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Role Of Preoperative And Postoperative Colour Doppler Sonography For Arteriovenous Fistula Access And Its Maturation

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Abstract

Introduction

Success of Dialysis in end stage renal disease is determined by good vascular access. Dedicated pre-operative planning and post-operative follow up by Colour Doppler can assist in creation of arteriovenous fistula and minimise its unnecessary failure.

Material and Methods

The study included 70 adult end stage renal disease patients referred by Nephrology department. Preoperative Colour Doppler was performed on upper limb vessels. AVF was created in 60 patients. Postoperative colour doppler was done on day 1, day 14 and day 42. UAB (University of Alabama at Birmingham) criteria of Arteriovenous Fistula vein diameter ≥4 mm and blood flow ≥500 mL/min has been taken as cut off for maturity of Fistula.

Results

Mean diameter of cephalic vein was 2.37mm at wrist and 2.82 at elbow. Mean radial artery diameter measured 2.14mm at wrist and 2.6mm at elbow. The mean ulnar artery diameter was 2.17mm at wrist and 2.85mm at elbow. Brachial artery measured 3.8mm mean at elbow. Postoperative colour doppler on day 1, day 14, day 42 showed blood flow rate> 500ml/min in 16 patients (26.66%), 35 cases (58.33%) and 51 cases (85%) respectively. Vein diameter > 4mm was recorded in 25 patients (41.66%), 49 cases (81.66%) and 58 cases (96.6 %) on Postoperative day1,14, and 42.

Conclusion

Our study showed that in Indian population successful fistula formation was possible with the cut off of vein diameter as 2mm. UAB criteria for maturation of fistula was more suitable to evaluate maturity of fistula.

Keywords: AVF, Dialysis, Colour Doppler

Introduction

Till advent of colour doppler, physical examination alone was an established norm for vessel selection to create AVF. Though physical examination was useful to examine veins it did not give much information about arteries and anatomical variants. [1,2]. Thus physical examination alone failed in 25-50% of patients [2]. Failure of vascular access in patients with end stage renal disease leads to their prolonged hospital stay and rise in morbidity and

mortality.[3] Vascular access procedures alone may cost 50.1% of inpatient expenditure.[4]

Doppler ultrasound has proved its merit in preoperative assessment and follow up of AVF but still needs acceptance. [5,6,7,8]. National Kidney Foundation Kidney Disease Outcomes Quality Initiative, the Japanese Society for Dialysis Therapy, and European Best Practice Guidelines, support Physical examination complemented by colour doppler.[9,10,11]

Haemodialysis can be achieved by either Arteriovenous fistula (AV fistula) or central venous catheters. However, AV fistulas lasts longer and has less complications. [12] AV fistula commonly created are radiocephalic fistula and brachiocephalic fistula [13]

Diabetes and Vascular disease usually coexist in patients with chronic renal disease which causes failure of maturation and maintenance of fistula due to various complications like thrombosis, stenosis, aneurysm and steal syndrome.[14] Doppler ultrasound aiding preoperative vascular mapping has increased the number of successful AVFs. Early detection of complications by doppler ultrasound by post operative monitoring has improved the survival of AVF [15,16] According to guidelines AVF creation should be attempted first. [17] European Society of Vascular Surgery Guideline recommend use of colour doppler in pre-operative planning for haemodialysis. [17,18,19] ESVS guidelines suggest a minimal arterial and venous diameter of 3 mm for brachiocephalic and brachiobasilic fistulas. [17,20]

Guidelines state that minimal internal radial artery diameter should be 2 mm for creaion of radiocephalic fistula, [17,20]. This has been further confirmed by other reviews [21] when standard vascular surgical technique is used. Fistula creations can be successfully done in radial artery lumen diameters of 1.5 to 1.6 mm, [22] in a healthy artery without calcification and with a good reduction of resistant index [23]. Venous suitability has been considered to minimal internal venous diameter of 2.0 mm as adequate. [17] Silva [24] proposed that a minimum of 2.5mm diameter is essential for arteriovenous fistulas. He followed up the cases and found that if the venous diameter was more than 2.5mm, the patients had a good outcome (83% of the AV fistulas were patent at the end of one year and only 8% of the fistulas had primary failure). Another study showed more than 3mm diameter veins was recommended. [25] KDOQI guidelines state the Rules of 6 (flow volume >600 mL/min, vein diameter >6 mm, vein depth <6 mm. [20,26] According to the University of Alabama at Birmingham (UAB) criteria an AVF vein diameter ≥ 4 mm, and an AVF flow ≥ 500 mL/min resulted in a mature AVF. Doppler ultrasound plays an important role in recognising early postoperative complications and allows early intervention to maintain and mature the fistula and reduce morbidity. [24]

