ORIGINAL RESEARCH

Technique and Outcome of Arterio-Venous Fistula for Dialysis Access

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ABSTRACT

Objective: Success of surgically constructed Arterio-Venous Fistula (AVF) for hemodialysisaccessd ependsoncareful patientse lection, siteselection, meticulous technique and postoperative care. This study aims to identify key steps to improve outcome and develop standard operating procedure of AVF surgery.

Design: This isaprospective study to observeout come of AV F surgery.

Setting: Study was doneatsingleinstitute, which isatertiarycare hospitali ncentral India.

Participants:116patients of Chronic Kidney Disease(CKD)were included between September 2020 to May 2022 (21 months).

Intervention:151 AVFconstructionsurgerieswеredonein116patientsfor hemodialysis access establishment.

Outcome measures: Surgical findings, outcome (maturation failure and flow dysfunction)and complicati on swer enoted. Minimum follow upperiod was1month and maximum 20 months.

Results:98distal AVFand53proximal AVF were made. Maturati on failurerate was 28.6%fordistal AVF and6% for proximal AVF. On table conversionrate from distal to proximal AVF was 17%. With low threshold for on table conversion failure rate wasreduceto10.4%ofdistalAVF.Complicationsnotedwerelimboedemain12.1% (n=14), skin ecchymosis in 6% (n=7), wound dehiscence in 4.3% (n=5), hematoma at woundsitein2.6%(n=3)andwoundinfectionin0.9%(n=1)patients.Brachialartery steal syndrome was observed in 1 patient.

Conclusion: Predictableout come and minimal complicationso fA VF surgerycanbe achieved with a standard protocol based approach. Skill development programs for surgeons and technicians are recommended.

Key Words: Arterioven ous Fistula, Hemodialysis, Radio-cephalic, Brachio-cephalic, Brachio-basilic

INTRODUCTION

Estimated prevalence of patients on chronic dialysis in India is 129 per million population.[1] Two main culprits for Chronic Kidney Disease (CKD) are Diabetes and Hypertension. Surgically constructed Arterio-Venous Fistula (AVF) provides safer and more durable access for hemodialysis and thus lower morbidity. But at the same time AVF surgery is eclipsed with chances of failure and significant complications. This study highlights salient points to improve outcome and develop standard operating procedure of AVF surgery.

MATERIAL AND METHODS

This is a prospective study done at single institute, which is a tertiary care hospital in central India. 151 AVF construction surgeries were done in 116 patients, between September 2020 to May 2022 (21 months). 65 patients were male and 51 were female. Age of patients range between 14 years to 67 years, with averageage51year.31%patients(n=36)wereunder40yea rage(youngonsetCKD). Surgical findings, outcome andcomplications were noted. Minimum follow up period was 1 month and maximum 20 months.

All patients were referred by Nephrologist for establishing dialysis access. All patients were already on hemodialysis through central venous catheter (CVC) at the time of presentation to our out patient clinic.

PATIENT SELECTION

All patients were operated under local anesthesia. Table-1 summarizes parameters considered for patient selection.

Table1: Parametersusedto considerapatient fitto undergoAVF surgery

1	Serumcreatininelessthan 10mG/dL
2	BloodHemoglobin more than 6G/dL
3	Bloodpressurebelow180/110mmHg
4	Patientshouldbeabletoliedownonoperatingtableforaroundtwohours without any problem
5	Orthopnoea should not bethere

Patients with past history of myocardial infarction, stroke, or with paresis of limbscan beoperated upon,if thecondition isunder controlwith regular medications. Written informed consent regarding "high risk of adverse cardiovascular event during surgery" must be taken from all such patients. Hemodialysis should be done one or two days before surgery. Patient undergoing AVF surgery should take their regular anti-hypertensive medications on thedayofsurgery.Thereisnoneedofovernightfasting.Anxietyisacauseofsudden riseinblood, pressure in thesepatients. Toavoidthis, patientshouldbe well explained about the nature of surgery and patient should take adequate sleep in night before surgery. For these reasons we avoid daycaresurgeryinpatientswhotraveltohospital from outstation.

SITE SELECTION

Non dominant upper limb is preferred for creating AVF. Veins should be palpated during clinical examination in outpatient department. [Figure-1] A good vein for making AVF is the one with around 2mm diameter and compressible. There should be minimum 5 cm long straight segment of vein distal to the fistula site, without tributaries. There should not be any superficial thrombophlebitis, deep vein thrombosis, or limb oedema. CVC should be avoided on the same side of anticipated AVF surgery. If CVC has been placed on same side, then there is risk of subclavian vein stenosis leading to limb oedema after AVF creation. In our case series 11patients had CVC on same side of AVF and one of them developed limb oedema due to subclavian stenosis.

