Evaluation of Outcomes and Complications of Arteriovenous Fistulas for Haemodialysis Access in Paediatric Patients with Chronic Kidney Disease

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M.Ch Vascular Surgery

Branch VIII

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CHENNAI,
TAMILNADU

CERTIFICATE

This is to certify that this dissertation entitled **"Evaluation of outcomes and complications of arteriovenous fistulas for haemodialysis access in paediatric patients with chronic kidney disease"** is a bonafide record of the research work done by Dr. Nupur Bit, for the award of M.Ch., Vascular Surgery, under the supervision of **Prof. T. Vidyasagaran MS, DNB, MCH,** Professor & Head, Department of Vascular Surgery, Rajiv Gandhi Government General Hospital, Madras Medical College, Chennai. I also certify that this dissertation is the result of the independent work done by the candidate.

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DECLARATION

I solemnly declare that this dissertation

"Evaluation of outcomes and complications of arteriovenous fistulas for haemodialysis access in paediatric patients with chronic kidney disease."

was prepared by me in the Department of Vascular Surgery, Rajiv Gandhi Government General Hospital, Madras Medical College, Chennai under the guidance and supervision of **Prof. T.Vidyasagaran, MS, DNB, M.Ch**., Professor & Head of the Department, Department of Vascular Surgery, Rajiv Gandhi Government General Hospital, Madras Medical College, Chennai. This dissertation is submitted to the Tamil Nadu Dr. M.G.R. Medical University, Chennai in partial fulfilment of the University requirements for the award of the degree of M.Ch. Vascular Surgery.

Nupur Bit

Place : Chennai

Date : 9th March 2013

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Nupur Bit

CONTENTS

Key words:

End-stage renal disease (ESRD)

Acute kidney injury (AKI)

Acute renal failure (ARF)

Renal Replacement Therapy (RRT)

Cuffed Venous Catheter (CVC)

Arteriovenous access (AV access)

Arteriovenous fistula (AVF)

Arteriovenous graft (AVG)

Chronic renal failure (CRF)

Vascular access (VA)

Radiocephalic fistula (RC-F)

Brachiocephalic fistula (BC-F)

Brachiobasilic transposition (BBT)

Renal transplantation (RTx)

Primary failure rate

Primary patency rare

Secondary patency rate

Peritoneal dialysis (PD)

Haemodialysis (HD)

Review of literature

Introduction:

Haemodialysis for long term became a possibility as a treatment option in chronic renal failure (CRF) in 1960 after Quinton and Scribner devised an external shunt that provided repetitive access to the circulation. The first arteriovenous (AV) access procedure was described by Brescia and Cimino in 1966.(1) Subsequently the development of various access techniques and devices occurred and today renal failure patients can survive on HD for decades.

An ideal vascular access (VA) system should have the following features:

1. Reliable, repetitive access to the circulation
2. Flow rates sufficient to deliver efficient dialysis
3. Prolonged patency
4. Low complication rate

However, no known method has been able to reach the 'ideal' situation. Haemodialysis access failure is today the commonest cause of hospitalization and is responsible for the highest number of hospitalised days for the patients on haemodialysis.

Types of vascular access (VA):

1. Placement of a temporary or permanent double lumen central venous catheter (CVC)

2. Creation of an autogenous arteriovenous (AV) access (native or natural fistula)
3. Placement of a nonautogenous AV access (bridge AV graft)

Most appropriate access option for a particular patient depends on several factors, such as:

1. Age
2. Comorbid states
3. Vascular anatomy
4. Previous access procedures
5. Timing of haemodialysis

Site selection:

Silva et al have recommended that a superficial vein diameter exceeding 2.5mm without segmental sclerosis, stenosis or occlusion should be selected for optimum results. The non-dominant arm and distal fistulas should be given preference.

Nomenclature: (SVS/ American Association for Vascular Surgery (AAVS) Reporting Standards for Vascular Accesses)

1. Autogenous AV access – An access created by a connection between an artery and a vein whereby the vein serves as an accessible conduit.
2. Nonautogenous AV access – An access created by connecting an artery to a vein with a graft. This may be prosthetic (eg, polytetrafluoroethylene,

polyurethane or Dacron) or biograft (eg, bovine heterograft or human umbilical vein).

3. Primary patency – The interval from the time of access placement until any intervention designed to maintain or re-establish patency or functionality.
4. Assisted primary patency – The interval from the time of access placement until access thrombosis, including intervening manipulations, such as balloon angioplasty, designed to maintain the functionality of a patent access.
5. Secondary patency – The interval from the time of access placement until access abandonment, including intervening manipulations, such as thrombectomy, designed to re-establish functionality in thrombosed access.

Outcome of Autogenous vs Nonautogenous AV Access procedures:

The primary failure rates for AVFs in adults, has been reported to be 8-40%.The 1-year primary patency rates for AVFs and AVGs in adults is in the range of 40-60% and 1-year secondary patency rates for AVFs is 52-80% while for AVGs, it is 54-83%.

Possible factors adversely influencing the maturation of autogenous AV access:

1. Vein size<2.5-3.0mm

2. Artery size<1.6mm
3. Diabetes mellitus
4. Elderly
5. Surgeon inexperience
6. African American race
7. Peripheral vascular disease
8. Obesity
9. Female
10. Previous failed access

NKF/DOQI guidelines:

The Centers for Medicare and Medicaid Services and the National Kidney Foundation – Kidney Disease Outcomes Quality Initiative emphasized the need for increased AVF use in adult haemodialysis patients while also decreasing CVC use.(22,3) Specifically, the Centers for Medicare and Medicaid Services End-Stage Renal Disease (ESRD) Clinical Performance Measures Project defined the objective as:

A primary AVF should be the access of choice for atleast 50% of all new patients while initiating haemodialysis. Also, a native AVF should be the primary access for 40% of all prevalent patients undergoing haemodialysis.(4)

CVC associated morbidity and mortality in adult patients receiving maintenance haemodialysis is now well recognized. This has led to an emphasis on creation of permanent VA, known as the Fistula First Initiative. The goal of this

coalition was to achieve the mentioned targets through change in concepts and process improvement.

Considerations in children:-

Vascular access(VA) has been heralded as the backbone to the provision of dialysis, and in children this poses unique challenges to the paediatric dialysis care provider due to the smaller vessel diameters and vascular hyperreactivity. Whether in the face of acute kidney injury (AKI) requiring renal replacement therapy (RRT) or as a result of chronic kidney disease (CKD), children cannot be considered “little adults”. Further it is imperative to provide adequate VA for current RRT requirements without compromising future potential access sites. This requires a different surgical philosophy and therefore it is important to study the factors which contribute to the success or failure of these interventions.

Although preemptive renal transplantation (PET) is the preferred RRT for paediatric ESRD, in our patient population scenario, it is not always feasible due to lack of suitable donors and other logistic considerations. Moreover in the subset of patients with peritoneal membrane failure, failed transplants or poor social conditions, chronic haemodialysis (HD) remains the only option.

Chronic haemodialysis (HD) access can be obtained in children by creation of a primary arteriovenous fistula (AVF), placement of an arteriovenous synthetic graft (AVG), or use of a cuffed central venous catheter (CVC). Deciding which access is best for a particular patient is based on the

patient's diagnosis, age and size, likelihood of transplant, procedural risk, and probability of long-term patency, surgical expertise, time available before starting dialysis.

CVCs are cuffed or uncuffed, tunnelled and dual lumen HD cathters inserted under fluoroscopic guidance into a central vessel (eg internal jugular vein or subclavian vein) often by an interventional radiologist. CVCs serve well in smaller children for whom the vessel calibre is too small for a permanent VA. However, they are associated with multiple problems like interrupted flow, poor position, frequent infection, thrombosis, or occurrence of central venous stenosis. Median patency of CVCs has been reported to be in the range of 4 to 10.6 months. Secondary patency rates have been reported to be 30-60%.

Increased use of peritoneal dialysis (PD), shortened time spent on dialysis therapy, perceived difficulties creating and using AVFs and AVGs in small children and improvement in CVC technology have contributed to the increasing use of CVC as permanent HD access in children and adolescents.

The choice between PD and HD is often multifactorial and the role of available surgical expertise and resources in the dialysis centre is significant in this decision. Often, there are other factors involved. Furth et al found more use of HD instead of PD in children of African American descent. Family, patient and provider preferences all accounted for the difference in choice of therapy by

race.(22) Similar differences based on ethnic background regarding choice of vascular access was also shown by Schoenmaker et al on 2012.(23)

Factors affecting patency of AV access in children:

1. Weight > 15kg
2. Vein calibre
3. Episodes of hypotension
4. Vessel thickness
5. High BP (can cause haematoma)
6. Age > 15 years

Other factors studied:

1. Gender
2. Ethnicity
3. Original disease leading to ESRD
4. Use of steroids
5. Age at onset of ESRD
6. Type of access used, date of creation, duration of function
7. Complications and interventions

Literature from India:

Literature from India regarding CKD in the paediatric age group is sparse.