Aim-

To study the role of Doppler ultrasound in evaluation of creation of arteriovenous hemodialysis fistula, its maturation

Materials And Method:

This study is observational prospective longitudinal study. Study was conducted in Department of Radio-diagnosis ESI-PGIMSR Basaidarapur, New Delhi from June 2022 till December 2022. Equipment used was Toshiba Xario 200Platinum Colour Doppler machine equipped with 10-14 Mhz Linear probe. All Adult patients with end stage renal disease referred from Nephrology Department for Vascular assessment and mapping with aim to construct first arteriovenous fistula in the upper limb were included in this study after taking informed consent. Inclusion criteria were adult patients (more than 18 years) with End stage renal disease sent for evaluation of vascular access for first AV fistula. Exclusion Criteria were patients with arterial anatomic variants. Sample size was 70 patients. Patients-age, sex, and comorbidities- body mass index, systemic arterial hypertension, heart failure, chronic obstructive pulmonary disease, diabetes mellitus and medication (antiplatelet or anticoagulant therapy) were recorded along with their consent for study.

Protocol: In Pre-operative examination the arteries in the non-dominant forearm and arm are examined first. The radial artery, ulnar artery followed by brachial artery are examined for diameter and peak systolic velocities. The arteries are examined for the diameter in the transverse plane starting from the wrist. Intimal thickness of artery is noted and examined for calcified plaques. Radial artery is preferred for arteriovenous fistulas. After arterial

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examination cephalic vein at wrist and forearm and basilic vein are examined for diameter. Any signs of thrombosis is noted by checking compressibility and spectral flow examination. The vein depth from skin surface was examined and marked for construction of fistula.

Similarly colour doppler examination of arteries and veins are done for dominant upper limb. If the cephalic vein is eligible for arteriovenous fistulas, the vein is examined up to the elbow and arm for its continuity and any stenosis. If there is any abnormality then basilic vein is used for access.

Post -operative arteriovenous fistula colour doppler examination: Colour Doppler examination was done on day 1, Day 14 and Day 42. In arteriovenous fistula formation, low pressure vein gets blood flow from high pressure artery, this causes venous dilatation with increased blood flow. Colour Doppler was done to examine the anastomosis, artery feeding it and draining vein. The blood flow is calculated in the long axis. Detailed evaluation was done to evaluate any evidence of thrombosis or stenosis.

Statistical Software-

MS Excel, SPSS version 22 (IBM SPSS Statistics, Somers NY, USA) was used to analyse data.

Results:

Out of 70 referred patients' maximum patients were from age group 51-60 years (38.5%) followed by age group 61-70 years (22.85 %) (Table 1)

Males were slightly more 36 (51.4%) as compared to females 34 (48.5%)- (Pie Chart)

On pre-operative evaluation of arteries, the mean radial diameter at wrist was 2.14mm and at elbow was 2.6mm. The mean ulnar artery diameter was 2.17 at wrist and 2.85 at elbow. Brachial artery measured 3.8mm mean at elbow. (Table-3,4) The cephalic vein measured mean diameter of 2.37mm at wrist and 2.82 at elbow. The basilic vein had a mean diameter of 2.58mm at wrist and 2.83 at forearm. (Table-3,5)

60 patients out of 70 underwent arteriovenous fistula formation. 4 patients were found unfit due to severe atherosclerotic changes(3patients), and smaller vascular diameter. 6 patients were lost on follow up. 49 out of 60 (81.66%) patients underwent radiocephalic fistula and 11 (20%) underwent brachiocephalic fistula. (Table-6)

UAB criteria of blood flow rate of ≥ 500ml/min and vein diameter of ≥ 4mm has been taken as cut off for maturity of Fistula.

