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The Role Of Perioperative Colour Doppler Ultrasound In The Prediction Of Short Term And Long Term Outcomes Of Arteriovenous Fistulae.

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ABSTRACT

An optimally functioning arteriovenous fistula (AVF) is required in all patients with end-stage renal disease (ESRD) for haemodialysis. The purpose of this study was to analyze the effect of using Colour Doppler (CD) perioperatively in patients scheduled for arteriovenous fistula (AVF) surgery. This study comprised two groups. Group A (n=100) included patients in which Radiocephalic (RC)/Brachiobasilic (BB) fistula was being used for vascular access without undergoing any prior CD study before the AVF creation surgery. Group B included (n=50) patients in which CD was used perioperatively to assess the diameter of the vein, blood flow across the arteriovenous anastomosis, and velocity in the proximal arterialized vein (within 2 cm from anastomosis). These factors were analyzed and assessed as determinators for the final success rate of AVF. Both the groups were compared using the Chi-square test for mean flow rate and patency rate, and a 95% confidence interval (CI) was taken for the study. *P value* < 0.05 was considered statistically significant. The rate of primary access failure (after one week of AVF surgery) in Group A was 20.7% and 18.7% for RC and BB fistulae respectively. The net patency rates at one year were 67.65% in the RC and 62.5% in the BB group. However, in Group B, the rate of primary access failure was 16.12% and 10.5% for RC and BB fistulae respectively and net patency rates at one year also improved to 74.19% in RC and 78.94% in BB group. The factors resulting in increased primary patency of arteriovenous fistula were veins greater than 2.5 mm and 3.2 mm in diameter for RC and BB fistulae respectively, a flow velocity of greater than 47 cm/sec and 52 cm/sec for functioning RC and BB fistulae respectively measured immediately post arteriovenous fistula construction and a mean flow of greater than 591 ml/min and 966 ml/min in successfully functioning RC and BB fistulae respectively across the arteriovenous fistula. A greater diameter size of veins, a higher flow velocity in functioning AVFs and a higher mean flow rate were all contributing factors towards the maintenance of patency in the long-term follow-up of AVF creation. All these parameters were calculated in the group undergoing perioperative CD assessment (Group B), which hence proves that perioperative Doppler assessment plays a significant role in the formation of patent and successful AVFs.

Keywords: brachiobasilic fistula, radiocephalic fistula, patency of arteriovenous fistula, arteriovenous fistula, perioperative doppler

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INTRODUCTION

Vascular access complications account for approximately 15% of hospital admissions among haemodialysis patients, and the provision and maintenance of vascular access remain a major factor in end-stage renal disease (ESRD) management programs [1]. It has been shown beyond doubt in numerous studies and hospital statistics that an optimally functioning arteriovenous fistula (AVF) is a good prognostic factor for evaluating patient morbidity and mortality in the dialysis phase [2]. Arteriovenous fistula has been reported to have variable success rates and a number of factors influence their patency (primary and secondary) [3]. The Colour Doppler (CD) is a non-invasive vascular access monitoring technique that can provide both hemodynamic and structural information regarding arteriovenous fistula patency [4]. Colour Doppler is widely used for the initial assessment of the status of vessels in AVF creation surgeries [5,6]. The purpose of this study was to evaluate the role of perioperative Colour Doppler in the operation theatre to assess the immediate flow characteristics of AVF and to see how it influences the final outcome.

MATERIALS AND METHODS

The study was a retrospective observational study carried out at a tertiary care hospital. All adult patients of Chronic Kidney Disease (CKD) who underwent AVF creation surgery over a three-year period from January 2017 to December 2019 were included. Patients with repeat AVF surgeries on the same vessels, AVF repair or augmentation surgeries, lost to follow-up or expired, were excluded from the study. In case one patient underwent two or more separate AVF surgeries due to failure of prior AVF, each AVF surgery was recorded as a separate event.

All patients of CKD referred for AVF surgery, underwent the creation of AVF surgery by an experienced surgeon after requisite pre-operative evaluation. The type of AVF was radiocephalic (RC) or brachiobasilic (BB), based on the clinical requirement of the patient and the decision of the operative surgeon. All patients underwent a screening ultrasound or CD prior to AVF creation. The surgery and postoperative care were performed based on standard guidelines and hospital protocol. These patients who underwent AVF surgery prior to July 2018 were included in the Direct Surgery group (Group A). Thereafter, for cases reporting during or after July 2018, a detailed peri-operative ultrasound/CD (detailed pre-operative ultrasound mapping and early post-operative evaluation within 48 hours) was done in all cases of AVF. This subgroup was included as the Perioperative Ultrasound Group (Group B).