Figure 1: Vein mapping by clinical examination in out patient clinic (A, B, C) and on operating table (D)

In most of the cases clinical examination is sufficient to make decision regarding site of AVF. Preoperative Colour Doppler study is indicated in selected cases like obese individual, previous history of failed AVF, and when clinical examination is suggestive of poor condition of vessels. In our study we have made 98 distal AVF (all Radio-cephalic) and 53proximal AVF (51 Brachio-cephalic and 2 Brachio-basilic). During 17 distal AVF surgeries we found that condition of vessels were not good and so intraoperative decision was taken to make proximal AVF. On table conversion rate from distal to proximal AVF was 17.3% (17 out of 98).

SURGICAL TECHNIQUE

Clinical vein mapping is done before surgery to define anatomy of the cephalic vein and to select appropriate site for AVF creation [Figure-1].Incision is marked at the site of AVF (between the vein and artery to be used). We give straight line incision for distal fistula (in forearm) and stair step incision for proximal fistula (at the elbow joint) [Figure-2].

Figure2: Incision marking fordistal and proximal AVF

Before givingincision,around15-20mLofLocalAnestheticsolution(2%Lignocaine + 1:80000 Adrenaline solution further diluted half using equal amount of normal saline) is injected subcutaneously around the incision site. Infiltration of this solution in subcutaneous space also makes dissection of superficial vein easier. After incising the skin, subcutaneous tissue is dissected with a pointed mosquito artery forceps to isolate the cephalic vein. All the tributaries of cephalic vein are ligated and vein is divided as distal as possible. [Figure 3A] The vein is then inflated with 10ml of heparin solution (50IU/ml) using 24G cannula. [Figure 3B] After this a 5Fr infant feeding tube is passed in the vein with continuous irrigation of heparin solution.Feedingtubeispassedforaround1525cmlength ofthevein.[Figure3C]Thisstepisveryimportantasitdilatestheveinandclearsallstagnantbloodfromthelumen.Now a micro-vascular clamp is applied over the vein and dissection of artery is started. [Figure 3D] After isolation of artery, around 3cm segment of artery is clamped using2inchbulldogclamps.Thereisnoneedtoseparatethevenaecomitansfromthe artery. Now the arteriotomy and venotomy is done. We prefer end to side fashion anastomosis. Size of the arteriotomy is kept around 7-10mm in case of distal fistula and around 3-4mm in case of proximal fistula. Size of arteriotomy should be keptlittle larger in case of thickened vessel wall. Anastomosis is done using 6-0 Prolene with 9.3mm, round bodied, taper point, double needle suture. Continuous suturing is done using parachute technique near apex. Needle at one end of suture is used for posterior wall anastomosis and needle at another end of suture is used for anteriorwall anastomosis. Patency of vein and artery lumen is checked at the end of posterior wall suturing and before starting anterior wall suturing. [Figure 3E] After completion of anastomosis clamps are opened and any point leak is closed with inturrupted sutures. Adventitia over the vein is carefully dissected off using microforceps and microscissors. Stripping of adventitia is specially important at the apex of the anastomosis, which is common point of stenosis of the fistula. After this at least 5-7 cm segment of efferent vein is dissected free from the surrounding subcutaneoustissue using mosquito artery forceps. [Figure 3F] At completion of above two steps, the vein should look like a uniform cylinder and there should not be hourglass appearance or ballooning. [Figure 3G] Now the thrill can be felt on palpation at the skin over efferent vein. Surgical wound is irrigated with 1% Feracrylum solution.Skin is closed in single layer using Nylon 3-0 suture. Similar technique is followedfor proximal AVF also. [Figure 4]

