Pre and Post AV fistula evaluation in 50 chronic kidney disease patients. - Single centre experience. Structured report and diagrams as a roadmap for better management.

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Learning objectives

**Pre-fistula evaluation:** To document and map the normal and variant anatomy of upper limb superficial veins and their relation with arteries.

**Post-fistula evaluation:** To document the AV fistula, flow volume and dynamics.
Background

CKD has risen to be an important public health issue. According to the 2015 Global Burden of Disease Study, kidney disease was ranked 12th as the most common cause of death, accounting for 1.1 million deaths worldwide. The CKD related mortality has increased by 31.7% over the last 10 years. [1]

A majority of these CKD population belongs to India with approximately 1.3 lac CKD patients being treated with hemodialysis. [1]

Hence, proper planning for dialysis initiation is important and thus the importance of pre-fistula mapping of both arteries and superficial veins in these patients with required doppler study.

Of similar importance is the post- fistula mapping of these arteries and veins just before initiating the dialysis and also during the maintenance phase to look for possible complications, if any and to look for their possible treatment. Thus, radiologists play a key role in the management of CKD patients.
Findings and procedure details

Majority of CKD patients are dependent on high vascular conduits for their dialysis. Dialysis can be carried out by hemodialysis catheters, arteriovenous grafts or fistulas and CAPD. Among the, arteriovenous fistulas are the most popular and form an ideal mean for dialysis. Variety of arteriovenous fistulas are designed for the purpose of dialysis.


Most of these fistulas are created by anastomosing the side of artery and end of vein. Fig. 12 on page 20 Fig. 13 on page 21 Fig. 14 on page 22

Most commonly used fistulas include:

1. Radiocephalic fistula, also known as Brescia-cimino fistula
2. Brachiocephalic fistula
3. Transposed brachiobasilic fistula

For the creation of these fistulae, the non-dominant upper limb is chosen with preference given for radiocephalic anastomosis. The 2006 guidelines proposed by the National Kidney Foundation as part of the Kidney Disease Outcomes Quality Initiative (KDOQI) also recommend that a radiocephalic fistula be the first choice for fistula creation. [2]

At our centre, a basic protocol is followed for proper assessment of superficial veins. This includes tying a tourniquet in the upper arm and following it up with doppler study of these veins by linear transducer of frequency 18-5 MHz. Also during this procedure the room temperature is increased to facilitate venous dilatation and later maximum diameter of the dilated veins are compared in both supine and sitting position.

Similarly, the corresponding arteries are studied to include their spectral waveform and also their maximum caliber. Fig. 2 on page 10

To predict the risk of arterial steal, arterial hyperaemic response is also studied in the desired arteries. To demonstrate this, spectral waveform is documented in the involved artery in two states: on clenching fist for 3 minutes and on releasing the
fist. Normal response is triphasic high resistance flow in clenched fist while low resistance monophonic flow in released fist. Failure to demonstrate this response is a contraindication for arteriovenous fistula creation. Fig. 3 on page 12 Fig. 4 on page 11

As a part of routine doppler study, the internal jugular and subclavian veins are studied on both sides too.

Documenting the variant anatomy of both upper limb arteries and branching pattern of superficial veins is an important attribute of the doppler study.

The variant arterial anatomy could include:

1. High bifurcation of brachial artery.
2. High origin of radial artery from axillary artery.
3. High origin of ulnar artery from axillary artery.

A consensus was reached upon by team of nephrologists, radiologists and vascular surgeon to reach upon an inclusion/exclusion criteria for accepting a particular superficial vein for fistula creation.

The criteria suggest to accept arteriovenous fistula vein only if its caliber is more than 2.5 mm and artery if its caliber is more than 2.0 mm.

Of 25 patients who were evaluated for pre-fistula mapping, 11 were females while rest 14 were male patients, majority 13 (%) belonged to 50-70 age group, 16 of them had left upper limb as non-dominant upper limb which was preferred. Of the lot, the majority- 20 patients suffered from diabetes mellitus, 16 patients suffered from hypertension and 14 had both. As per the inclusion/exclusion criteria- cephalic vein was suitable for fistula creation in 15 patients in the forearm and 17 patients in arm while basilic vein was suitable in 20 patients.

The tabulated format which is currently practised for pre-fistula venous and arterial anatomy is shown in figure. To simplify and further help in describing the vascular anatomy a pictorial representation of the same is also given to all these patients. Fig. 10 on page 18

Post-fistula

After surgical creation of arteriovenous anastomosis, it is prudent that the adequacy of the anastomosis is surveyed by doppler study.
Both arteries and vein are scanned in longitudinal and transverse manner with study of surrounding perivascular space.

The surgically created fistula has to be "mature" so as to be used for dialysis. Ideally, this maturity is assessed 6-8 weeks after fistula creation. However, in our hospital, the team has started and accepted the idea of doing doppler study for the same after 1 month and deciding the further course of action.

Maturity of the fistula is judged on the basis of two parameters mainly: the maximum caliber of the AV fistula vein and flow volume.

The routine investigation for post-fistula doppler focuses on both B mode and color-power doppler study for the entire system involved.