The electronic and hospital records and documents available for all patients were studied. Demographic parameters, course of AVF, complications, details of AVF cannulation, ultrasound/ CD data, and other requisite details were recorded for all patients. The baseline patency of AVF at one week and after one year was noted. Requisite Institutional Ethics Committee (IEC) approval was obtained for the study.

During ultrasound and CD examination, Grayscale B mode was done to get the morphological status of vessels (diameter of artery and vein, and condition of vessel wall). Colour Doppler imaging was used to assess the haemodynamics including the peak systolic velocity (PSV) (in cm/s). The following ultrasound details of perioperative ultrasound were collected and recorded:

- Preoperative diameter and PSV of artery and vein to be used for AVF
- Postoperative condition of feeding artery, anastomosis, and the vein to exclude stenosis or other complications.
- Postoperative diameter and PSV of the artery, proximal arterialized vein (within 2 cm from anastomosis), and anastomotic segment

Failure of AVF was defined as thrombosis, lack of patency of AVF or inability for cannulation of AVF for haemodialysis. It could be early occurring in the immediate or early postoperative period likely due to thrombosis. Primary AVF failure is defined as thrombosis or inability for cannulation of fistula for haemodialysis within 3 months of creation.

Statistical Methods

Quantitative data were presented in terms of mean and standard deviation. Qualitative or categorical data were presented as absolute numbers and proportions. The success and failure rates in both

groups were compared using the Chi-Square test. The mean diameter, velocity, and mean flow rate of successful and unsuccessful fistulae of Group B were evaluated using T-test. The various flow rates of successful and unsuccessful fistulae in group B were compared using Chi-square test. P< 0.05 was considered statistically significant. IBM SPSS version 21 was used for statistical analysis.

RESULTS

A total of 172 AVF were created over this period from January 2017 to December 2019 which 150 AVF were included in the study (12 patients had expired, and 10 patients underwent AVF on the same vessel or had additional augmentation surgeries, and were excluded). The baseline characters of included cases are given in Table 1.

Table 1: Baseline characteristics and clinical presentation of the study population

S No	Characteristics		Direct Surgery group (Group A) (Total = 100) (% of total)	Perioperative USG group (Group B) (Total = 50) (% of total)
1.	Mean age in years (Mean±SD)		53.2 ± 5.2	49.5 ± 6.4
2	Number of males (% of total)		62 (62%)	27 (54%)
3.	Underlying medical comorbidities (% of total)	Hypertension	72 (72%)	39 (78%)
		Diabetes	66 (66%)	30 (60%)
		Coronary artery disease	22 (22%)	09 (18%)
		Dyslipidemia	23 (23%)	10 (20%)
4.	Etiology of CKD (% of total)	Diabetes	56 (56%)	24 (48%)
		Hypertension	13 (13%)	05 (10%)
		Chronic Glomerulonephritis	08 (8%)	06 (12%)
		Chronic Tubulointerstitial disease	12 (12%)	09 (18%)
		Others/Unclassified	11 (11%)	06 (12%)
5.	Stage of CKD (% of total)	CKD5D	40 (40%)	13 (26%)
		CKD5	46 (46%)	25 (50%)
		CKD4	14 (14%)	12 (24%)
6.	Type of AVF created (% of total)	RC AVF	68 (68%)	31 (62%)
		BB AVF	32 (32%)	19 (38%)

Group A

100 patients were evaluated in this group; 68 had Radiocephalic (RC) and 32 had Brachiobasilic (BB) fistulae. 14 out of the 68 RC fistulae had failed within the first week of surgery whereas six of the 32 BB fistulae failed to mature. The rate of primary access failure (access never used for dialysis) in this group was 20.7% and 18.7% for RC and BB fistulae respectively (Table 2).

During the next year, an additional eight RC and six BB fistulae got blocked. The net patency rates (total number of fistulae minus the blocked ones including the ones which had primary access failure) at one year were 67.65% in the RC and 62.5% in the BB group (Table 3). The mean flow rates across functional AVF in this group were 679 ml/min in the RC and 847 ml/min in the BB group.