In a report in 2002, Hari et al from AIIMS described their experience with HD in 53 children with ARF or CKD. In their patients aged 2-16 years, PD was used as the modality for RRT. If the patient was more than 2 years old and continued to require dialysis support beyond 2 weeks, HD was initiated. Patients younger than 2 years were managed with intermittent PD. In their 53 patients, the subclavian vein was used for dialysis in 49.3% sessions, femoral vein in 38.2% and internal jugular vein in 10.2% sessions. An AVF was used for 2.3% sessions. The authors clarify that since most of their patients were dialyzed for less than 6 months, they preferred to use temporary CVCs. They report rates of infection and thrombosis of the catheters to be 21.7% and 26.1% respectively.

In 2007, K. Elancheralathan as part of his MCh dissertation studied 142 patients with CKD who underwent VA creation procedures in Madras Medical College, Chennai. This included 21 children. Eleven of these procedures failed, however, the remaining were lost to follow-up.

Methodology:

The Institutional Review Board at Madras Medical College approved the following study.

Aims:

A. Primary
    1. To calculate the primary patency rates of AVF/AVGs in children
    2. To discover factors which may predict the patency
B. Secondary
    1. To study the perioperative complication rate

Study design:

Prospective observational study

Duration:

Jan 2010 – Jan 2012

Inclusion criteria:

All children (upto age 18) with CKD referred to the Department of Vascular Surgery for creation of a permanent vascular access were included.

Exclusion criteria – nil

Pre-procedure planning:

History and physical examination including history and scars of previous access procedures, and an evaluation of the superficial veins and peripheral arteries. Venous duplex for vein mapping if by physical examination the veins were equivocal. Venous duplex for deep vein patency if history of current or past catheter dialysis.

Anaesthesia:

For AVF, young children were either sedated or administered GA if necessary. Some older patients were able to tolerate the procedure with local anaesthesia or regional anaesthesia (subclavian or axillary block). Regional anaesthesia with sensorcaine and lignocaine induces vasodilatation and reduces postoperative pain. One dose of antibiotic was given either in the ward on the morning of the procedure or during induction of anaesthesia.

Procedures:

1. Radiocephalic fistula
2. Brachiocephalic fistula
3. Brachiobasilic transposition – single stage
4. Brachiobasilic transposition – two stage
5. AV graft – brachial artery to axillary vein
6. GSV transposition from brachial artery to axillary vein

Interventions:

1. Thrombectomy and redo AVF
2. Pseudoaneurysm ligation
3. Haematoma evacuation

Postoperative care:

To avoid postoperative thrombosis after creation of AV access, careful attention was paid to maintaining systolic blood pressures and avoidance of dehydration in the immediate post-operative period. On the discretion of the operating surgeon, sometimes an antiplatelet agent was used for a week post-operatively. Routine heparin therapy was not used. Antibiotics were given at the discretion of the operating surgeon.

Procedure:

For radiocephalic, brachiocephalic and transposed basilica vein AVF, an end to side vein to artery anastomosis was performed using either 7-o or 8-o monofilament (prolene) suture using continuous technique under 3.2x or 3.5x or 4.0x or no loupe magnification, depending on surgeon preference. Immediate postoperative patency was confirmed by the presence of a thrill or a bruit on auscultation. Doppler was not routinely done.

Many children develop vasospasm intraoperatively in the arteries and veins, and as such, infiltration of diluted papaverine solution was used intraoperatively at the discretion of the operating surgeon.

Statistics:

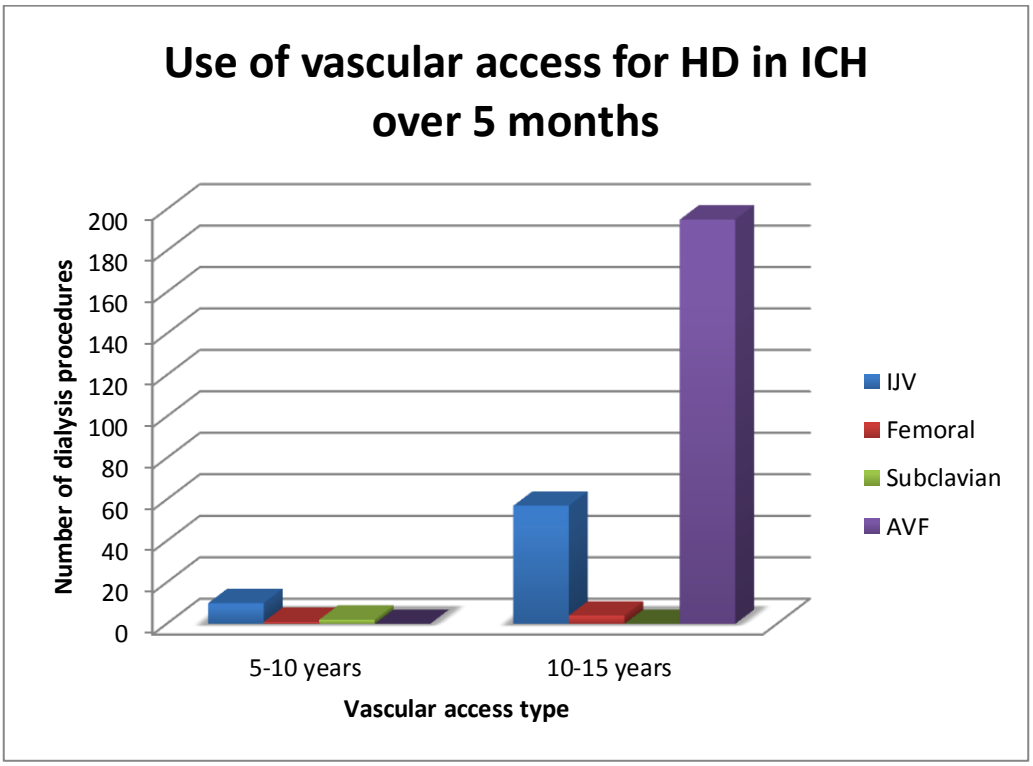
Demographics and complications were analysed using Fischer's exact test or Chi square analysis. Non-parametric data was presented as median and range. Factors associated with primary access failure were also analysed using Fischer's exact test or Chi square tests between groups. Differences in mean ages and weights were studied using unpaired t test for each access type. Access survival was presented as Kaplan Meier survival curves. Primary access failures were included in the analysis while determining the actuarial survival of functioning access. Correlation of patient age and weight to patency was done using Linear regression model.

All p values are two-sided and $p \leq 0.05$ was considered statistically significant. Statistical analyses were performed using SPSS version 15.0 (SPSS, Chicago, IL, USA).

Results:

Demographics:

Over a 5 month period in ICH the following graph shows the use of various vascular accesses for haemodialysis.



Total number of patients = 74 (males =49: females =25)

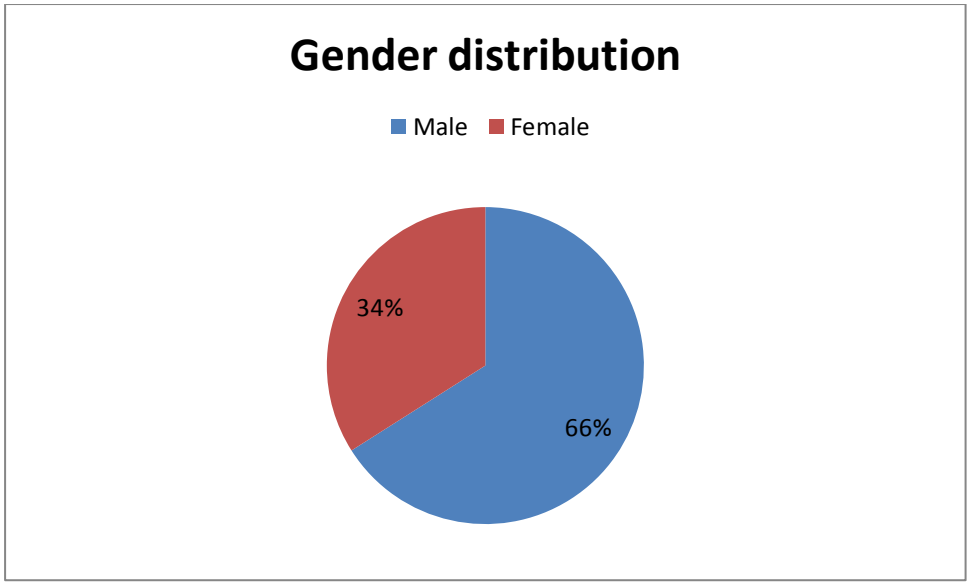


Figure 1. Gender distribution

Total number of procedures =100

Gender : males = 66 females = 34

Mean patient age at time of start of chronic HD – 10.86 years (range –2-18 years)

