CHAPTER 1

ARTERIOVENOUS VASCULAR ACCESS SELECTION AND EVALUATION

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On behalf of the Canadian Society of Nephrology Vascular Access Work Group
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INTRODUCTION

When making decisions regarding vascular access creation, the clinician and vascular access team must evaluate each patient individually with consideration of life expectancy, timelines for dialysis start, risks and benefits of access creation, referral wait times as well as the risk for access complications. The role of the multidisciplinary team in facilitating access choice is reviewed as well as the clinical evaluation of the patient.
ARTERIOVENOUS (AV) ACCESS CONSIDERATIONS

- Clinician and vascular team must evaluate each patient and weigh these issues to determine the best course of action.

- Together with the patient, the vascular access team should plan out the dialysis access options.
# AV ACCESS CONSIDERATIONS

<table>
<thead>
<tr>
<th>Patient Choice</th>
<th>Life circumstances, goals and preferences</th>
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<tbody>
<tr>
<td></td>
<td>Understanding of the risks/benefits of various access types</td>
</tr>
<tr>
<td></td>
<td>Suitability of access type to patient characteristics</td>
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<tr>
<td>Life Expectance and Comorbidities</td>
<td>Life expectancy</td>
</tr>
<tr>
<td></td>
<td>Comorbidities (i.e. metastatic cancer, severe heart failure, significant peripheral vascular disease)</td>
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<tr>
<td></td>
<td>Young patient with low comorbidity, good vessels and long expected time on HD should be strongly recommended a fistula</td>
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<td></td>
<td>Choices may be limited for a patient at the opposite spectrum, but fistula creation in the elderly can be successful</td>
</tr>
<tr>
<td>Centre Specific Variation</td>
<td>Recommendation varies depending on program factors such as infrastructure, program culture or philosophy regarding vascular access, impact access choice and access placement</td>
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</table>
### AV ACCESS CONSIDERATIONS

**Suitable Vasculature**
- Fistula and graft maturation requires an adequate cardiac output, arterial conduit, vein size, compliance, and unobstructed outflow veins

**Timing of AV Access Creation**
- Timing for creation is complex
- Guidelines recommend evaluation for fistula at GFR of 15 – 20 ml/min/1.73m² with progressive kidney disease
- Study in Ontario found 40% of fistulas placed within 3-12 months from start of hemodialysis
- Grafts require a shorter maturation time: 3-4 wks after placement for a standard graft, to same day for an early cannulation graft
- Time to dialysis is influenced by rate of progression
- Use of ESKD risk equations can help predict risk of progression

**Impact of Primary Failure**
- Occurs when a fistula either thromboses prior to its use or lacks suitability for use on dialysis
- Defined by reliability of cannulation, adequate blood flow on dialysis, appropriate clearance and whether catheter-free use is achieved
- Primary failure rates for fistula is variable between 25-60%; should be considered in decision making

(Also see Chapter 2: AV access failure, stenosis and thrombosis)
ROLE OF MULTI-DISCIPLINARY TEAM IN ACCESS CHOICE

• Model of care should be individualized, patient centered
• Decision-making requires input from the multi-disciplinary team: vascular access nurse or nurse educator, nephrologist, surgeon, radiologist, patient and family members

Process

Timely Referral to Nephrologist and Surgeon Patient Education and Discussion Investigations and Interventions

Use and Maintenance Coordinate Evaluation Access Creation Desired Dialysis Access

Facilitated by regular and inclusive multi-disciplinary communication and coordination
## PROPOSED ROLES FOR THE MULTI-DISCIPLINARY TEAM

<table>
<thead>
<tr>
<th>Team Member</th>
<th>Role Pre-Creation</th>
<th>Role Post-Creation</th>
</tr>
</thead>
</table>
| Nephrologist                     | • Educate patients w CKD educator regarding CKD progression and renal replacement therapy (RRT) modality options  
                                            • Educate patient re: choice of dialysis access based on clinical circumstances (comorbidities, rate of progression)  
                                            • Discuss risks and benefits of peritoneal catheter and hemodialysis vascular access.  
                                            • Provide timely referral to the surgeon and/or interventionist | • Monitor w the VA coordinator, the access after creation for signs of complications and facilitate interventions to maintain long-term function  
                                            • Manage vascular access complications (e.g. catheter related malfunction or infection or fistula or graft complication) |
| Surgeon/ Interventional Radiologist or Nephrologist | • Evaluate re: choice of vascular access based on patient and vessel characteristics  
                                                    • Discuss surgical and interventional risks and benefits for each access with patient/family | • Create the vascular access and manage immediate perioperative complications including revisions as required  
                                                    • Perform facilitative and/or corrective procedures to attain and/or maintain patency e.g. coil embolization, angioplasty, thrombolysis |
# Proposed Roles for the Multi-Disciplinary Team