Group B

50 AVFs done during the study period were prospectively evaluated, (31 RC and 19 BB). Five out of 31 RC fistulae had failed within the first week of surgery whereas two of the 19 BB fistulae failed to mature. The rate of primary access failure (access never used for dialysis) in this group was 16.12% and 10.5% for RC and BB fistulae respectively (Table 2).

It was noticed that the rate of primary access failure dropped in Group B to 14% as compared to 20% in Group A, which was statistically significant (Table 2).

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After one year, three more RC and two more BB fistulae got blocked. The net patency rates at one year were 74.19% in the RC group and 78.94% in the BB group (Table 3).

The preoperative vein diameter had a great bearing on arteriovenous fistula patency. Table 4 shows the comparison in the vein diameter between the successful and unsuccessful groups. It was seen that veins with a preoperative diameter of more than 2.5 mm, when used for RC fistula creation have more chances to mature into successful access. The BB fistulae with a preoperative vein diameter of more than 3.2 mm were seen to have better outcomes (Table 4). The fistulae were evaluated perioperatively for Velocity and Flow rate of blood in them. Both of these values were used to see if they are useful indicators to predict their final outcome (Table 4).

Table 2: Rates of primary AVF failure after one week of AVF surgery in both groups

Type of AVF created	Group A (Direct Surgery group)		Group B (Perioperative USG group)		p-value (chi-square test)
Parameter	Total	Failed cases and failure rate (% of total)	Total	Failed cases and failure rate (% of total)	(Not Applicable)
RC AVF	68	14 (20.7%)	31	5 (16.12%)	0.601
BB AVF	32	6 (18.7%)	19	2 (10.5%)	0.435
Total AVF	100	20(20%)	50	7 (14%)	0.376

Table 3: Rates of AVF patency after one year of AVF surgery in both groups

Type of AVF created	Group A (Direct Surgery group)		Group B (Perioperative USG group)		p-value (chi-square test)
Parameter	Total AVF	Patent AVF n (%N)	Total AVF	Patent AVF n (%N)	(Not Applicable)
RC AVF	68	46 (67.65%)	31	23 (74.19%)	0.67
BB AVF	32	20 (62.5%)	19	15 (78.94%)	0.36

Table 4: Comparison of initial peri-operative USG findings in AVF of Group B between patent and non-patent AVF after one year of surgery

Mean±SD	Type of AVF	Patent AVF	Non – patent AVF	*p* value (t-test)
Mean vein diameter (mm)	RC	2.51±0.21	1.61±0.15	0.000008
	BB	3.25±0.18	2.20±0.14	0.03
Flow Velocity of blood (cm/sec)	RC	47±1.62	29±1.58	0.000001
	BB	52±2.73	26±1.41	0.002
Mean flow rate across AVF (ml/min)	RC	591±3.71	127±1.58	0.00000
	BB	966±4.54	237±2.8	0.00005

It was seen that a statistically significant difference was noted in the patency of AVF if velocity was greater than or equal to 47 cm/sec for RC fistulae and 52 cm/sec for BB fistulae. Mean flow rates across the AVF were found to be 591 ml/min in the successful RC fistulae and 966 ml/ min in functioning BB fistulae which were also found to be statistically significant.

During the perioperative evaluation of fistulae, it was also discovered that their success rate was influenced by the flow rates across the anastomoses as depicted in Table 5. Mean flow greater than 600ml/min across the arteriovenous fistula resulted in the successful functioning of all the fistulae,

however, lower flow rates of less than 300 ml /min resulted in AVF failure in all the patients with BB fistulae, and 71.43 % of patients of RC fistulae.

Table 5: Association of Mean flow rates in successful and unsuccessful AVF's in Group B

Mean flow rates in ml/min	Radiocephalic		Brachiobasilic	
	Successful(%)	Unsuccessful(%)	Successful(%)	Unsuccessful(%)
<300	2 (28.57%)	5 (71.43%)	Nil	2 (100%)
300 – 600	8 (72.73%)	3 (27.27%)	5 (71.43%)	2 (28.57%)
>600	13 (100%)	Nil	10 (100%)	Nil
Total patients	23	8	15	4
p-value (Chi square test)	0.002		0.008	

DISCUSSION

Early failure and inadequate flow rates are the most frequent problems occurring with arteriovenous fistula cases. Causative factors for poor outcome remain speculative and clarification of factors that may lead to lower flow rates and early failure prior to AVF reconstruction would be of great interest. Such factors, if found, may direct the operation to be performed under more suitable conditions or at better anatomical locations, since most patients require a well-functioning AVF in a short time.