Mean time for treatment with chronic HD - 5.78 months

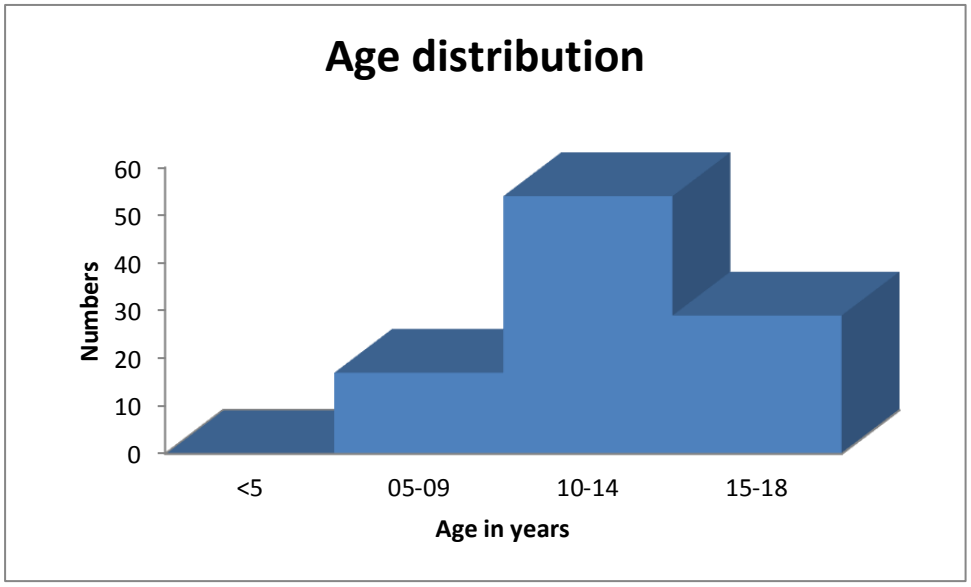


Figure 2. Age distribution

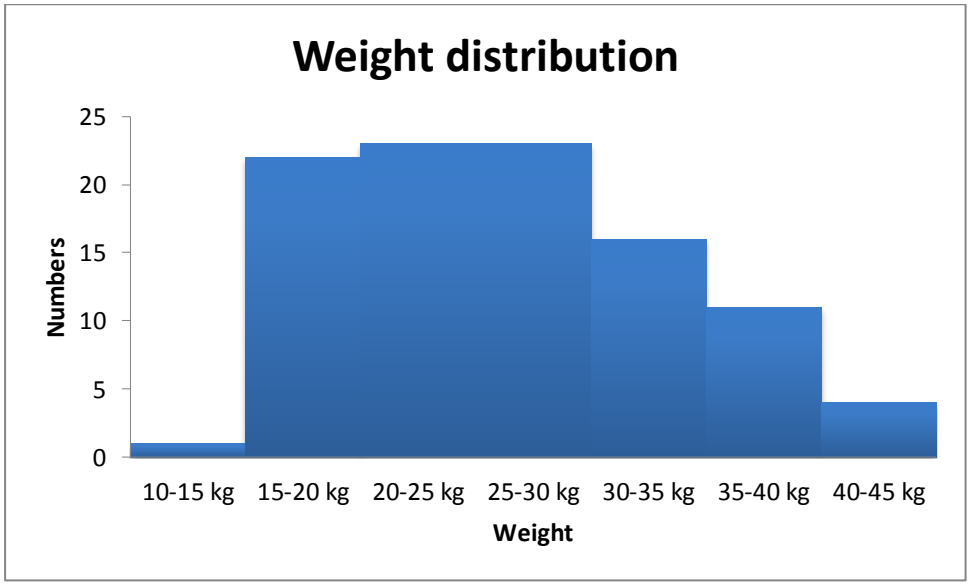


Figure 3. Weight distribution

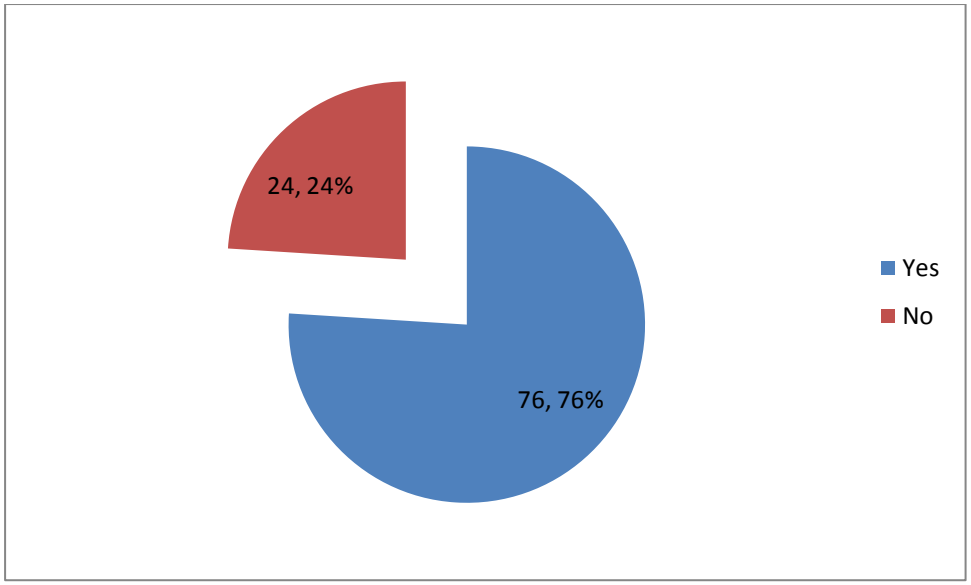


Figure 4. Percentage of patients already on dialysis.