<table>
<thead>
<tr>
<th>Team Member</th>
<th>Role Pre Creation</th>
<th>Role Post Creation</th>
</tr>
</thead>
</table>
| Peritoneal and/or Vascular Access coordinator | - Facilitate communication between nephrologist, surgeon, radiologist and patient/family  
- Coordinate peritoneal dialysis or HD vascular access management (e.g. booking of diagnostic tests, communicates with patient re: dialysis access appointments) | - Monitor patient’s dialysis access on a regular basis and informs nephrologist and/or surgeon/interventionist of concerns  
- Key “point person” for patient when access issues arise |
| Patient and Family | - Provide information about patient’s life circumstances (social, occupational, cultural, religious, functional, etc.).  
- Provide information about patient dialysis access preferences, life goals, and concerns.  
- Ask questions to ensure they understand various dialysis access options to their satisfaction | - Provide information regarding any changes in life circumstances or preferences |
Vessel anatomy of the arm

• Knowledge of vessel anatomy is important for access creation (See Figure 1)
• Cephalic vein most commonly used for upper extremity AV fistula (See Figure 2)
• Radiocephalic fistula at wrist is 1st choice HD access (See Figure 2) followed by brachiocephalic fistula at elbow (See Figure 2)
• Basilic vein on ulnar side and median basilic vein near elbow are other options
• Basilic vein in medial of upper arm is most common deep vein to create the “transposed basilic vein” AVF
• Brachial veins in upper arm are used for dialysis access as last resort
• Grafts made from synthetic material are used if AVF not suitable. The forearm loop, upper arm straight and thigh loop grafts are most common (See Figure 3)

See Atlas Dialysis Vascular Access by Tushar J. Vachharajani, MD, FASN, FACP
EVALUATION FOR AV ACCESS CREATION - ANATOMY OF THE ARM

Figure 1: Vasculature

- Brachial A
- Axillary V
- Cephalic V
- Radial A
- Basilic V
- Median ante-brachial V
- Ulnar A

Figure 2: AVF Creation

- Brachial-Cephalic (2nd choice)
- Proximal Radial - Median Ante-brachial
- Radial-Cephalic @ the wrist (1st choice)
- Radial-Cephalic @ the snuffbox

Visual provided with permission by Spergel et al.
EVALUATION FOR AV ACCESS CREATION-
ANATOMY OF THE ARM

Figure 3: Graft Creation

Visual provided with permission by Spergel et al.
EVALUATION FOR AV ACCESS CREATION

History and physical examination

Perform past medical history; current medical issues; access-focused history:

• HD access focused history to reveal past access procedures (i.e. Peripherally inserted central catheters (PICCs), Cardiac implantable electronic devices (CIED), past HD access history)
• Provides insight on potential complications i.e. fistula maturation failure and steal syndrome

Physical exam should detect:

• Scars from prior catheter insertions; arm or facial swelling or collateral veins
• CIED (wires are factor for central vein stenosis)
• Arterial evaluation to ensure adequate blood flow; dual blood supply to hand
• Vein anatomy augmentation – Inflate blood pressure cuff to 5 mmHg above measured diastolic pressure

Vessel mapping:

• Ultrasound mapping practice varies by center and surgical expertise
• Vein and artery evaluation – see next slide
• Use in patients with high risk for fistula failure to mature; obesity; history consistent with central vein stenosis (CVS)

Venography:

• Ideal for identifying and potentially treating CVS
# EVALUATION OF VEIN AND ARTERY ANATOMY FOR ACCESS PLANNING