Bhalodia and associates studied proximal and distal radiocephalic (RC) fistulae in 100 patients retrospectively [7]. At 12, and 24 months, the patency rate was calculated. It was noticed to be 92% and 86% for proximal radio-cephalic fistulas and 74% and 76 % for distal cases respectively. Glass and colleagues included 215 patients in their study [8]. During the course of their study, they discovered that their primary and primary assisted patency rates at 6, 12, and 24 months were 63%, 40%, and 26% and 74%, 56%, and 38%, respectively, while the secondary patency rates at 6, 12, and 24 months were 85%, 72%, and 65%, respectively. In our study, the net patency rates of RC fistulae as calculated from Group A were 79.41% and 67.65% at one month and 12 months respectively. These figures are comparable to these two studies however in group B the primary patency rates improved further to 83.88 percent and 74.19 percent at one month and one year respectively. In Group A, Brachiobasilic fistulae had the primary patency rate of 81.25 % as compared to 89.47% in Group B. The net patency rates at one year also improved in Group B as compared to Group A (78.94% vs 62.5%) which was found to be statistically significant.

Shintaro Shibutani and associates examined the long-term follow-up of 24 of 298 patients having undergone Brachiobasilic (BB) fistula [9]. Of these, the primary patency rate was 89.7% at one year, 69% at two years and 52% at 10 years. Ivan D Maya and associates reported that on excluding primary access failures of AVFs, the median cumulative survival was almost similar for transposed brachiobasilic fistulas and brachiocephalic fistulas (4.1 and 3.4 years respectively) [10]. Haci Alper Uzun and colleagues showed in their study for 21 patients, except for two patients, the transposed Basilic Vein in the forearm stayed patent during follow-up with a patency rate of 90.5% [11].

Physical examination is the traditional surgical evaluation performed before haemodialysis access placement. Sometimes palpation and inspection are difficult, especially in obese arms, and few of the patients have vessels, visible throughout their entire course. Patients with ESRD often have had multiple venipunctures and numerous intravenous lines placed and thus have an increased likelihood of venous thrombosis or occlusion. Surgeons commonly assess the suitability of the vein segment by using a tourniquet proximally and inspecting the calibre of distended veins. However, many times the draining veins have segmental stenosis or webs which cannot be assessed during the physical examination. In the study conducted by us, we routinely assessed our patients with physical examination along with CD during Out Patient Department (OPD) consultation.

Intraoperatively many of the patients were noticed to have large-calibre veins that were simply too deep to be visualized or palpated at physical examination. Prior to the use of Colour Doppler (CD) for vascular mapping, the surgeons would have concluded that there were no suitable options for a fistula and,

therefore, constructed a fistula at the elbow or constructed a graft arteriovenous fistula instead. Therefore, preprocedural vascular mapping ensured that vessels of inadequate size were avoided. Secondly, the surgeons avoided the use of veins that though having a suitable calibre at the site of anastomoses, had an unsuspected occurrence of stenosis or thrombosis in the draining vein.

The vast gain in anatomic knowledge obtained with CD mapping assists in planning surgeries and is especially invaluable in patients who are difficult surgical cases to tackle (like obesity, diabetes, history of prior access, and elderly women). Vein problems are common in these patients, and, thus, the physical examination may be difficult. There is a substantial learning curve with CD mapping. The interpretation may be difficult without understanding the various AVF and graft configurations. When few veins are present, both the forearms and the upper arms will need to be examined. In these instances, CD mapping can be a long and tedious procedure. A typical examination of both forearms and one or both upper arms performed by an experienced sonographer takes 45 minutes.

CD vessel mapping prior to haemodialysis access placement has been the subject of many investigations. Boonying Siribumrungwong et al found high maturation rates in the group of favourable-examined patients [12]. In the other group of unfavourable-examined patients, preoperative vascular mapping helps to identify nonpalpable favourable veins with a successful maturation of 18.75%. The corresponding duplex scan reduced the rate of unsuccessful operation significantly ($p = 0.037$) but did not increase the maturation rate. In our study, preoperative CD upper extremity vein mapping has been shown to improve early patency rates by helping to identify suitable vein conduits for optimal AVF creation.