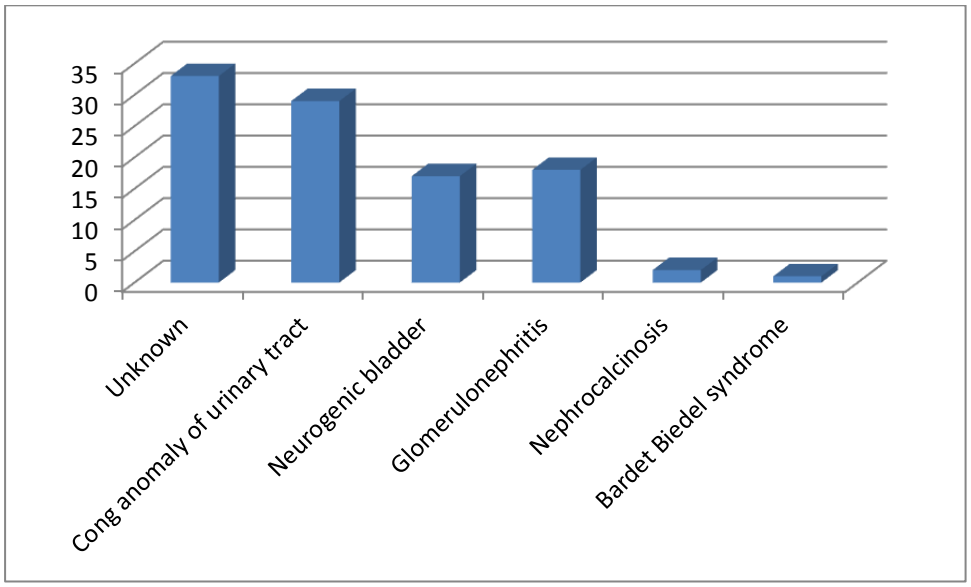


Figure 6. Primary disease - cause of CKD

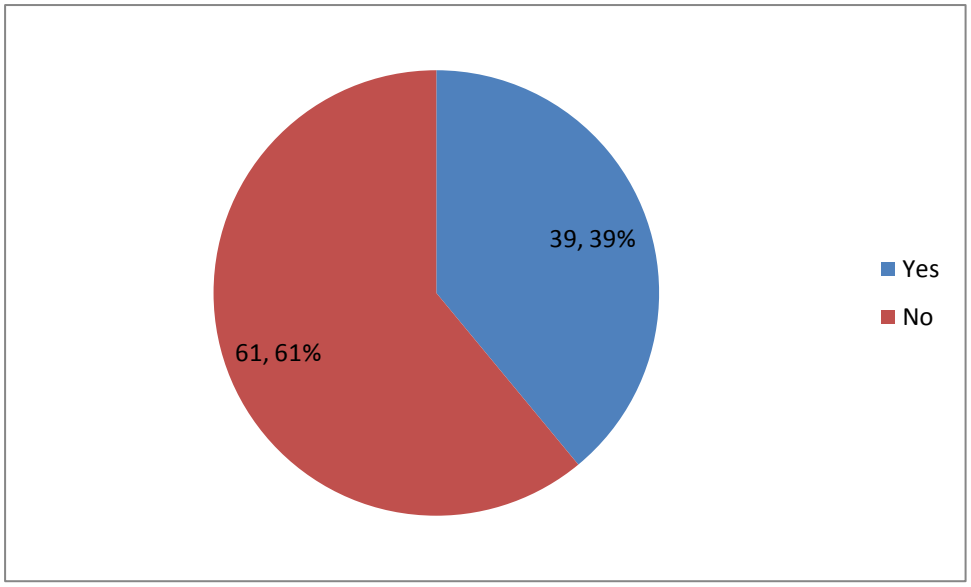


Figure 7. Percentage of patients who had pre-op duplex

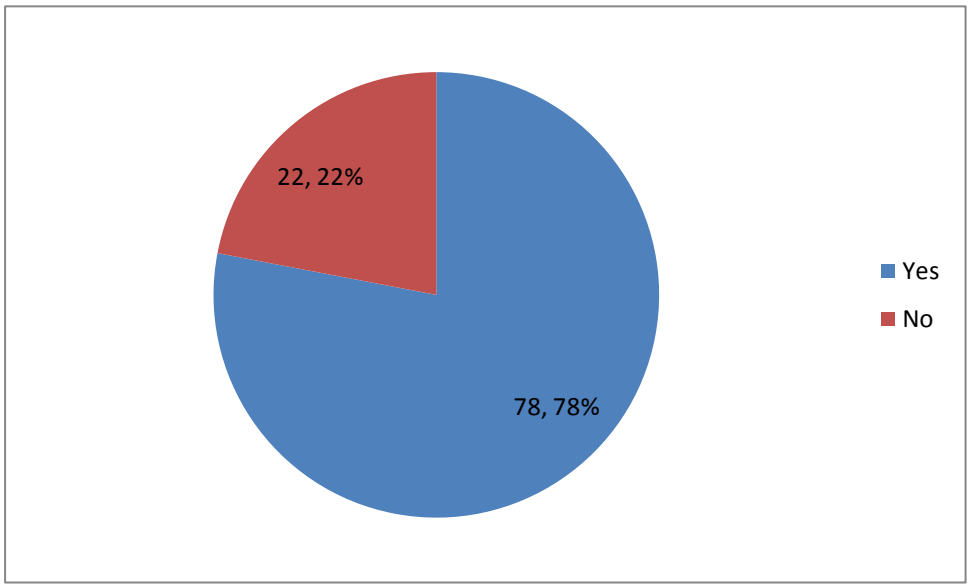


Figure 8. Primary success rate

The primary failure rate was 22%.