<table>
<thead>
<tr>
<th>Physical Exam</th>
<th>Vein Anatomy</th>
<th>Artery Anatomy</th>
<th>Central Vein Anatomy</th>
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<tbody>
<tr>
<td></td>
<td>Compressible/distensible</td>
<td>Compliant</td>
<td>Absence of collateral vein on chest or abdomen</td>
</tr>
<tr>
<td></td>
<td>Absent occluded segments</td>
<td>Palpable pulses</td>
<td>Absent pacemaker</td>
</tr>
<tr>
<td></td>
<td>Length of vein sufficient for cannulation (≥15 cm)</td>
<td>Difference of &lt; 20 mmHg between the two arms</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Straight vein segment</td>
<td>Patent palmar arch</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Superficial vein</td>
<td></td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Ultrasound</th>
<th>Absence of stenosis/synechiae (fibrous scars)</th>
<th>Absence of stenosis</th>
<th>Absence of central vein stenosis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Absence of intraluminal webs</td>
<td>Normal flow and velocity waveforms</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Continuity of outflow vein with central veins</td>
<td>Diameter of artery ≥2.0 mm or greater at the site of planned anastomosis</td>
<td></td>
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<tr>
<td></td>
<td>Diameter of the venous outflow of ≥2.5mm for fistula and &gt; 4mm for a graft</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Vein depth &lt; 1 cm from surface of skin</td>
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</table>
SURGICAL CONSIDERATIONS FOR AV ACCESS PLACEMENT

- Preoperative evaluation and surgical technique are important for vessel maturation and preventing primary failure
- Access creation during surgical training leads to better AV access outcomes
- Postoperative evaluation as well as interventions (if necessary) are critical in treating secondary failure

Anesthesia issues
- The type of anesthetic may impact on subsequent vessel dilation and maturation
- Native fistulas can usually be constructed under local anesthetic. Transposed fistulas and grafts may require regional nerve blocks or general anesthesia

Surgical factors

Fistula maturation will be affected by the following:
- Surgical angle of anastomosis of the artery to the vein affects wall shear stress; more acute anastomotic angles promote neointimal hyperplasia and subsequent stenosis formation
- Type of material used to create the anastomosis (vascular clip vs suture)
- Intraoperative blood flow of less than 120ml/min achieved post anastomosis is predictive of primary failure
HEMODYNAMICS OF AVF CREATION

Arteriovenous Vessel Remodeling

- Physiological changes, including:
  - Blood flow rapidly \( \uparrow \) 10 to 20 fold after the fistula is created
  - Cardiac output \( \uparrow \) in response to baroreceptor induced changes
  - Results in \( \uparrow \) shear stress, sensed by the endothelial cells

- Mediators (eg/nitric oxide, metalloproteinases) induce vasodilation and vascular remodelling to \( \downarrow \) pressure and shear stress in the vascular system to accommodate the \( \uparrow \) flow from the fistula

- Larger vessel size can predict fistula maturation, e.g. upper arm fistulas and fistulas in men are more likely to mature
HEMODYNAMICS OF AVF CREATION

Cardiac Hemodynamic Changes with AV Access Creation

- Fistula creation results in cardiac hemodynamic changes that are characterized by a hyper-dynamic circuit

- Studies show ↑ in cardiac output by 15-20% post fistula creation

- ↑ in atrial natriuretic peptide (ANP) and brain natriuretic peptide within 2 weeks reflecting ↑ left atrial and left ventricle stretch from the ↑ volume

- ↑ in ANP has been correlated to ↑ in CO

- Left ventricle hypertrophy (LVH) is an adaptive response to the ↑ cardiac workload
HEMODYNAMICS OF AVF CREATION

Right Ventricle Remodeling and Pulmonary Hypertension

- ↑ in blood volume + ↑ RV performance may → ↑ pulmonary flow and possibly ↑ pulmonary pressure → pulmonary hypertension
- Prevalence of pulmonary hypertension in HD patients is ~ 40%
- Pulmonary hypertension post fistula creation is thought to be related to chronic vasoconstriction and endothelial dysfunction in the pulmonary circuit
- Hemodynamic changes associated with graft placement are less pronounced than those with fistula creation

Cardiac Remodeling and Patient Selection

- Based on expected physiology of an ↑ demand on CO some would avoid placement of fistula in patients with severe heart failure
CLINICAL EVALUATION OF FISTULA MATURATION

• Adequate maturation can be identified by appropriate blood flow and diameter and adequate vein length for cannulation.
• Vessel should be easy to palpate, easy to compress and should collapse with arm elevation (indicating no CVS).
• KDOQI established ‘Rules of 6’: by 6 wks, the flow of a fistula should be 600 ml/min, 0.6 cm diameter, < 0.6 cm below the skin, and have at least 6 cm of straight segment for cannulation.
• Use of ultrasound to assess flow and vessel diameter at 2 and 4 months post fistula creation has been shown to predict subsequent dialysis suitability.
• Routine maturation assessment should be obtained by month 2 in order to facilitate interventions for the immature fistula.
ASPECTS OF CANNULATION