Alexandru Oprea et al in their study declared findings suggesting that a preoperative vein diameter of ≥1.9 mm and artery diameter of ≥1.5 mm have a successful maturation rate of AVF greater than 60% in ESRD patients [13]. When compared to the size of the vein (diameter) used for AVF creation, the maturation rate of surgical AVF increases proportionally to the diameter size.

Hai Lei li et al in their study determined that the best cut-off diameter for the cephalic vein and radial artery was 1.85 mm and 2.05 mm, respectively [14]. They also described the importance of a suitable segment from the wrist to the antecubital fossa (forearm fistula) or the antecubital fossa to the axilla (arm fistula) with the absence of significant central vein stenosis in the ipsilateral extremity. Carney Chan et al noted a successful overall maturation rate of 72% when veins at least 2.5 mm in diameter were used [15]. The only adverse significant predictor for fistula maturation in their study was BMI greater than 29.5. Therefore, they concluded that fistula location, sex and age shouldn't be used to preclude patients with a vein diameter of at least 2.5 mm from consideration for AV fistula creation. On the contrary, Kian Guan Lee et al stated that maturation rates with and without vein mapping were 72.2% and 82.4%, respectively, ($P = 0.001$) and in patients with vein diameters of less than 2 mm and more than/equal to 2 mm, there was no statistically significant difference in maturation rates [16]. Ali Kordzadeh et al concluded that the optimal range of radial artery for maximum maturation and primary patency of radiocephalic AVF creation was at least 2 mm [17]. A diameter of at least 2 mm (of the cephalic vein) results in the best primary patency outcomes and maturation and a threshold below 1.5 mm isn't advocated.

In our study, the mean preoperative vein diameter was seen to be 2.51 mm in the successful group of Radiocephalic fistulae whereas it was 1.61 mm in the unsuccessful group. Brachiobasilic fistulae which failed to mature had a mean vein diameter of 2.21 mm as compared to 3.25mm in the successful group.

Agnes Masengu et al concluded in their cohort study that a radial artery flow rate <50 mL/min was associated with a sevenfold increased risk of failure to mature in radio-cephalic arterio-venous fistula, which to our knowledge has not been previously reported in the literature [18]. Perioperative ultrasound mapping adds an objective assessment in the clinical prediction of AVF failure to mature.

In our study, the mean perioperative flow across the anastomoses was seen to be 591 ml/min in the successful group of Radiocephalic fistulae whereas it was 127 ml/min in the unsuccessful group. Brachiobasilic fistulae which failed to mature had a mean flow rate of 237 ml/min as compared to 966 ml/min in the successful group.

We found the use of colour Doppler in the perioperative period to be most useful in both choosing the right vessels for arteriovenous fistula and in analyzing the peak systolic velocities and blood flow across the fistulas. These factors were found to be good predictors of future patency of these fistulas.

Although there isn't any definitive data in the literature, any intervention that helps increase blood flow to the extremity may improve the chances of a fistula developing successfully. Therefore, we recommend regular hand-arm exercises, until the fistula matures. Fifteen softball arm squeezes every 5 minutes, starting from the postoperative evening is our standard practice.

Narayan Prasad et al established that diabetes was associated with poor primary and secondary patency rates [19]. The primary patency rates at 3, 6, 12, 18, and 21 months were 82%, 78%, 73%, 70%, and 70%, respectively. The diabetic population is a challenge, because of the greater likelihood of failure with any type of access procedure.

One of the limitations of the study is that factors other than the radiological causes of failure (like Diabetes, Hypertension, Obesity etc) were not studied.

CONCLUSION

Intraoperative Colour Doppler is a useful tool for the successful construction of AVF. A mean preoperative vein diameter of more than 2.5 mm was associated with a better final outcome. Fistulae with a velocity recorded to be more than 45 cm/sec have a higher chance of maturation. Blood flow across the arteriovenous fistulae is also a good predictor as those with flow rates over 590ml/min are more likely to be successful.

The perioperative colour Doppler helps evaluate the blood flow and velocity across the anastomoses on the table and thus predict their outcome. The fistulae with low flow rates may thus be revised in the same setting either proximally or on the opposite limb.

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