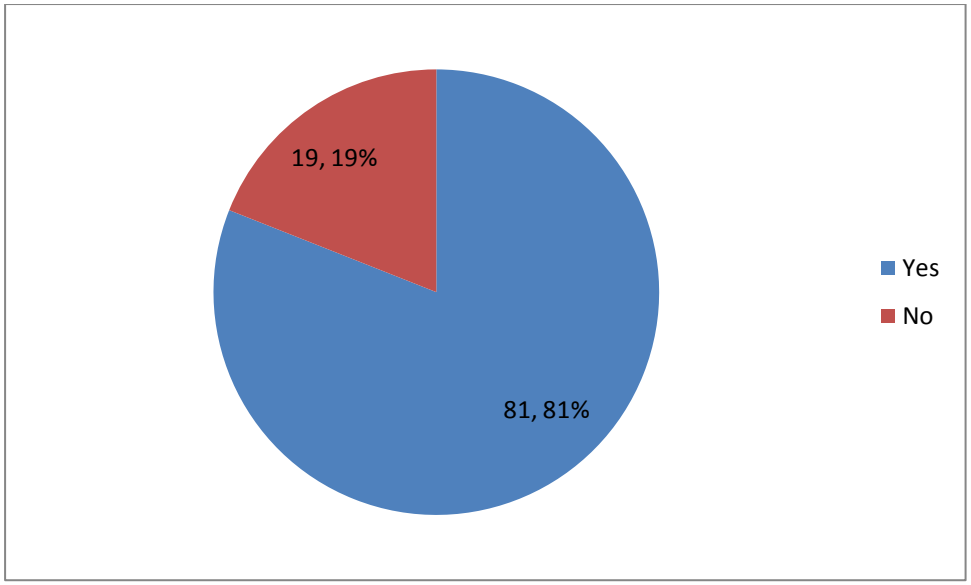


Figure 9. Use of magnifying loupes

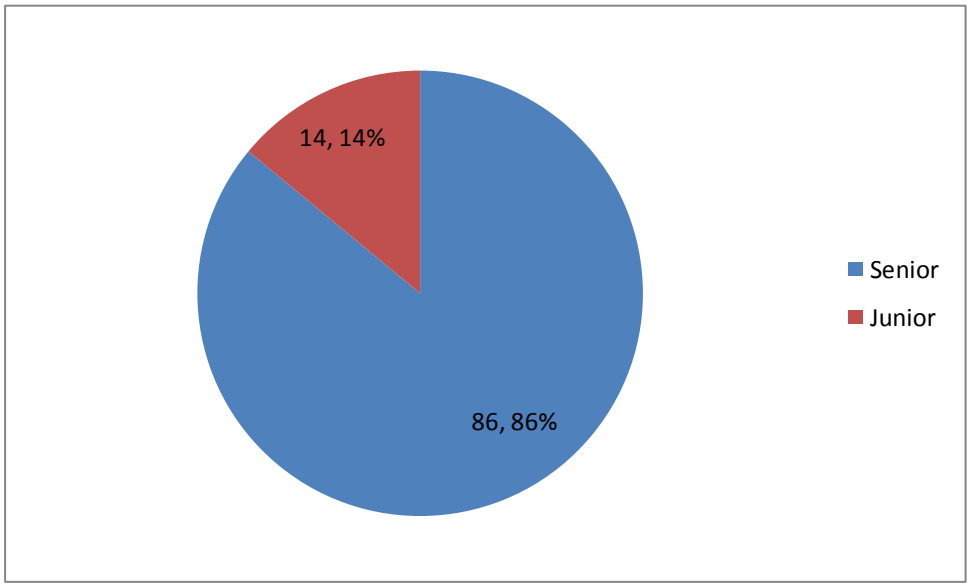


Figure 10. Procedures done by senior/junior surgeons

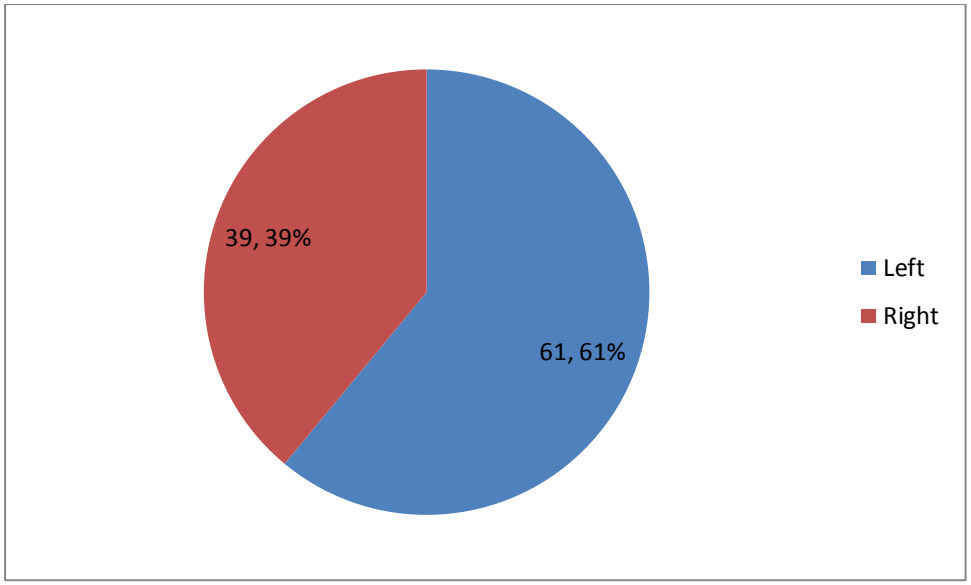


Figure 11. Side of procedure

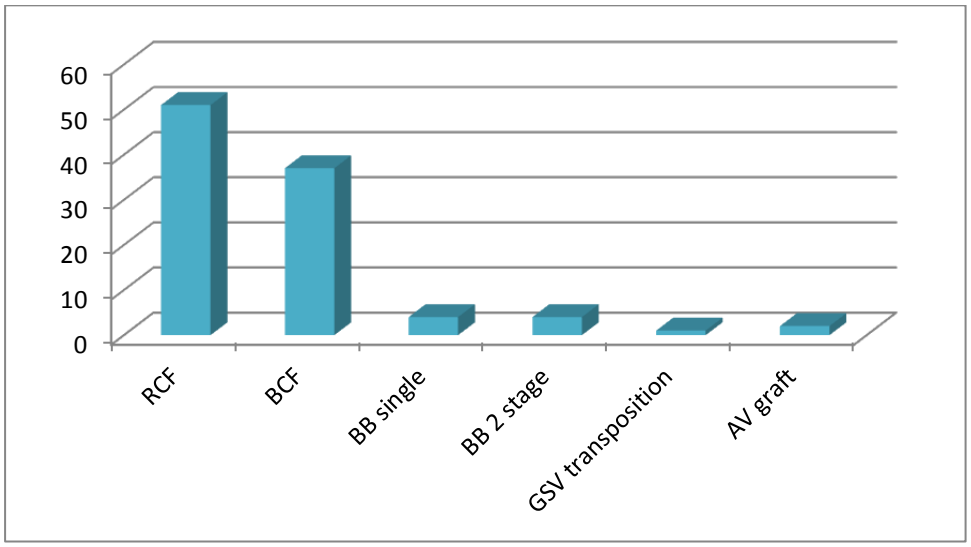


Figure 12. Type and frequency of procedures done

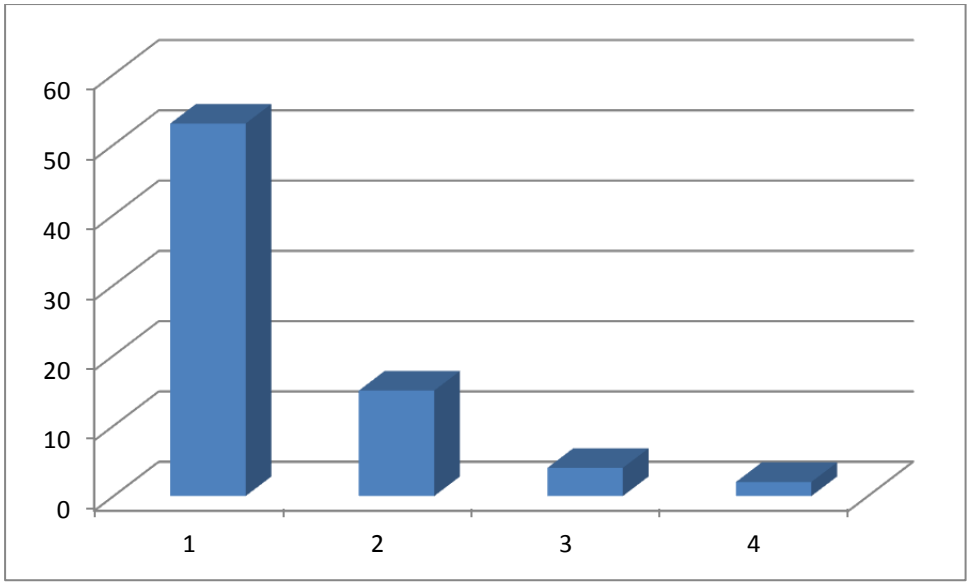


Figure 13. No of procedures done per patient

Table 4.

	AVF/AVG	Primary failure	P value
N access (N patients)	100 (74)	22	
% male	66	16	0.451
Primary disease unknown %	32	9	0.315
N with age < 10 years at creation of VA	17	2	0.263
N with weight <20kgs at creation of VA	22	2	0.098
N on dialysis at creation of VA	76	18	0.469

Side of procedure(left)	61	13	0.835
N of patients with previous failed procedure	29	7	0.793
Age at onset of CKD (mean ± SD)	12.41 ± 2.79	22	0.033
Mean number of months on dialysis	7.36 ± 6.42	22	0.141
Use of pre-op duplex	39	8	0.774
Use of surgical loupes	74	13	0.071
Experience of surgeon (senior)	86	17	0.182
Prolene (8/o)	55	9	0.117