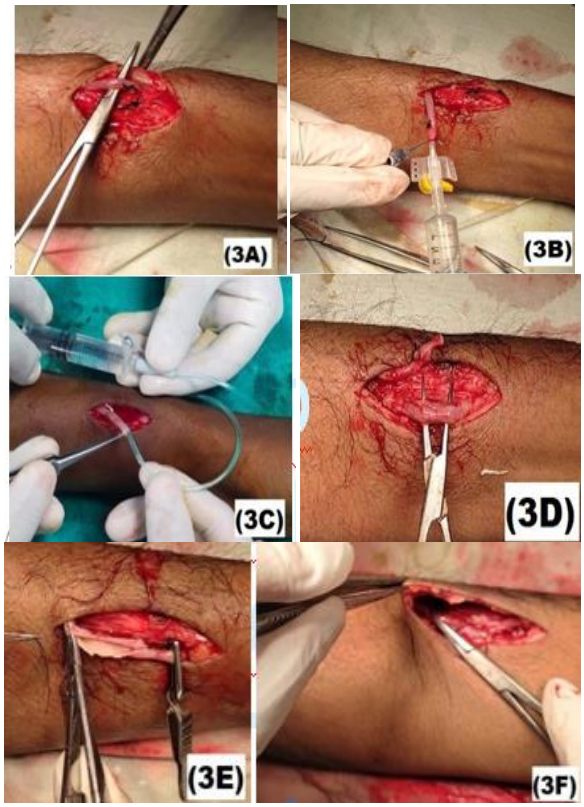

Figure 3: Steps of distal AVF surgery. (A) Vein dissection, (B) Inflation of vein with heparin saline, (C) Clearing of vein using 5Fr infant feeding tube, (D) Artery dissection without separating venae concomitants, (E) Checking patency after completion of posterior wall suture, (F) Dissection of efferent vein free from the surrounding subcutaneous tissue (G) Uniform cylinder like appearance of vein after completion of AVF, (H) Thrill can be felt on palpation

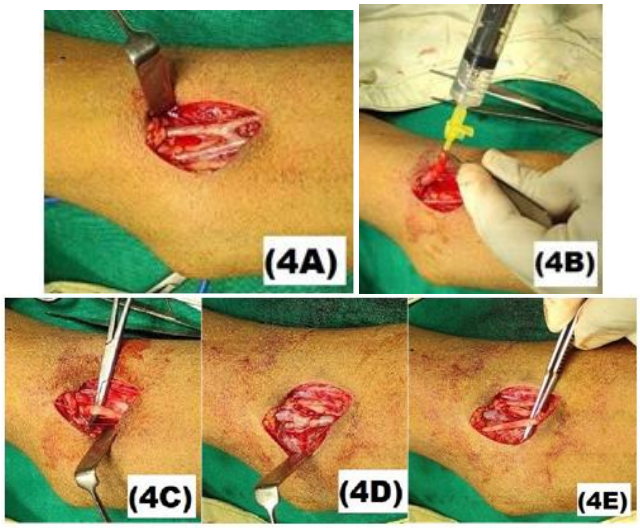

Figure 4: Steps of proximal AVF surgery. (A) Vein dissection, (B) Inflation of vein with heparin saline, (C) Artery dissection, (D) Uniform cylinder like appearance of vein after completion of AVF, (E) Basilic vein should be preserved if possible We found that on table palpable thrill is a reliable indicator of successful maturation of AV fistula in future. Palpable pulsations are also acceptable, provided that the vein is getting filled adequately. In case there are no pulsations felt on palpation, then surgeon should try to find the cause of poor flow. In such situation, anastomosis can be done again or the decision to make a proximal fistula may be taken.

POSTOPERATIVE CARE

Clinical examination of wound is done in evening of the surgery to check for any hematoma formation and presence of palpable thrill. Oral antibiotics and acetaminophen are given for 5 days. NSAIDs are avoided in CKD patients. Limb elevation in arm pouch is done for two weeks. We do not use any drug for anticoagulation in AV Fistula patient. Hemodialysis should be deferred for 48 hours after AVF surgery.Limb exercise is started from first postoperative day. Soft ball squeezing exercise, wrist movements and elbow movements are advised as much as possible. Sutures are removed after two weeks. Suture removal may be delayed becauseofpoorwoundhealinginthesepatients.Patientise xplainedtoavoidany
needle prick, blood pressure measurement or trauma in operated limb. Dialysis through AV Fistula can be started after 4-8 weeks, once it is matured. A fistula can be considered as mature or suitable to support haemodialysis when it has 4-5mm vessel diameter, allows insertion of two needles and can provide sufficient blood flow, i.e. at least 500mL/min.[2,3]