• Cannulation technique is an important aspect of long term AV access patency
• Each blood vessel puncture may incite local trauma and subsequent venous neointimal hyperplasia and stenosis formation
• Nurse training, education and a focus on assessment and cannulation will support AV survival

Needle technique options
• Three types of needling techniques; area wall, rope ladder and buttonhole
• Area wall - needling the same selection of fistula or graft which has highest failure rate due to aneurysm growth and should be avoided
• Rope ladder - the rotation of needle sites in a ladder formation along entire length of fistula or graft
• Button hole (only used in fistulas) - needling in same site epithelializes the track of tissue. Reported as less painful needling by some but has higher risk for infection, especially *s. aureus*
• Button hole is indicated in short length fistula, fistula with aneurysm or in some home HD patients with use cannulation protocol
ASPECTS OF CANNULATION

Impact of needle size and direction of placement
• Venous needle to be placed in the antegrade position, in the same direction as the blood flow.
• Antegrade needle placement reduces hematoma formation and reduces the tendency for pseudoaneurysm development upon needle withdrawal.
• Most programs initiate needling at low pump speed with smallest gauge needle and slowly advance to the speed needed for adequate clearance.

Other features of needling technique
• Tourniquet use – multinational study showed tourniquet use improved access survival as compared to compression of fistula.
• Bevel up – uncertainty and lack of evidence leads to recommendation to follow your unit-specific protocol.
• Ultrasound assisted needling – a tool to assist with cannulation but requires specialized skill and training.
• Steel vs Teflon needle use – steel is the most commonly used needle, however Teflon (angiocatheters) may be used for new or fragile AV access, nocturnal or restless patients but requires knowledge of the different needling technique required.
ASPECTS OF CANNULATION

Infiltration

• Referred to as a ‘blow’ and estimated to occur in ~35% of cannulations, is when the needle is dislodged from inside the fistula or graft during needle insertion or dialysis treatment.

• It occurs when the needle slips out of the fistula, passes through the wall of the fistula allowing blood to infuse into the surrounding tissue.

• Infiltration is often associated with pain, warmth and bruising which can involved the entire arm and even track into the thoracic region.

• Risk factors include:
  - Cannulator experience
  - Immature fistula
  - Deep vessel depth
  - Stenotic accesses
  - Hastened hemostasis
  - Anticoagulant therapy
  - Peripheral arterial and vascular disease
  - Age
ASPECTS OF CANNULATION

Cannulation of an AV access is a skill that deserves careful attention and adequate staff resources to facilitate and ensure long term survival and AV patency

• The following are links include details on cannulation technique:

http://www.ishd.org/7-the-care-and-keeping-of-vascular-access-for-home-hemodialysis-patients


SUMMARY OF RECOMMENDATIONS

• Patients should undergo careful assessment by the VA team to determine if they are eligible for AV access creation

• Potential candidates will have evaluation by a surgeon who may also wish to perform Duplex US venous +/- arterial mapping to determine eligibility

• Eligible candidates should be offered AVF creation but the VA team should carefully consider baseline comorbidity, anatomical and other relevant factors so the risks and benefits of the procedure can be well explained to the patient

• Final decision to proceed with VA creation should be made by a multidisciplinary team (nephrologist, surgeon, vascular access nurse) and the patient/family
SUMMARY OF RECOMMENDATIONS

- Despite the relatively high risk of primary failure, most patients who are eligible should undergo AVF creation to reduce the risk of catheter related complications.
- Risk of AVF creation is relatively small and the risk of catheter complications is very hard to predict.
- An individualized approach that takes into consideration the patient’s chronologic and physiologic age, comorbidities, anatomic factors and patient concerns is suggested.
- AVF creation results in an increase in cardiac output.
- Over time, AVF creation is associated with cardiac remodeling and LV hypertrophy.
- It is unclear if AVF creation facilitates the development of pulmonary hypertension.
SUMMARY OF RECOMMENDATIONS

• Cannulation technique impacts access survival; infiltration and subsequent hematoma ↑ risk of access thrombosis
• Area wall technique should be avoided as it leads to aneurysm formation
• Buttonhole is associated with ↑ risk of infection; protocols should be put in place to manage this risk including use of topical antimicrobial prophylaxis