Table 5. Primary result vs age group

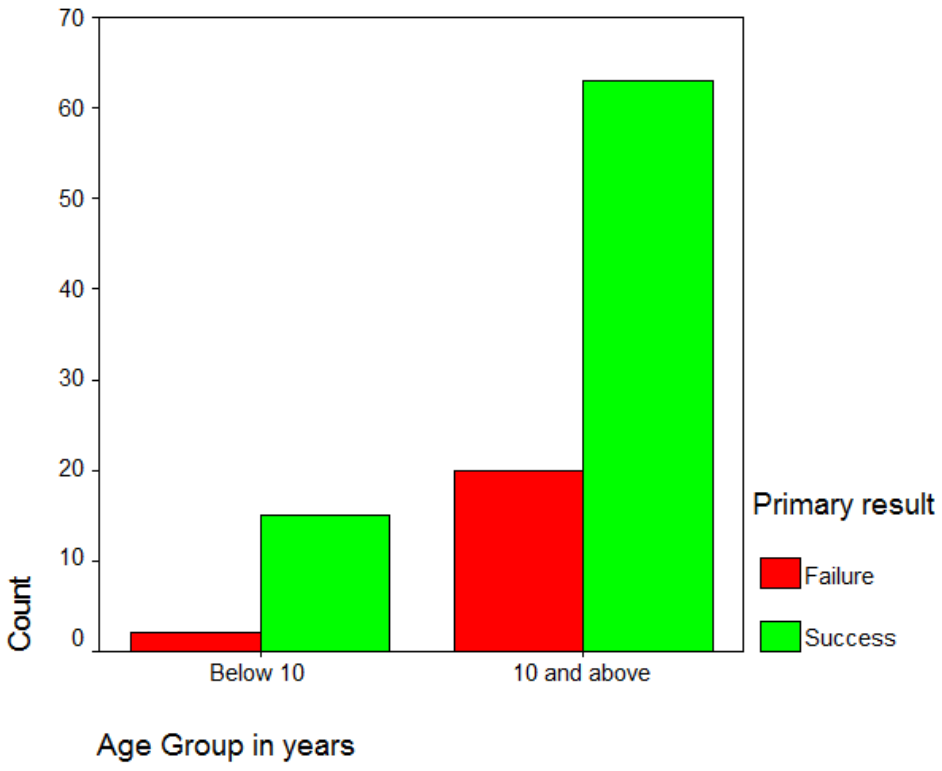


Figure 14. Primary result vs age group in years

Table 6. Primary result vs weight of patient

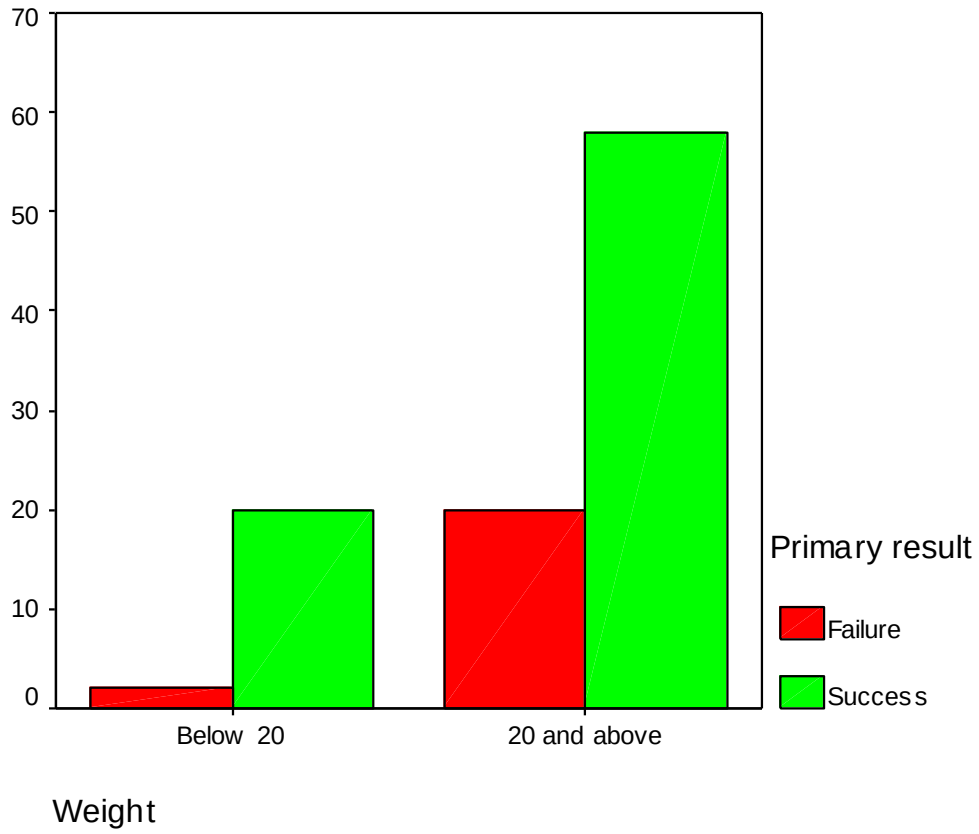


Figure 15. Primary result vs weight in kgs

Table 7. Type of procedure vs weight of patient

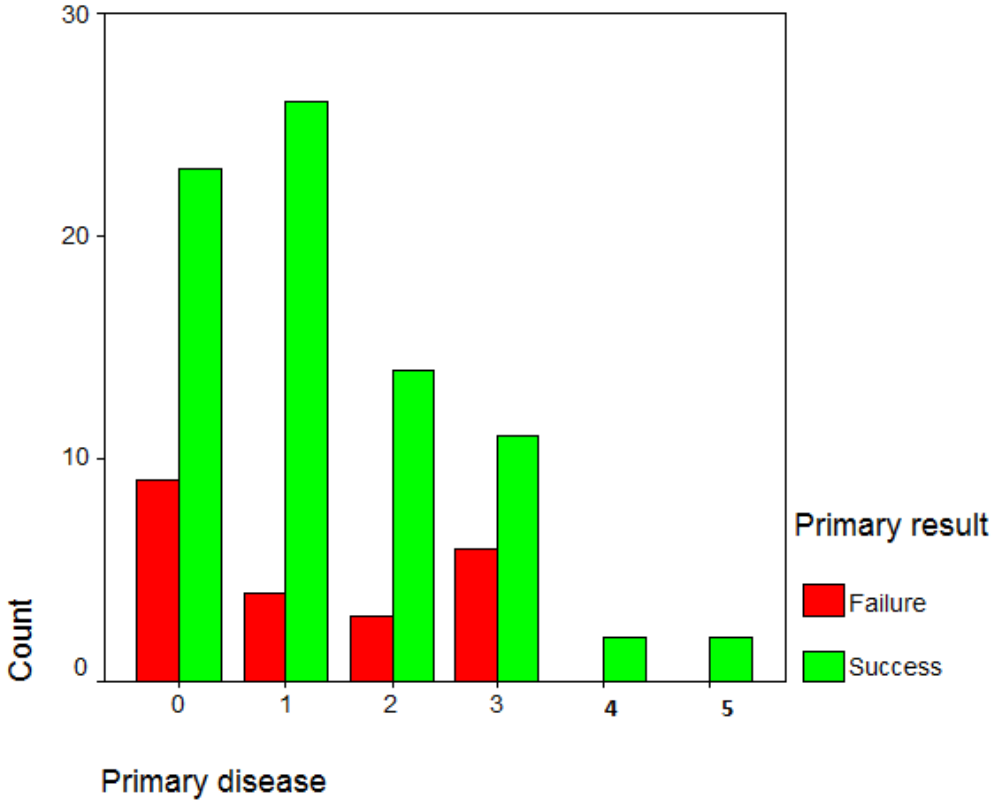


Figure 16. Primary result vs primary disease causing CKD

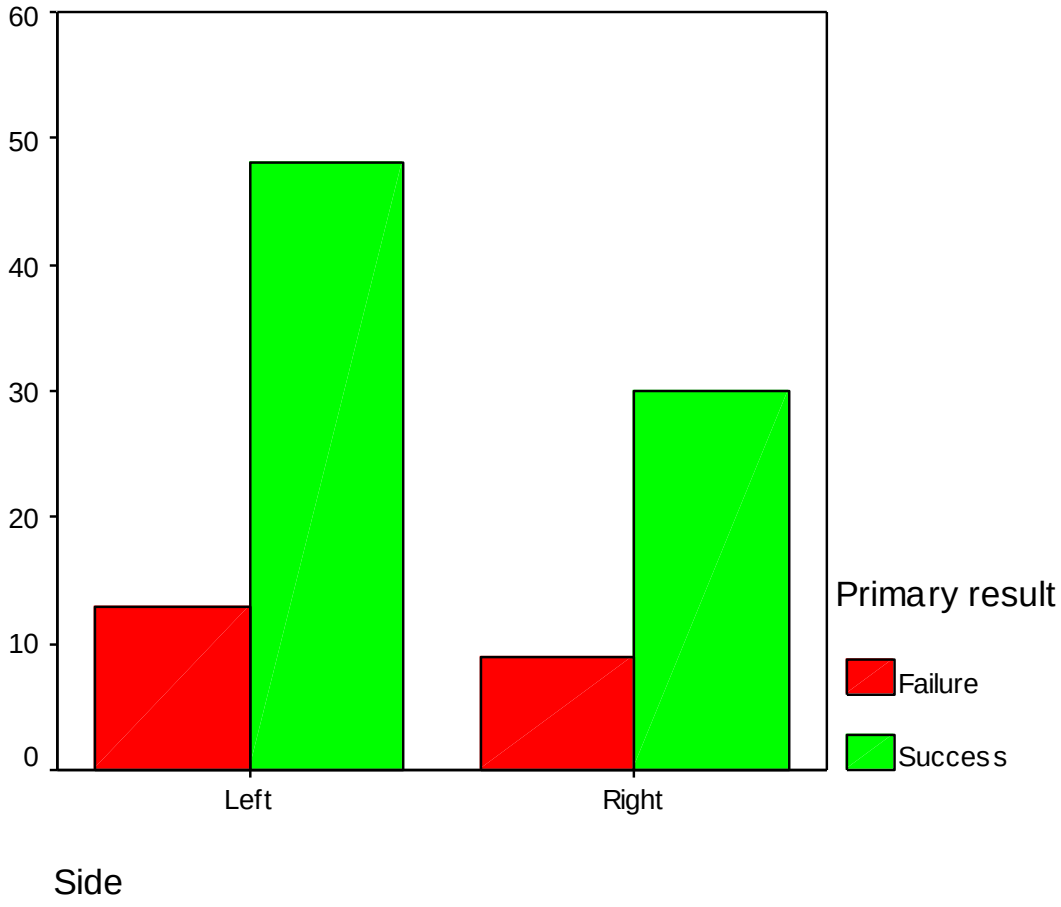


Figure 17. Primary result vs side of procedure

Table 8. Primary result vs type of procedure

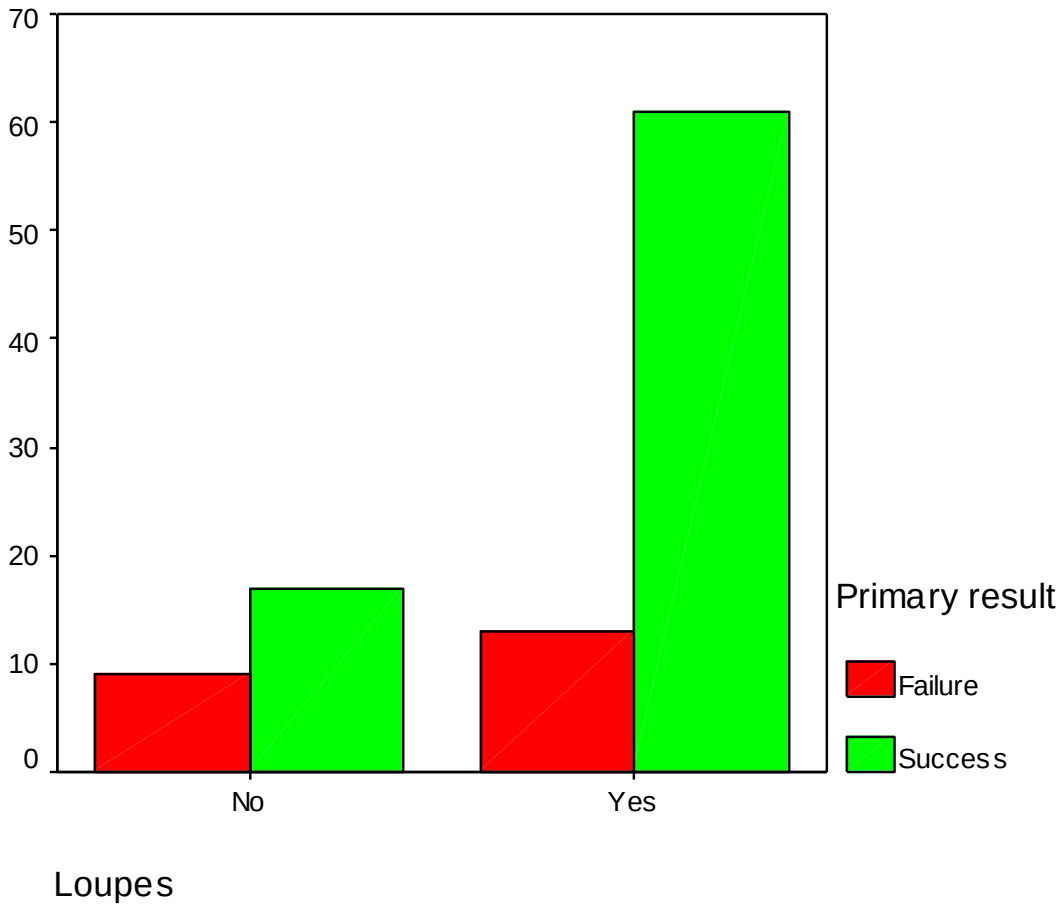


Figure 18. Primary result vs use of magnifying loupes

<u>Complications:</u>

1. Seroma / edema 10
2. Infection 1
3. Steal symptoms 1
4. Pseudoaneurysm 1
5. Bleed, ooze 2

Additional procedures required:

1. Thrombectomy 2
2. Pseudoaneurysm ligation 1

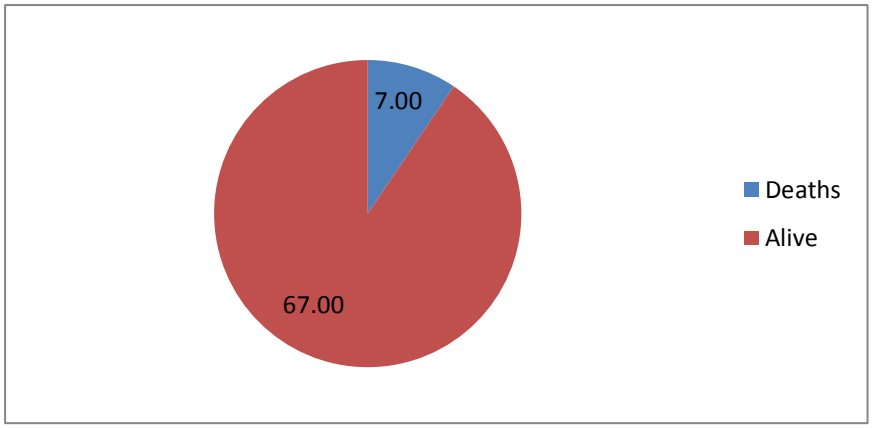


Figure 19. Mortality rate

Seven patients died due to complications of chronic renal failure. At the time of death, all of them had functional fistulas.

