial disease, i.e. high-resistance biphasic or triphasic waveform, prestenotic pattern or arteriosclerosis/microvascular disease of the hand and potential for complications. Onset of symptoms can be immediate or in the early post-operative period, but also in intermediate to late presentations, each with its own management challenges [57];
3. target artery pulse wave regularity/irregularity indicative of bradycardia/tachyarrhythmia at the time of examination and suggestive of pre-existing cardiovascular disease, especially in the elderly. The potential consequences on fistula maturation, primary success or longer-term outcomes of this are admittedly under-reported [3, 58].

Target inflow arterial assessment for endoAVF creation

While the above principles would still hold valid during assessment for endoAVF creation, further assessment steps should be considered:

- assessing the calibre (diameter) and quality of the target access artery or arteries (brachial, radial and ulnar) for percutaneous Seldinger access and the ability to accommodate a 4-Fr (1.7-mm) or 6-Fr (2-mm) catheter for endoAVF creation [24, 25];

Table 4. Algorithm for preoperative arterial assessment

Assessment level	Clinical assessment	US-guided surgical AVF assessment	Additional US-guided endoAVF assessment	Comments
Distal arterial assessment	Palpable pulse: Y/N Pulsatility: (scores 1-4)[a]	Radial/ulnar artery diameter[1]: mm Calcification: Y/N Flow: T/B/M Compressibility: Y/N	Proximal forearm Radial/ulnar/interosseous artery diameter[2]: mm Calcification: Y/N Flow: T/B/M Compressibility: Y/N	[1]Access artery size to accommodate 4-Fr catheters [2]Artery size to accommodate 4-Fr or 6-Fr catheters for fistula creation
Proximal arterial assessment	Palpable pulse: Y/N Pulsatility: (score 1-4)[a]	Brachial artery high bifurcation[3]: Y/N Brachial/radial/ulnar diameter: mm Calcification: Y/N Flow: T/B/M Compressibility: Y/N	Confirmed continuity of artery from access site to creation site[4]: Y/N Distance between artery and vein at creation site >1.5 mm: Y/N[b] Target vessels run parallel over 2 cm: Y/N[c]	[3]Access artery size to accommodate 6-Fr or 4-Fr catheters [4]Arterial access site may be at wrist or in mid-arm and dependent on 4-Fr or 6-Fr device

Flow: T/B/M, triphasic/biphasic/monophasic. Y/N, yes/no.
Rapid survey to confirm artery presence, patency and level of bifurcation, if applicable, should be conducted prior to full assessment.
[1–4]Comments relating to surgical and endoAVF assessments in respective columns.
[a]Pulsatility score as described by Nursal *et al.* (2006) [39].
[b]As per published data using single-catheter endoAVF system; see Table 3, Hull *et al.* (2017, 2018) [25, 50].
[c]As per published data using two-catheter endoAVF system; see Table 3, Radosa *et al.* (2017) [29].