Post-operative Day 1 – Evaluation of blood flow rate and vein diameter was done.16 patients (26.66%) had flow rate > 500ml/min and 25 patients (41.66%) had vein diameter > 4mm. (Table-7)

Post-operative Day 14 – revealed that 35 cases (58.33%) had blood flow rate of > 500ml/min and 49 cases (81.66%) had vein diameter of > 4mm .1 patients showed early thrombosis and were immediately referred for its treatment (Table -8)

Post-operative Day 42 – showed that 51 cases (85%) had blood flow rate >500ml/min and 58 cases (96.6 %) had vein diameter of > 4mm (Table -9)

Discussion

Dialysis is a temporary renal replacement therapy for patients with chronic renal disease. AVF is the preferred access for haemodialysis. Good vascular access is important for haemodialysis and survival of the patients. Colour Doppler is now an important diagnostic tool and is used both for preoperative and post-operative assessment of the vessels and its blood flow. Doppler also allows early detection of complications. It helps surgeon in deciding the vessel suitability. Increase of number of AVF led to increased reporting of AVF failure. In last 30 years AVF failure was as high as 66%. [27] Itoga recommended use of early Doppler screening to minimise the number of unsatisfactory maturations of AV Fistulas. [28] On the other hand systemic review found that Doppler US does not help in successful AVF patency. [29] The Ultrasound examination is deficient in visualization of central veins. [30]

There is no clear consensus in identifying criteria for maturation of fistula. In USA, blood flow rates should be 300-350ml/min with 6-8 dialysis per month for maturation of fistula. [31] In Europe, lower blood flow rates are accepted. [32,33] KDGIGO guidelines recommend Rule of 6 for maturation of arteriovenous fistulas - Blood flow rate of >600 ml/min; Vein diameter of >6mm; Vein depth of <2mm. [20,26]

Doppler picks up complications early so that timely intervention can be done.Most of the patients in our study were seen in the age group of 51to 60 years. This is in concordance with the study performed by

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Robbin et al [34] who had a mean age group of 52.2 years for forearm fistula and 57.4 years for upper arm AV fistula. Gender distribution was nearly equal with males (51.4%) being marginally more. In our study Physical examination was paired with Colour doppler for pre-operative vascular mapping. Out of the 70 patients 60 underwent AVF creation. Our study performed better than earlier studies in terms of AVF formation where only physical examination was performed. The results of successful AVF formation were better (85.71%) as compared to studies by Silva et al (64%), Allon et al (63%) and Malvroh et al (70%) which only depended on physical examination. Our study showed more creation of Radiocephalic fistula (49) as compared to Brachiocephalic fistula (11)81.66% than Wells et al (96 ,29) 76.8%.

Different studies give different minimum arterial diameter cut off. Parmar et al have reported that there is increased frequency of failure (46%) of fistula in artery diameter less than 1.5 to 1.6 mm. [35] Wong et al. [36] gave an arterial diameter of ≤1.6 mm as cut off for failure. Silva et al. reported a minimal diameter of 2 mm. [37] Lockhart et al proposed that arterial diameter of less than 2mm is not fit for AVF creation. [38] AVF success rate of 50 % have been demonstrated in <1.5mm arterial diameter. [35] In our study radial artery measured >2mm in 38 patients (54%) in wrist and 61 patients (87%) in elbow. The condition of artery was also evaluated for atherosclerotic plaques or wall calcification and it should have normal flow pattern. In our study 3 (4.28%) out of 70 patients had extensive calcified atherosclerosis in both radial and brachial artery hence these patients were not considered for surgery.

Sedlacek M et al. [39] state that minimum peak systolic velocity 50cm/sec is essential for arteriovenous fistula. Lockhart et [40] says that there is no need to measure PSV and it has no role in fistula prognosis. Cut off criteria for eligible cephalic vein with tourniquet in upper arm was 2.5mm at the wrist. In our study we found that only 35 (50%) patients had cephalic vein of >2.5mm in wrist and 54 (77%) in forearm. This would have resulted in significant number patients being declared unfit. Hence, it was decided to take cephalic vein diameter >2mm as cut off in wrist and forearm/elbow in patients with normal the arterial system. 18 patients (25.7%) in our study had the cephalic vein was <2mm in wrist and 4 (5.7%) patients had cephalic vein <2mm at forearm/elbow. This could be explained by ethnic and demographic variation. In our study 48 (80%) patients underwent radiocephalic fistula and 12 (20%) underwent brachiocephalic fistula in comparison to 96 (76.8%) and 29 (23.2%) in Wells et al.