At our hospital, the focus is made at three levels:

1. Site of fistula.
2. Artery
3. Vein and its tributaries.

The reporting format practiced in our institute is shown in image. Fig. 11 on page 19

In all three, B mode examination is essential to look for the maximum caliber and depth from skin. Also B-mode examination is essential to look for thrombus formation, luminal narrowing or any abnormal pseudoaneurysm formation within the associated vein. Also note is made of surrounding soft tissue to look for associated hematoma/seroma formation.

Spectral waveform documentation is essential to assess the entire system with spectral waveform taken at all three levels. Normal waveform at all the levels is low resistance biphasic/monophonic; thus if the waveform changes of triphasic then it suggests occlusion at any one level.

Ideally, the volume flow in the associated vessel should be more than 500 cc and less than 2.5 litres (clinical condition of the patient has to be assessed to look for signs of volume overload), any aberration from these volume levels suggest an abnormality. The volume in associated arteriovenous vein is taken at atleast three levels (in forearm/arm) to get an idea about the competency of the fistula.

The reporting format followed at our hospital is shown in figure. It is always complimented with a pictorial representation of the same. Also, the course of vein is marked on patients
upper limb to assess the dialysis technician for making the required punctures. Fig. 9 on page 17

The complications to be looked for include:

1. Juxta-anastomotic stenosis: JAS is defined in the literature as greater than 50% reduction of the luminal diameter of the outflow vein within 2 cm or 5 cm from the arteriovenous anastomosis. JAS appears to be the most frequent stenosis seen in radiocephalic fistulas and also is considered as the most common cause of failure of maturity of the fistula. However, the incidence of JAS in matured fistulas has also been noted.

There are various theories to explain the pathophysiology behind JAS. The theories include loss of the vasa venosum during skeletonization for mobilization of the most peripheral part of the vein, low and fluctuating shear stress at this location, kinking, increased turbulence of the vein just downstream from the anastomosis and torsional stress. A combination of few or all of these stresses leads to intimal injury with a subsequent cascade of proinflammatory cytokines further causing proliferation of smooth-muscle cells, myofibroblasts, and an extracellular matrix that result in neointimal hyperplasia and subsequent stenosis.

The typical creation of the radiocephalic fistula requires moving the peripheral portion of the cephalic vein in three different directions to meet the radial artery: from superficial to deep, from lateral to medial, and from laying horizontal to laying vertical. According to Bharat et al. [3], such changes in the position of vein creates torsional stress within the juxtaanastomotic segment. By replacing the above mentioned technique by a piggyback straight onlay technique, which consists of anastomosing the underside of the more superficial cephalic vein with anterior aspect of the deeper radial artery the failure rate of primary radiocephalic fistula has reduced from 40.3% to 16.7% and reduced the 1-year rate of JAS from 18.5% to 5.1% [4]. Also a steeper anastomotic angle (< 30°) might help in reducing the disturbed flow and thus subsequent occurrence of JAS.

Treatment: Endovascular approach is required for both cannulation which can be further supplemented with balloon angioplasty.

2. Steal syndrome:

This results when there is stenosis in artery proximal or distal to the site of fistula creation. Doppler parameters suggests reversal of blood flow with markedly reduced systolic flow in the artery distal to the fistula. There is an estimated 5-20 times increased rate of
steal syndrome in patients with brachiocephalic fistulas (5-20%) rather than in those with radiocephalic fistulas (1%) [4]. This rate of occurrence is also a primary reason for considering brachiocephalic fistula only when radiocephalic fistula has failed to work. Fig. 5 on page 13

Similar to this, arteriovenous fistula has also been documented as a very rare cause of subclavian steal syndrome. In both these cases, surgical revision of the fistula is the ideal treatment.

3. Cephalic arch stenosis:

It is the most common cause of dysfunction of brachiocephalic fistula. The percentage of occurrence of hemodynamically significant CAS is 30-77% of all dysfunctional brachiocephalic fistulas [5]. In contrast, CAS is rarely seen in dysfunctional radiocephalic fistulas.

Causes which explain this phenomenon in association with brachiocephalic flow include extrinsic compression by the enclosing clavipectoral fascia and high turbulent flow the system.

This stenosis can further cause aneurysmal dilatation of the fistula which can further progress to poor access and increased occurrence of thrombosis thus leading to progressive failure of the fistula.

Treatment: the first-line treatment of CAS is balloon angioplasty followed by stent-graft placement, fistula flow reduction and if everything fails then surgical turndown.

4. Proximal Swing Segment Stenosis:

This complication occurs mainly with brachiobasilic fistula. The surgically created curve of the basilic vein just peripheral to its anastomoses with the brachial vein constitutes the proximal swing segment. It is at this site that the basilic vein transitions from its surgically created superficial and lateral location to its naturally deeper and more medial location and approximately 70% to 75% of stenoses occur at this location [6].

Treatment: Balloon angioplasty forms the primary treatment measures; however follow-up with few interventions may be required.