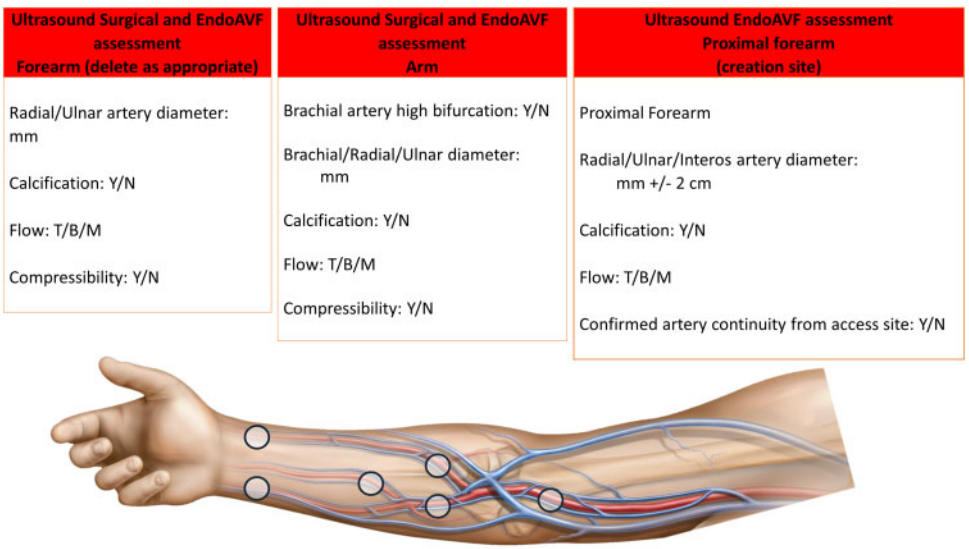

FIGURE 1: Algorithm for preoperative US-based arterial assessment and mapping prior to surgical AVF or endoAVF creation. A detailed recording chart with additional comments is available in Table 4.

- taking into account the continuity and tortuosity of the target artery or arteries (brachial, radial, ulnar and interosseous) in the proximal forearm, and depending on the endoAVF creation device used, an additional minimum distance of 2 cm across the potential target site for fistula creation could be reasonable and has been reported (distal to the creation site may be cranial or caudal, depending on the access site) [24, 29]. Again, percutaneous access and the ability for advancement of a 4-Fr or 6-Fr catheter should be confirmed;
- the calibre and quality of the artery or arteries at the fistula creation site (radial, ulnar or interosseous) and an additional distance of ~2 cm across this site; and
- a distance of no more than 1.5 mm between the deep artery and vein has been proposed when specifically using a single-catheter system in cases, while vein tortuosity may be a relevant consideration for both systems.

The above-mentioned additional steps (summarized in Table 4 and Figure 1) are necessary to ensure that preoperative mapping has identified not only the suitability, but also any potential challenges that might be encountered during the procedure of endoAVF creation, as well as the most appropriate access site, or sites, for the procedure.

Outflow venous assessment

Outflow venous assessment is focused on suitability of central venous outflow to the right heart and is primarily clinical and patient history-related. Although US may be used to assess the

cephalic arch and the axillary and subclavian veins in select individuals (often related to body habitus), it plays a minor role in venous outflow mapping. The presence or absence of normal venous phasic flow and evaluation on Valsalva manoeuvre can be considered but cannot exclude central venous steno-occlusive disease [59]. The series of clinical assessments for suitability for endoAVF creation are the same as those carried out for surgical AVF creation:

- history of previous, or presence of current, TCVCs ipsilateral and contralateral to the target limb being assessed—ideally documenting the sites, number and duration, if available;
- any known history of previous central venous intervention (TCVC-related or other);
- ipsilateral implanted cardiac devices such as pacemakers or defibrillators;
- previous history of ipsilateral limb, chest or neck level surgery, trauma, radiotherapy or deep vein thrombosis; and
- visible neck, shoulder or chest wall venous collaterals, which may be indicative of central venous steno-occlusive disease.

The above findings may be associated with ipsilateral limb swelling but are not exclusive to all aetiologies of outflow disease. Aberrant anatomical variations or conditions with venous compressive symptomatology, such as venous thoracic outlet syndrome, have a rare symptomatic incidence in reported literature on dialysis access, and the rate of occurrence is likely small but may also be variable. Where any suspicion exists of outflow venous steno-occlusive disease, a diagnostic central venogram may be useful to exclude any significant disease and also to confirm continuity prior to access formation [60].