RESULT

Total 98 distal AV fistula (all radio-cephalic) were created out of which 17 (17.3%) were converted to proximal fistula on operating table itself, due to poor condition of vessels or inadequate flow. While another 11 AV fistula failed to mature during follow up period (28.6% immaturity rate). Out of 70 RC fistula who have started undergoing dialysis through AVF, 6 came to OPD for loss of flow after few months (8.6% flow dysfunction rate).Total 53 Proximal AV Fistula (51 Brachio-Cephalic and 2 Brachio-Basilic) were created. In 16 patients directly proximal AV fistula was made withoutattempting distal AV fistula, because of poor condition of vessels on clinical examination and colour Doppler. In 17 patients surgery was started with distal AV Fistula, but converted to proximal AV fistula on operating table itself. 17 Proximal AV fistula were made as

second surgery in patients of failed previous distal AV fistula. Out of these 50 proximal fistula, 3 had inability to develop adequate flow (6% immaturity rate), thus proximal fistula was made in other limb. Out of 3 failed proximalfistula,2werehavingpreviousfaileddistalfistulainsamelimb.Noneofthe proximal AV Fistula developed loss of flow (stenosis) after starting dialysis through the fistula.

In 2 patients procedure was abandoned without making any successful AV fistula,reasonbeingabsenceofsuperficialveins(emptycubitalfossa)inbothpatients. [Figure 5]

Figure 5: Empty cubital fossa (in few patients superficial veins are not found in cubital fossa)

Among postoperative complications limb oedema was most common. Limb oedema was found in 12.1% (n=14) patients. Other complications were skin ecchymosis in 6% (n=7), wound dehiscence in 4.3% (n=5), hematoma at wound sitein 2.6% (n=3) and wound infection in 0.9% (n=1) patients. [Figure 6] Brachial artery steal syndrome is a late complication of proximal fistula, it was found in 1 patient (/1.9%). Early manifestation of steal syndrome is ischemic neuropathy. One patient of distal AV fistula had developed subclavian vein stenosis due to central venous access on same side. [Figure 7] Rupture and aneurysm of AV fistula did not occur in any of our operated patients. We have treated two patients of aneurysm referred to us from otherhospital. [Figure 8and 9] Wedidnot find any cardiaccomplication due to AVF.

Figure6:Complicationso fAVFsurgery(A) Limboedema,(B) Ecchymosis, (C) Wound dehiscence

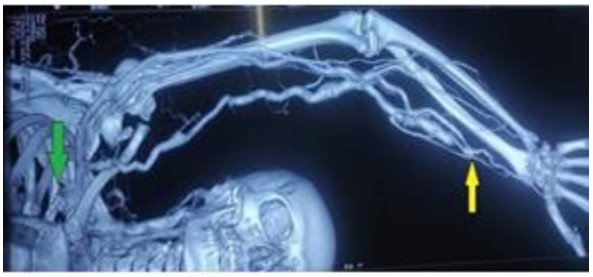

Figure 7: 3D reconstructed computed tomography venogram image of subclavian veinstenosiscausinglimboedemain patient with AVF(Greenarrowshowssite of/subclavianveinstenosis and yellowarrow showssite of AVF)

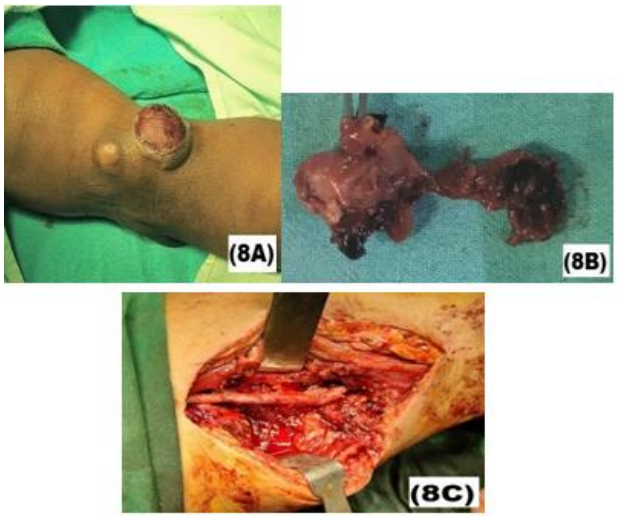

Figure 8: (A) Pseudoaneurysm formation due to ruptured AVF, (B) Surgically removed pseudoaneurysm, (C) Brachial artery was repaired using saphenous vein graft.