Post operatively, the doppler was performed in the Day 1, Day 14 and Day 42. In our study UAB criteria was followed to assess the maturity of fistula which is blood flow rate at the draining vein ≥ 500ml/min and vein diameter of ≥ 4mm. The [40] Blood flow in Arteriovenous fistulas increases rapidly on its creation. 55% of radiocephalic fistula and 83% brachicephalic fistula achieve the criteria for a mature fistula on day 1. [41] Different studies have different criteria for maturation. In USA, fistula blood flow rates is 300-350ml/min with 6-8 dialysis in a month. [42,43] In Europe, the criteria are lower blood flow rates with longer times. [44,45]

On day 1 our study showed radiocephalic fistula blood flow of 380ml/min which is similar to Robbin et al [34] 375ml/min. Brachiocephalic fistulas in their study 750ml/min matured earlier as compared to our study 450ml/min.

On day 14 of the study demonstrated blood flow in radiocephalic fistula to be 550ml/min compared to Robbin et al 510ml/min. Brachiocephalic fistula in our study showed blood flow rate of 620ml/min in comparison to Robbin et al blood flow rate of 1004ml/min

On day 42 of the study our study showed blood flow rate of 720 ml/min and 850 ml/min for radiocephalic and brachiocephalic AVF respectively. On other hand Robbin et al 2016 showed 684 ml/min and 1065 ml/min. On comparison with Robbin et al blood flow rates in radiocephalic fistula is similar, on other hand blood flow in brachiocephalic fistula was lower in our study as compared to their study. This can be attributed to smaller (.25cm) mean diameter of cephalic vein in our study as compared to 0.38cm of Robbin et al. KDOQI guidelines of maturation includes blood flow >600ml/min: [20,26] but in our study we have considered >500ml/min for maturity which is UAB criteria.

Conclusion:

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Colour doppler ultrasound aids in identifying native vessels and its mapping for preoperative AVF formation, and postoperatively for AVF maturation.

Preliminary colour doppler screening and vascular mapping has helped in selecting the vascular site and increased the number of AVF and minimised failure rate. Our study showed that radiocephalic fistulas was most common site followed by brachiocephalic fistula. Brachiocephalic fistulas show early maturation.

Our study was consistent with UAB criteria (University of Alabama at Birmingham) for maturity which that is blood flow rates ≥500 mL/min and vein diameter ≥4 mm. Preoperative colour doppler resulted in improved radiocephalic (71%) and brachiocephalic fistula (82%) on day 42. our study showed that cut off mark of more than 2mm diameter of cephalic vein should be taken. Some studies have taken cephalic vein more than 2.5mm as cut off for successful maturity of arteriovenous fistula. However, in our study it was seen that such a cut off would make almost 50 % of patients' ineligible for haemodialysis. Hence in this study the cut off taken was more than 2mm..Post operative doppler follow up led to early detection of thrombosis on day 14 and timely intervention saved arteriovenous fistula.

Recommendations-

Pre-operative doppler study in evaluating the arterial and venous system has shown increased maturity and post-operative doppler study helped in early detection and reduction of long-term complications.

Hence colour doppler study should be done along with physical examination as the gold standard for assessment of AVF.

Limitations-

Ultrasound is a operator dependent modality and this may result in variable outcomes.This is a small cross-sectional study with a small sample size. Only adult patients with first AVF creation were included.

Only radiocephalic and brachiocephalic fistula were included the study; other types of fistula and grafts were not included in the study. Although this study was a prospective study the patient was followed up for a short period of time (6 weeks).

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Figure Legends / Tables

Table 1: Age distribution of subjects

		Count	%
Age (in years)	<40	5	7.14%
	41 to 50	14	20%
	51 to 60	27	38.57%
	61 to 70	16	22.85%

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	71 to 80	7	10%
	>80	2	2.85%
	Total	70	100.0%