Venous conduit assessment

Conduit assessment likely has the most significant impact on end users of dialysis VA, that is, the patient and their dialysis nurse. A suitable conduit is vital to ensuring initial usability and longevity. When undertaking mapping, the end user's tools, that is, the dialysis needle types, have to be kept in mind. Although these can be variable and dependent on centre use and availability, they have to be detailed and taken into consideration, while applying the aforementioned principles of functional usability (summarized in Table 5 and Figure 2). Variations in practice have been reported, each with its own merits. These include assessment with and without tourniquet application, pre- and post-tourniquet distensibility and vein outflow percussion. Superiority of one test over another or a combination of these is supported only by sparse evidence and would be the focus of a separate study [46, 61]. As a common baseline, all conduit assessments, as reported in the literature, should ideally include:

- the calibre and quality of the target vein for manipulation at creation;
- the patency/continuity and calibre change of the conduit and the presence of any significant side branches;
- the presence of acute or chronic occlusive or non-occlusive thrombus, which can, at best, prompt follow-up reassessment, thus making the operating surgeon or radiologist aware of a higher risk of failure, or at worst can exclude the target conduit;
- the depth and tortuosity of the target conduit—this should ideally take into account the ability to accommodate a 1.5-cm straight needle used at an approximate 45° angle, but

Table 5. Algorithm for preoperative venous assessment

Assessment level	Clinical assessment	US-guided surgical AVF assessment	Additional US-guided endoAVF assessment	Comments
Distal venous assessment	Visible vein: Y/N Visible vein with tourniquet: Y/N Vein percussion: Y/N	Cephalic/basilic vein diameter[a] at creation site: mm Cephalic/basilic vein diameter[a] at distal forearm site: mm Cephalic/basilic vein diameter[a] at mid-forearm site: mm Cephalic/basilic vein diameter[a] at proximal forearm site: mm	Median cubital perforator present[1]: Y/N Proximal forearm Radial/ulnar/interosseous vein diameter[a] at creation site[2]: mm Radial/ulnar vein diameter[a] at wrist[3]: mm Selected wrist access vein in continuity with creation site: Y/N	[1]Presence of perforator to share flow to superficial veins [2]Vein size to accommodate 4-Fr or 6-Fr catheters for access creation [3]Vein size to accommodate access for 4-Fr or 6-Fr catheters
Proximal venous assessment	Visible vein: Y/N Visible vein with tourniquet: Y/N Vein percussion: Y/N History, signs or symptoms of central venous steno-occlusive disease	Cephalic/basilic vein diameter[a] at creation site: mm Cephalic/basilic vein diameter[a] at distal arm site: mm Cephalic/basilic vein diameter[a] at mid-arm site: mm Cephalic/basilic vein diameter[a] at proximal arm site: mm Axillary/cephalic arch/subclavian vein patency: Y/N Axillary/subclavian vein flow: normal phasic/augmentation on Valsalva	Brachial vein diameter/s[a] at mid-arm site[4,5]: mm Selected distal/mid-arm access vein[6] in continuity with selected creation site: Y/N Selected cannulation vein/s in continuity with selected creation site: Y/N	[4]Access size to accommodate 6-Fr or 4-Fr catheters [5]Comparison of size with superficial veins for estimation of shared flow and/or assess need for embolization [6]This can be a superficial vein if links to creation site present

Rapid survey to confirm vein presence and patency should be conducted prior to full assessment. Y/N, yes/no.
[a]Vein diameter may be measured before and/or after tourniquet application, and changes in diameter recorded.
[1–6]Comments relating to surgical and endoAVF assessments in respective columns.

Ultrasound Surgical and EndoAVF assessment Forearm/arm (delete as appropriate)	Ultrasound EndoAVF assessment Proximal forearm and arm (access and creation)
Cephalic/Basilic diameter at wrist/arm creation site: mm	Median cubital vein perforator present: Y/N
Cephalic/Basilic distal forearm/arm : mm	Proximal Forearm Radial/Ulnar/Interos vein diameter/s at creation site: mm
Cephalic/Basilic mid forearm/arm : mm	Radial/Ulnar vein diameter at wrist (access): mm
Cephalic/Basilic proximal forearm/arm : mm	Brachial vein diameter/s at mid arm (access): mm
Axillary/cephalic arch/Subclavian vein patency: Y/N	Access wrist or mid arm vein continuity to creation site: Y/N
Axillary/Subclavian : normal phasic/augmentation on Valsalva	Selected cannulation vein/s continuity to creation site: Y/N