Figure 9: True aneurysm (excessive dilation of efferent vein because of large size of proximal AVF). True aneurysm does not require surgical intervention unless causing cardiovascular complications or distal limb ischemia. There were systemic problems (unrelated to AVF surgery) observed during postoperative period in few CKD patients due to their chronic illness and multiple comorbidity. Orthopnoea, breathlessness, hypertensive emergency, myocardial infarction, sudden hypotension, shock and seizures were observed. Two patients died during postoperative period, before starting dialysis. Thus it is important to explain risk of systemic complications to the patient preoperative. The hospital in which AVF surgery is performed, must have intensive care unit (ICU) support. large accessory vein, (viii) Juxta Anastomotic Stenosis (JAS) of vein, (ix) poor flowin artery due to arteriosclerosis, (x) hypotension during hemodialysis in postoperative period, and (xi) wound infection leading to thrombosis.[6,7,8] Neointimal hyperplasia (thick vessel wall) is the major cause of JAS.[6,9] Neointimal hyperplasia may be preexisting in CKD patients, or it may develop after creation of AVF. [Figure 10]

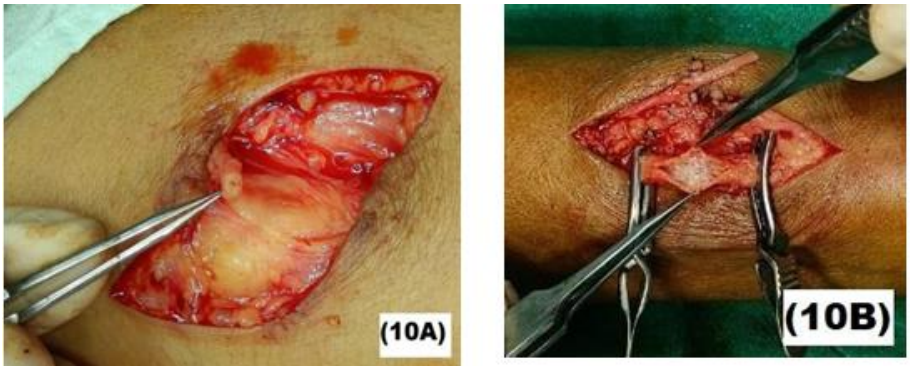

Figure10:(A)Neointimalhyperplasia(thickvesselwall)ofcephalicvein,(B)Arteriosclerosis (calcification of vessel wall) of radial artery

Few authors suggest that colour Doppler study can be used during surgery to predict AVF maturation.[10,11] However we do not do intra-operative Doppler. On table pal pablethrillisareliable in dicator of success fulmaturatio no fAV fistulain future.[12,13] Thrill indicates spiral laminar flow (SLF) within the AVF.[14]
In long term dialysis patients, AVF flow dysfunction is common. Thus Distal AVF (Radio-cephalic) should always be preferred over proximal AVF (Brachio-cephalic or Brachio- basilic) whenever it is possible, so that there is another chance of making proximal fistula in future. In case of failure of distal AVF, we make proximal AVF in same limb. In case of failure of proximal AVF, we have to make AVF inother limb. Non-working limb should be preferred for making AVF in patients with single useful hand, like patients with hemiplegia or club hand deformity, below elbow amputee etc. Cephalic vein is preferred over basilic vein due to its proximity to radial artery in forearm and more superficial course in arm. We found flow dysfunction in 8.6% of distal AVF and none of proximal AVF. However follow up period in our study is short to get true flow dysfunction rate.