Patency curves:

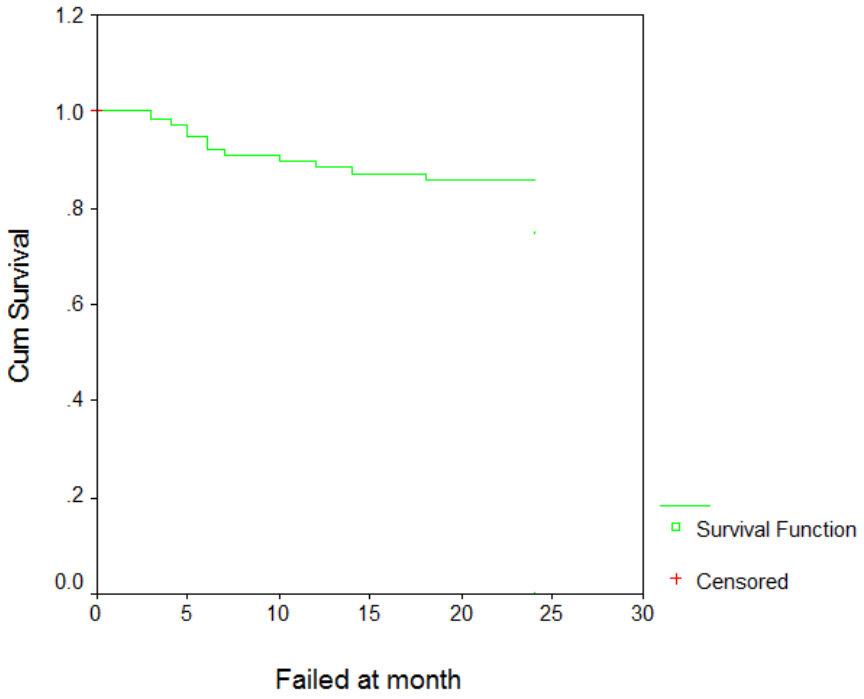


Figure 20. Kaplan Meier curve showing cumulative vascular access survival for all procedures

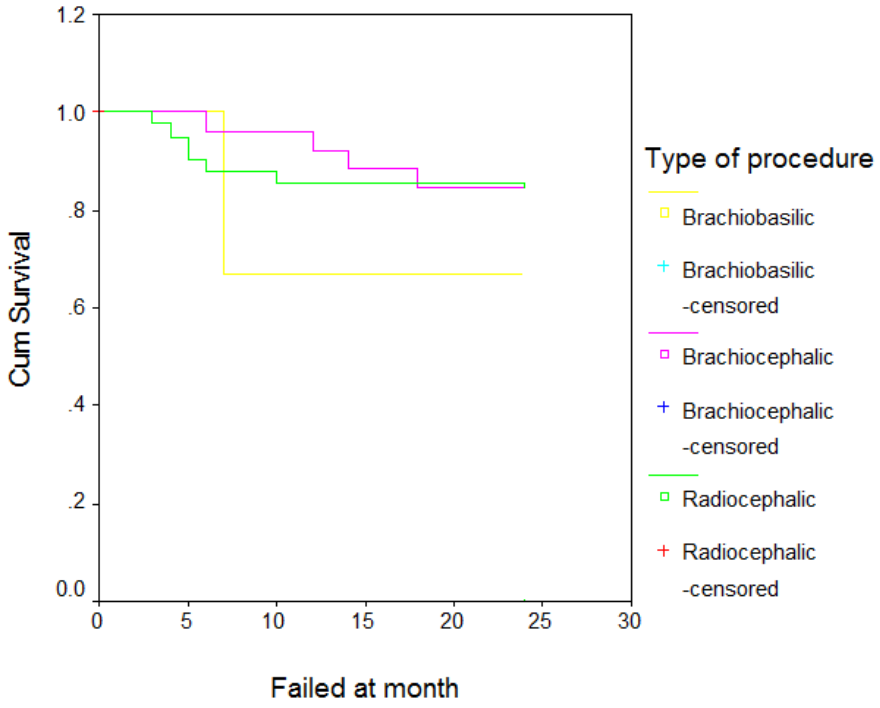


Figure 21 Kaplan Meier curve showing survival rates of fistulas based on the type of procedure

Discussion:

Demographics:

During the study period, 100 vascular access procedures were undertaken on 74 patients (male 49) children and adolescents. Mean patient age at initial access formation was 12.35 years (range 8-16 years).

Type of access:

Seventy-two patients had creation of autogenous fistulas and only 2 had synthetic AVGs inserted in the forearm. Of 100 procedures undertaken, 51% were radiocephalic fistulas, 37% were brachiocephalic fistulas and 8% were brachiobasilic transpositions. One patient had transposition of GSV and anastomosis from brachial artery to axillary vein. Fifty three patients (71.6%)underwent a solitary vascular access procedure.

The only two patients who had insertion of AVGs were females (16 and 18 years old) who had a synthetic graft placed in the forearm from brachial artery to axillary vein.

Primary success/ failure:

Primary access failure occurred in 22 of 100 procedures (22%). Thereafter, four fistulas failed over the study period.

In the analysis of factors and their potential correlation to the primary result, only age at onset of CKD was found to be statistically significant. Age and weight of the patient at the time of creation of vascular access was not related to the success of the procedure. However, the results also show that patients with age <10 years were maintained on catheter based haemodialysis in ICH and these patients were not referred for the creation of AVF. Even weight did not have a correlation to the primary result.

Figures 20 and 21 are Kaplan Meier curves showing the actuarial survival of the vascular access. They show that radiocephalic and brachiocephalic fistulas have better patency than brachiobasilic fistulas.

Complications and interventions:

Eighty-one procedures were uneventful. Ten patients developed edema and/or seroma formation which resolved with conservative management. One patient had infection of the wound following superficialization of a brachiobasilic fistula. One patient developed a pseudoaneurysm of the left radiocephalic fistula which required ligation of the left radial artery.

One patient developed steal symptoms of left upper limb after creation of an AVG which resolved with conservative management. Two patients had minor oozing from the wound which required opening of a few sutures to let out the haematoma and frequent dressing changes for 1 day.

One patient developed thrombosis of the right brachial artery and disappearance of thrill after a brachiocephalic fistula. He underwent exploration of wound, thrombectomy of the brachial artery and redo brachiocephalic fistula after 2 days. Thereafter, the fistula was functional.

One patient developed thrombosis of the AVG and required graft thrombectomy after which it was functional till she was lost to follow-up.

Seven patients died due to complications of renal failure.

Discussion of results:

Choice of vascular access in children is often dictated by their size and age. In ICH, over a month period, all patients under 10 years of age underwent HD by CVC, either through IJV, subclavian or femoral catheter. However, 76% of the dialyses in children aged 10-15 years was done through an AVF.

Creation of permanent vascular access in children maybe technically more difficult; however, reliable access can be achieved in even small children weighing as less as 15kgs. Even though p value was not statistically significant, we still fell that the most important factor is the use of magnification (surgical loupes) and meticulous care during vessel handling.

In this study, the majority of patients underwent autologous fistula creation which supports the theme of the Paediatric Fistula First Initiative.

However, only 24% of these were created pre-emptively, rest were on dialysis either through PD or CVC.

In our study, there was primary failure rate of 22% which is consistent with the figures quoted in international studies on paediatric vascular access procedures.

Table 3. International Studies of Hemodialysis Accesses in Pediatrics

Reference	Study Location/Year	No. of Patients	No. of AVFs (%)	No. of AVGs (%)	Demographics		Microsurgery (yes/no)	Comments
					Age (y)	Weight (kg)		
Bourquelot et al[11]	Paris, France/1990	380	404 (93)	30 (7)	7 (1-16)	18 (4-48)	Yes	63% Children < 10 kg with distal AVF, 96% immediate patency, 85% patency of RC AVF at 2 y, 60% at 4 y; total 65 distal fistulae with venous stenosis required revision
Sanabia et al[17]	Madrid, Spain/1993	74	74 (86)	12 (14)	9.2 (1-15)	?	Yes	Cumulative patency for RC fistula 79%, 75%, and 70% at 1, 2, and 5 y
Lumsden et al[18]	Atlanta, GA/1994	24	15 (17)	46 (51)	11.1 (3-17)	32 (12-41)	No	33% Primary failure AVF, thrombectomy required in 25 AVGs
Bagolan et al[19]	Rome, Italy/1998	90	112 (100)	0	5.6 (5 mo-18 y)	28 (6.5-54)	Yes	9% Early and 26% late complications (usually thrombosis); 4-y patency rates 70% (patients > 15 kg) and 56% (patients < 15 kg)
Garcia de Cortazar et al[20]	Santiago, Chile/ 1999	60	60 (40)	3 (2)	10 (1.8-15)	?	?	33% Initiated HD with AVF; mean life span: AVF, 524 d (20-1,277 d); permanent CVC, 73 d (9-147 d); 2-y survival AVF, 95%; 1 mo CVC, 50%; complications, 44% AVF *v* 75% CVC
Sheth et al[21]	Houston, TX/2002	47	24 (33)	28 (39)	13.1 (0.9-21)	46 (18-81) AVF, 41.5 (10.4-145) AVG	No	28% CVC only, 30% AVF or AVG only, 43% CVC + AVF/AVG
Gradman et al[22]	Los Angeles, CA/2005	47	47 (100)	0	14.6 (5-20)	44/47 < mean for age	Yes	1- and 2-y Primary patency, 100% and 96%; 1- and 2-y secondary patency, 100%
Our study	**Chennai, India, 2013**	**74**	**98 (98%)**	**2**	**12.4 (6-18)**	**12.2 (14-45)**	**Yes**	**Primary failure rate 22%**

Abbreviations: AVF, arteriovenous fistula; AVG, arteriovenous graft; RC, radiocephalic; CVC, central venous catheter; HD, hemodialysis.