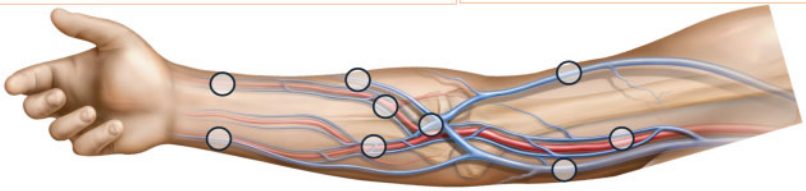

FIGURE 2: Proposed algorithm for preoperative US-based venous assessment and mapping prior to surgical AVF or endoAVF creation. A detailed recording chart with additional comments is available in Table 5.

also to allow sufficient room to rotate needle sites over an acceptable distance. A recommended template for this is often quoted as following the rule of 6s for success [5].

Target venous conduit assessments for endoAVF creation

With regard to additional steps when assessing for endoAVF creation, the nature of the venous draining system or shared outflow channels needs to be considered. As this is, in essence, a single side-to-side or latero-lateral anastomosis within the deep venous and arterial system, drainage of the fistula is dictated by the anatomical location and communication between the deep and superficial venous systems. An important consideration to remember is the potential bidirectional or craniocaudal drainage from an endoAVF anastomosis. Identification of the dominant drainage is important, as this would influence the expected flow through the desired target venous conduit. The following steps are suggested as part of a logical and systematic approach (summarized in Table 5 and Figure 2):

- the presence of a median cubital vein (MCV) perforator—described as the most consistent communication between the deep and superficial venous systems and crucially providing a link to the target venous conduit [24];
- continuity of the MCV with the target superficial venous conduits, namely the cephalic and/or basilic veins, should be assessed for, and the aforementioned venous conduit assessment steps should ideally be followed;
- continuity of the MCV with the target deep venous creation site or sites (radial, ulnar and interosseous) is necessary for adequate, if not direct, inflow;
- continuity and tortuosity of the target creation site vein or veins in the deep system (radial, ulnar, interosseous) in the proximal forearm, and dependent on EndoAVF creation device used, an additional minimal 2 cm distal to the potential fistula creation target site is recommended (this may be cranial or caudal dependent on access site). This follows the same methodology described for arterial assessment and may be carried out concurrently; and
- the calibre of the target deep vein or veins (radial, ulnar and brachial) should be determined for percutaneous access and the ability for advancement of a 4-Fr or 6-Fr catheter. Again, this follows the same methodology mentioned for arterial assessment and may be carried out concurrently.

Assessment for aberrant anatomy such as high bifurcation, as described above for arterial assessment, should also be included in the venous conduit assessment. Qualitative, if not quantitative, assessment of ideally all potential venous outflow conduit (calibre difference) in the superficial and deep venous systems in the upper arm (cephalic, basilic and brachial veins) can help to identify potential flow dominance. This can be confirmed by performing a completion angiogram post-creation, which will determine the need for deep vein embolization for flow divergence [24].

DISCUSSION

Preoperative mapping for planning of AVF creation has been reported in the literature as providing potentially significant outcome benefits [43, 45, 46, 48]. When evaluating these higher levels of evidence, they have used appropriately defined criteria of selection on preoperative evaluation and their respective outcomes form the basis of clinical practice recommendations and guidelines [38–42]. Other studies also exist in literature but are retrospective or prospective cohorts observational in nature [54, 62–65]. In addition, there was a wide range of outcomes from all these studies, including success rates of intraoperative identification of suitable anatomy, maturation, use of access for dialysis, interventions required for maintenance and exposure to TCVCs [17, 43, 45, 46, 66]. Admittedly, these are clinically significant outcomes; however, uniform interpretation can be difficult, as definitions of these reported outcomes have been inconsistent and derived from heterogenous cohorts [46].