Table 2: Sex distribution among patients

		Count	%
Gender	Female	34	48.5
	Male	36	51.4
	Total	70	100.0%

Figure 2: Pie diagram showing Sex distribution of subject

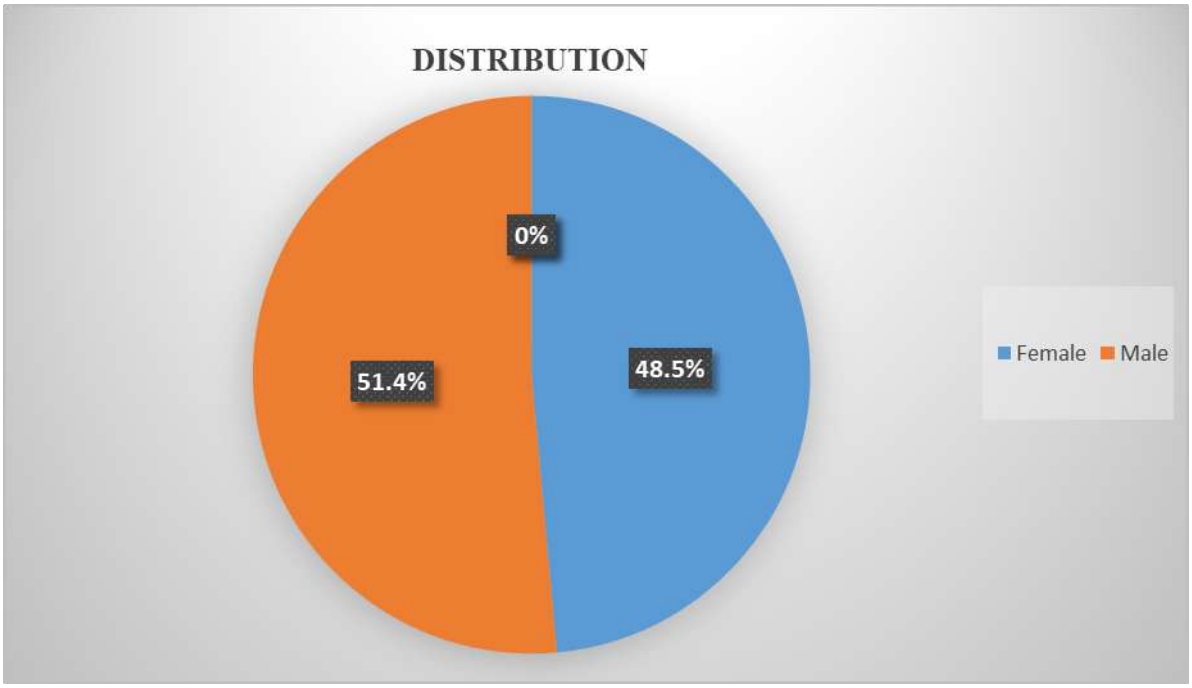

Table 3 – Preoperative evaluation of arteries and veins

	Mean	SD	Minimum	Median	Maximum
Radial artery at Wrist (mm)	**2.14**	**0.35**	**1.7**	**2.2**	**3.6**
Ulnar artery at Wrist (mm)	**2.17**	**0.34**	**1.5**	**2.1**	**3.2**
Radial artery at Elbow (mm)	**2.6**	**0.44**	**1.2**	**3.1**	**4.1**
Ulnar artery at Elbow (mm)	**2.85**	**0.52**	**1**	**3.2**	**4.2**
Brachial artery at Elbow (mm)	**3.8**	**0.54**	**2.6**	**3.7**	**5.1**
Cephalic Vein at Wrist (mm)	**2.37**	**0.52**	**1.6**	**2.4**	**4.2**

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Basilic Vein at Wrist (mm)	**2.58**	**0.46**	**1.5**	**2.8**	**3.6**
Cephalic Vein at Forearm (mm)	**2.82**	**0.55**	**1.7**	**2.7**	**4.6**
Basilic Vein at Forearm (mm)	**2.83**	**0.47**	**1.8**	**2.8**	**3.8**

Table 4 : Distribution of Radial artery diameter

		Count	Frequency %
Radial artery at Wrist(mm)	**1.5 - 1.80**	**12**	**17.14**
	1.8 to 2.0	**20**	**28.57**
	2.0 to 2.4	**24**	**34.28**
	2.4 to 2.7	**9**	**12.85**
	2.7 to 3	**4**	**5.71**
	>3	**1**	**1.42**
	Total	**70**	**100.0%**
Radial artery at Elbow (mm)	**1.5 – 1.8**	**2**	**4.28**
	1.8 to 2.1	**7**	**10**
	2.1 to 2.4	**11**	**14.28**
	2.4 to 2.7	**17**	**24.28**
	2.7 to 3.0	**21**	**30**
	>3	**12**	**17.14**
	Total	**70**	**100.0%**