In our sample of 25 patients who underwent post-fistula doppler study, 8 were females and the rest 17 were male. Also, the majority (11 of 25) of the population studied belonged to age group 50-70 years followed by 70-90 age group (7 of 25). Also, the preferred upper
limb for fistula creation turned out to be left upper limb (16 of 25) and the most preferred site was radiocephalic (13 of 25) while brachiobasilic fistula was found only in 1 patient. Also, only 1 patient out of 25 sample size who had radiocephalic fistula in forearm had thrombotic occlusion in the artery and 2 of 25 patients had venous thrombosis (both of them associated with radiocephalic fistula). Only 4 patients had volume flow in vein less than 500 cc. Only one patient had developed pseudoneuromysm which appeared to be in association with brachiocphallic fistula. Fig. 7 on page 15
Fig. 1: Schematic representation of arteries and superficial veins in upper limb and their relationship.

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**Fig. 2:** Diagrammatic representation of superficial veins and arteries in left upper limb with their relationship done prior to surgical construction of fistula. Cephalic vein shows partial thrombosis in its course through distal forearm.

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**Fig. 4:** Maximum calibre and distance from skin measurements for basilic vein in its course through arm.

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Fig. 3: Maximum calibre and distance from skin measurements of cephalic vein in their course through arm.

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Fig. 5: Schematic representation of steal syndrome in a patient in whom brachiobasilic anastamosis was created. This steal syndrome was demonstrable after 3 months of its creation.

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Fig. 6: Thrombosis is seen within the course of cephalic vein in mid arm.

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**Fig. 7:** A large pseudoaneurysm was seen in association with radial artery post radiocephalic fistula creation. On PW, classical to and fro movement was demonstrated.

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Fig. 8: On CD, communication between the pseudoaneurysm artery is seen.

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**Fig. 9:** Course of cephalic vein is drawn on a patient's arm who had brachiocephalic fistula to help the technician get appropriate sites for puncture.

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### LEFT UPPER LIMB DOPPLER FOR EVALUATION OF AV FISTULA

Caliber of veins are as follow:

<table>
<thead>
<tr>
<th></th>
<th>Left Cephalic vein</th>
<th>Left Basilic vein</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Caliber</td>
<td>Depth</td>
</tr>
<tr>
<td>Mid arm</td>
<td></td>
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<tr>
<td>At elbow</td>
<td></td>
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<tr>
<td>Mid forearm</td>
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<tr>
<td>Near wrist</td>
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- Cephalic and basilic vein show normal course and caliber throughout the upper limb.
- Radial and ulnar arteries at forearm show normal course and caliber. Maximum caliber of radial artery at left distal forearm is — mm and depth of — mm from skin.
- Maximum distance between cephalic vein and radial artery at distal forearm is — mm.
- Maximum distance between basilic vein and brachial artery at above elbow is — mm.
- Basilic vein opens into axillary vein and cephalic opens in subclavian vein.
- Patent palmar arch is seen.
- Left subclavian vein and internal jugular vein show normal color flow and phasic variation.

**Fig. 10:** Reporting format for pre-fistula doppler study.
**POST AV FISTULA DOPPLER**

A) FEEDING ARTERY:

1. Radial artery
2. Diameter (Normal > 1.6 mm)
3. Intima media complex (changes of atherosclerosis)
4. Stenosis / occlusion
5. Flow (Normal low resistance monophasic flow, triphasic flow is abnormal)
6. Peak systolic velocity
7. Flow volume

B) AT FISTULA:

1. Location
2. Diameter
3. Depth from skin
4. Stenosis / occlusion
5. Pulsatile flow
6. Peak systolic velocity (Normal < 400 cm/sec)
7. Flow volume (Normal in arm > 900 cm/sec & forearm > 600 cm/sec)

C) DRAINING VEIN:

1. Cephalic vein
2. Course, Diameter, depth, peak systolic velocity and flow volume are shown in diagram.
3. Stenosis / occlusion
4. Pulsatile flow
5. Peak systolic velocity (Normal < 300 cm/sec)
6. Flow volume (Normal >500 ml/min)

D) Branching of draining vein

E) RI of both feeding artery and draining vein

F) Pseudo-aneurysm

G) Radial & ulnar arteries at wrist joint

**Fig. 11:** Reporting format for post-fistula doppler study.

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Fig. 12: Diagrammatic representation of brachiocephalic fistula with cephalic vein showing branching pattern in its course through mid arm.

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Fig. 13: Diagrammatic representation of transposed brachiobasilic fistula. There is severe stenosis in the basilic vein near its drainage into deep veins in proximal most part of arm. Also, post-operative seroma formation is seen in the arm.

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**Fig. 14:** Diagrammatic representation of radiocephalic fistula. Volume flow at different levels in cephalic veins and its various branches is also shown.

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Conclusion

A schematic and structured reporting format with a simple diagrammatic representation of the same in pre-fistula mapping by a radiologist can ease out the burden on a vascular surgeon and appears to be essential in pre-operative planning.

In the post-fistula state, the mapping is essential to look for ideal sites for puncture and also in knowing and dealing with the associated complications.

Both the mappings together can help in prolonging the patency of fistula and are proving as a boon for most of the CKD patients who are on maintenance dialysis.
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