When evaluating assessment methodology, RCTs can provide the most consistent validated workflow with appropriate rigour. This evidence although limited, have generated systematic reviews and meta-analyses of their outcomes and over the years has resulted in a paradigm shift to now being recognized as acceptable if not standard practice (Table S2, Supplementary

data) [5–12]. Recommendations were based on clinical examination, in combination with US assessment, with a minimum set of criteria as the threshold for higher success rates. These recommendations were derived from a range of sources, ranging from expert opinion (including from the latest American KDOQI 2019 and Spanish GEMAV 2017 guidelines) to existing literature critically appraised as moderate- or low-level evidence studies. Interestingly, the ESVS CPG rated the same available literature as Class I, Level A. The European Renal Association's Best Practice recommendations and guidelines 2007 remained pertinent to this review at the time of this synthesis, as the recently published 2019 guidelines focus on other areas of VA for dialysis (detailed in Table S2, Supplementary data). As stated in the 2007 recommendations and guidelines, there is clearly a need to expand the evidence base with high-quality studies. Until further such studies are available, the current recommendations and guidelines remain the cornerstone of evidence on which to base our clinical practice. Equally, it could also be argued that there may be marginal over-analysis of studies, which at best could be considered moderate in quantity and of moderate quality (Table 2).

Any preoperative assessment and mapping must retain assessment of factors that will have significant bearing not only on procedural factors but also on outcomes for the end users, specifically the patient and their cannulator and the cannulation process. With regards to surgically created AVFs, this follows standard dialysis circuit methodology which includes assessment of arterial 'inflow,' central venous 'outflow' and target cannulation vein or 'conduit'. A similar methodology is necessary with some additional considerations when including endoAVF creation within the patient's assessment pathway. In this review, validated methodology as derived from these was summated to provide an assessment workflow for preoperative evaluation prior to creation of any AVF for dialysis access including a percutaneously created endoAVF. When comparing additional assessments required, these follow similar logical assessment steps and are not significantly different in comparison. These are numerically minimal but a learning curve is expected. However, it could be argued that a similar if not significantly larger learning curve was required when US assessment was proposed to be used in conjunction with clinical examination. In reported literature, clinical examination in controlled trials has been described as being conducted by consultant surgeons or surgical trainees with appropriate specialist experience, whereas US assessment has been described as being carried out also by radiologists, nephrologists, VA clinical nurse specialists or vascular scientists demonstrating clear portability of these skills [38–40].

The proposed additional assessments are based on the same principles of traditional clinical and US assessments but with the addition of evaluating new sites of AVF anastomosis creation. This can potentially open more 'doors' as additional options for individual patients. For the core end users, appropriate conduit identification again follows the same traditional methodology previously described however, additional assessments have to take into consideration and anticipate the effect of shared outflow and estimation of outflow dominance. It is important here to remember that vessel or conduit diameter derived surface area is an important factor in flow dominance, wherein significantly large deep brachial veins in the presence of significantly small calibre superficial veins (or absence thereof) will provide the dominant outflow. This can help procedural guidance, specifically requirement for deep vein embolization for diversion of flow, but also expectant arterial and venous cannulation sites. As further evidence gathers in literature, these factors may likely be investigated for correlation to dialysis function and access circuit survival.

CONCLUSION

As existing literature summaries suggest, there is still a need for adequately powered prospective studies to strengthen the evidence base. There is equally if not more of a need for standardization of definitions. This should ideally be approached prior to attempting direct comparisons between endoAVFs and surgically created AVFs. Summaries of literature on preoperative mapping for native AVFs suggest their use can be beneficial and is widely accepted. These can avoid negative surgical explorations, increased numbers of fistulas created, possibly reduce the number of immediate AVF failures and increase the number used for dialysis [43, 48]. When interpolating this practice into preoperative assessment of percutaneously created AVFs, additional attention to outcomes needs to be considered. Inadequate procedural planning can potentially result in increased procedural failures or failure to achieve desired outcomes both with surgical AVFs as well as endoAVFs.

SUPPLEMENTARY DATA

Supplementary data are available at ckj online.

CONFLICT OF INTEREST STATEMENT

None declared pertaining to this study.

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