Table 5: Distribution of Cephalic Vein

		Count	%
Cephalic Vein at Wrist(mm)	**1.5 to 1.8**	**10**	**14.28%**
	1.8 to 2.1	**9**	**12.85%**
	2.1 to 2.4	**16**	**22.85%**
	2.4 to 2.7	**21**	**30%**
	2.7 to 3	**11**	**15.71%**
	>3	**3**	**4.26%**
	Total	**70**	**100.0%**
		Count	**%**
	1.5 to 1.8	**1**	**1.42%**

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Cephalic Vein at Forearm (mm)	1.8 to 2.0	5	7.14%
	2.0 to 2.4	10	14.28%
	2.4 to 2.7	19	27.14%
	2.7 to 3	17	24.28%
	>3	18	25.71%
	Total	70	100.0%

Table 6: Type of Fistula distribution

		Count	%
Type of Fistula	Nil	10	14.28% of 70
	Brachiocephalic Fistula	11	18.33% of 60
	Radiocephalic Fistula	49	81.66% of 60
	Total	70-10=60	100.0%

Table 7: Postoperative Day 1 Changes

		Count	%
Diameter of vein (mm)			
	2.5 to 3.0	9	15
	3.0 to 3.5	9	15
	3.5 to 4.0	15	25
	4.0 to 4.5	10	16.66
	4.5 to 5 .0	12	20
	5 to 5.5	2	3.33
	5.5 to 6	1	1.66
Velocity (cm/sec)	< 30 cm/sec	0	0
	30 – 40 cm/sec	6	10
	40 – 50 cm/sec	19	31.66
	50 – 60 cm/sec	27	45
	> 60 cm/sec	8	8
Blood Flow Rate (ml/min)	< 100 ml/min	0	0
	100 – 200 ml/min	8	13.33
	200 – 300 ml/min	11	18.33
	300 – 400 ml/min	16	26.66

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	400 – 500 ml/min	9	15
	500 – 600 ml/min	9	15
	>600 ml/min	7	11.66

Table 8: Post operative Day 14

		Count	%
Diameter of Vein (mm)	2.5 to 3.0	3	5
	3.0 to 3.5	2	3.33
	3.5 to 4.0	6	10
	4.0 to 4.5	12	20
	4.1 to 5 .0	22	36.66
	5.0 to 5.5	6	10
	5.5 to 6.0	7	11.66
	> 6mm	2	3.33
Velocity in cm/sec	< 30 cm/sec	1	1.66
	30 – 40 cm/sec	1	1.66
	40 – 50 cm/sec	16	26.66
	50 – 60 cm/sec	24	40
	> 60 cm/sec	18	30
Blood Flow Rate (ml/min)	< 100 ml/min	0	0
	100 – 200 ml/min	3	5
	200 – 300 ml/min	5	8.33
	300 – 400 ml/min	8	13.33
	400 – 500 ml/min	9	15
	500 – 600 ml/min	9	15
	>600 ml/min	26	43.33

Table 9: Post operative Day 42 Changes

		Count	%
Diameter of vein (mm)	2.5 to 3.0	0	0
	3. to 3.5	0	0
	3.5 to 4.0	1	1.66

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	4.0 to 4.5	**9**	**15**
	4.5 to 5 .00	**16**	**26.66**
	5.0 to 5.5	**8**	**13.33**
	5.5 to 6.0	**5**	**8**
	> 6mm	**21**	**35**
Velocity in cm/sec	**< 30 cm/sec**	**2**	**3.33**
	30 – 40 cm/sec	**7**	**11.66**
	40 – 50 cm/sec	**11**	**18.33**
	50 – 60 cm/sec	**17**	**28.33**
	> 60 cm/sec	**23**	**38.33**
Blood Flow Rate ml/min	**< 100 ml/min**	**0**	**0**
	100 – 200 ml/min	**0**	**0**
	200 – 300 ml/min	**0**	**0**
	300 – 400 ml/min	**1**	**1.66**
	400 – 500 ml/min	**7**	**11.66**
	500 – 600 ml/min	**9**	**15**
	>600 ml/min	**42**	**70**

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