DISCUSSION

Along with meticulous technique, success of AVF surgery also depends on careful patient selection, sitesele ction and post operati vecare. Ther earesigni fi cant rates of maturation failure in literature ranging from 20% to 60%.[2,4,5] We also found similar failure rate, that is 20.5% (31 out of 151 AVF). Chances offailure were much more in distal AVF (28.6%) compared to that in proximal AVF (6%) in our series. We have low threshold for on table conversion from distal to proximal AVF. With this approach we could make more number of distal AVF and reduce the incidence of maturation failure to 10.4% (14 out of 134 AVF). Factors implicated in AVF maturation failure are (i) female gender, (ii) increasing age, (iii) diabetes, (iv) vein diameter <2mm, (v) use of previous ipsilateral CVC for HD,(vi)AVF createdafter the start of HD through CVC,(vii) presence ofa Thrombus formation is most common cause of AVF flow dysfunction. Factors implicated in AVF thrombosis are (i) repeated cannulation causing intimal injury, (ii) stasis of blood because of pseudoaneurysm or true aneurysm formation. (iii) hypercoagulable state because of associated systemic co-morbidity or (iv) infection introduced during cannulation. Opinion regarding use of colour Doppler study for preoperative vein mapping and postoperative monitoring is divided in literature. [2,3,15-19] Inmost of the patients preoperative vein mapping can be done with clinical examination alone. Help of colour Doppler is needed in selected cases.[20] It must be emphasized that Colour Doppler has a good positive predictive value for identifying individual with poor condition of vessels, however it has poor negative predictive value to rule out such individuals. It means that many times we find poor condition of vein or artery during surgery, even in individuals with no such finding in preoperative Colour Doppler study.
For postoperative monitoring frequent clinical examinations by a trained personnel is recommended.[2] Self examination of fistula by patient is also effective strategy for monitoring.[21] Colour Doppler is reserved for selected cases of failing AVF to plan further management.[22]
End to side technique of anastomosis is most frequently used. One should not make an acute angle, longitudinally rotate the veins, or change their anatomical position whil ema king AVF.[9] Anas to moticangle in flue nce srateandpattern of flowin endtoside RCAVF. Nirvanaetalcorrelate danastomoti cangle<30°withhigherrates of reintervention.[23] While Pousset et al has found that increasing the anasto motic angle leads to increased wall shear stress.[24] Thus the optimal anastomotic angle is between 20° to 45° for RCAVF. To keep such an acute angle of anas to mosis, it is necessary to make a longer arteriotomy. Anastomotic angle does not influence flow in BCAVF. Another technique is side to side anastomosis which can be used for making AVF at forearm level using proximal radial artery or brachial artery. It has advantage of dialysis access in antegrade as well as retrograde vein. Distal valvulo to my using vein probe is required to establishing reterograde flow in vein.[25] This techniqueavoid srequiremen to fsuperficialization ofbasilicveinin thearm.[12,13,26] Howeverside to side AVF has high risk of venous hypertension with swelling of the hand.[27] AV Graft(PTFEgraft)isanothermethodofestablishingdialysisaccess.Studieshave suggested that AVF has longer duration of event free patency and lessercomplications compared to AVG.[28] However there is no conclusive evidence about superiority of AVF over AVG in terms of chances of failure.[28,29] Also the cost of PTFE graft is high.
Complications associated with chronic use of AVF are aneurysm, stenosis, congestive heart failure, steal syndrome, ischemic neuropathy and thrombosis.[9] Congestive cardiac failure is not common in AVF; it is limited to very high flow rate (1010mL/min or more).[30,31] Frequency of complications is more in old age patients and patients with proximal AVF.[32] All of the hemo dialysis vascular access types and configurations have alimited life expectancy and, accordingly, will ultimately fail or start to fail.[2] Flow can be effectively reestablished in a failing AVF using endovenous or surgical intervention.[33] Every effort should be made to salvage the functioning AVF in orderto save virgin vessels for future use.[34] However affordability and availability of such treatment in a public hospital in our region is still limited. We find that making another AVF proximal to the previous failed AVF is a practical approach in patients who can not come for regular follow up. It is needed to develop facility to perform intervention for failing AVF salvage, at more number of tertiary centers in India. It is estimated that about two thirds of all patients with

kidney failure in India died without receiving dialysis in 2010.[1] Inability to have access to the hemodialysis serviceisama jorpro blemin India. Almost60%ofpatientsondialysishadto travel >50km to access HD.[1] Most of the maintenance HD stations in India are able to provide HD through AVF only. By creating an effective and long-lasting arteriovenous fistula (AVF), we can improve life expectancy and quality of life for these patients.[21] But there is shortage of surgeons skilled in creating AVF and technicians trained to providing appropriate AVF care. Thus AVF training programs for peripheral surgeons and technicians is needed.[3] As AVF need continuous care, thus "health camp model" providing expert care only for short period of time, should be discouraged. Instead "skill development model" which enables local health care provider to create and take care of the AVF is recommended. Being trained in microvascular surgery, Plastic Surgeons can be an important asset for training other surgeons the skill of AVF creation and management.

CONCLUSION

AVF surgery is unique in its own kind of difficulties. High risk patients and high failure rate makes it more challenging. Standard protocol based approach hand dedicated team of trained professionals is required to produce predictable results with minimum complications. In India, there is huge gap between number of patients on hemodialysis and available surgeons skilled to create AVF. Skill development programs for surgeons and technicians at peripheral station are recommended for effective delivery of healthcare to the CKD patients. This Horizon is yet to be conquered!

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Nil

ETHICS STATEMENT

Written informed consent was obtained from all patients. This study was performed, and manuscript was written conforming to the Declaration of Helsinki.

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