Photographs:

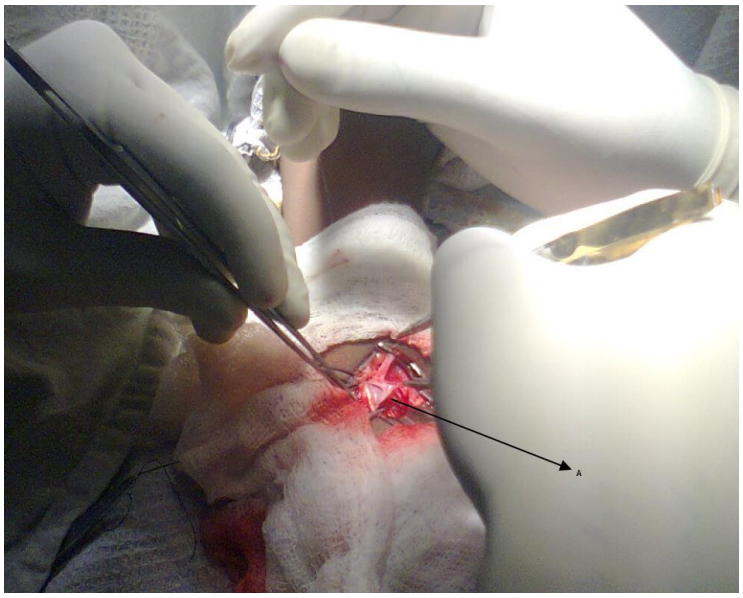
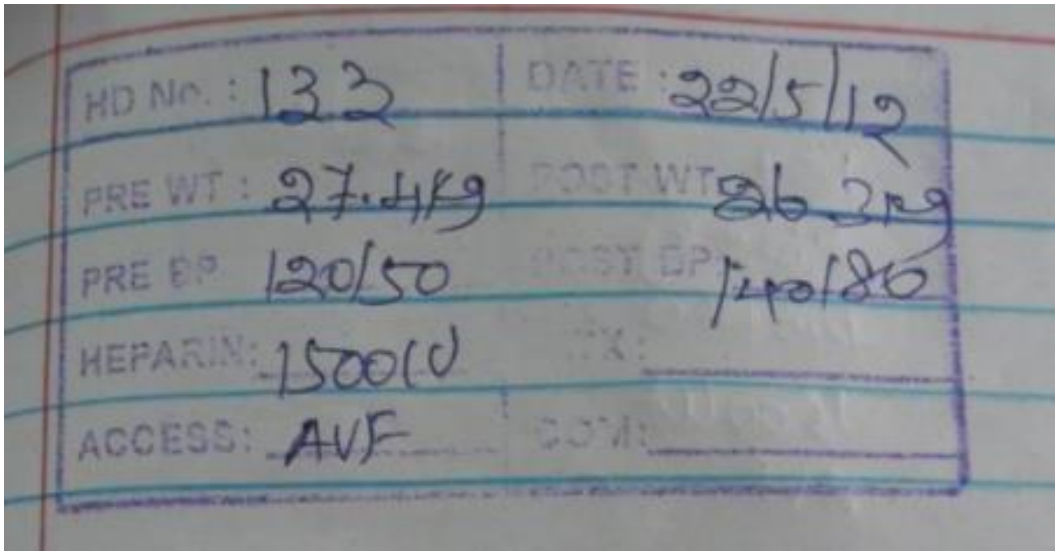


Photo 1. Intraoperative photograph showing that part of the anastomosis has been completed. A is the anastomosis.

Photo 2. Intraoperative photograph showing the completed anastomosis.

Photo 3. Intraoperative photograph showing the array of microsurgical instruments used.

Photo 4. A boy with ESRD receiving haemodialysis via his right brachiocephalic fistula.



HD No. : 133 | DATE : 22/5/12
PRE WT : 27.4kg | POST WT 26.3kg
PRE BP 120/50 | POST BP 140/80
HEPARIN: 1500 IU | TX:
ACCESS: AVF | COM:

Photo 5. Dialysis details of the above boy.

Photo 6. Boy with ESRD receiving haemodialysis via left brachiocephalic fistula

Photo 6. Dialysis settings

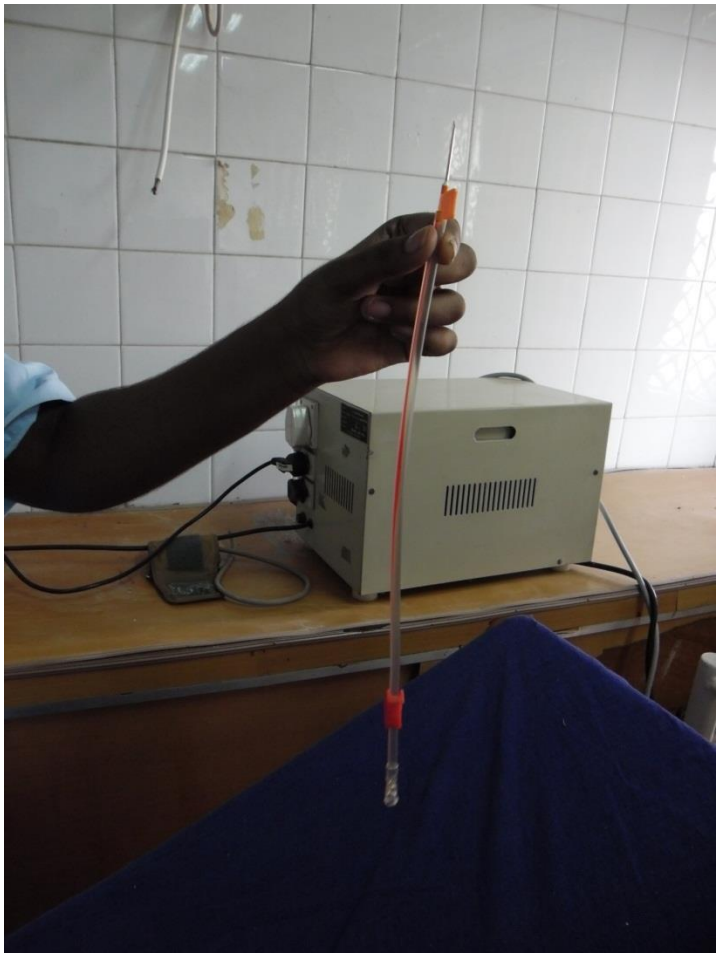


Photo 7. Cannula used to access the AVF.

Photo 8. Intraoperative photograph showing the completed anastomosis - radiocephalic fistula.

Photo 9. Photograph showing previous failed AVFs in a boy who underwent left radiocephalic fistula.

Photo 10. Postoperative photograph showing a two-stage brachiobasilic transposition right arm.

Photo 11. Collage of photographs of children with ESRD with a successful creation of AVF.

Conclusions:

An arteriovenous fistula is the optimal vascular access in children undergoing haemodialysis. With the Paediatric Fistula First Initiative, various centres worldwide have started using microsurgical techniques to create fistulas and use it as the primary vascular access with good results even in small children. The various advantages of using an AVF as the primary access in children includes its long life, low rate of complications and lower overall costs, albeit it has a higher primary failure rate than CVCs or AVGs.

This study shows how even in resource-challenged countries, children with ESRD can be successfully managed on long term haemodialysis with AVF. These children tend to have less complications and hospitalizations compared to their counterparts who have CVCs for long durations.

These results show that even in countries with limited resources, it is possible to reach and even surpass the KDOQI recommended target of 50% AVF use as primary access choice in children with ESRD. The communication between the surgeon, pediatric nephrologist and the dialysis technician/staff is integral in determining time to first use and proper cannulation technique to ensure adequate use for dialysis. We have confirmed what others have shown; that AVF can be successfully used in paediatric HD patients with careful diagnostic evaluation, optimal access site selection, meticulous microsurgical

technique and multidisciplinary management of the access. Based on our results, we would advocate paediatric dialysis centres to work in collaboration with a vascular surgeon who is versed in these techniques to create a functioning AVF.

Limitations:

Even though this study was undertaken as a prospective cohort analysis, follow-up was inadequate. When the children came, it was usually for a failed fistula requiring creation of a new one. It is difficult to calculate how many children succumbed to their disease.

Moreover, measures to check dialysis adequacy were not reliable and varied from centre to centre. Therefore, this was not included as part of study.

Implications for further research:

Health related quality of life studies can be performed in these patients and their parents/caregivers to understand the significance of the impact of the disease and the various treatment modalities (CVC, PD vs HD) have on their daily life.

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