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Comparison of adequacy of blood flow between proximal forearm AV fistula placed at elbow and distal forearm AV fistula placed at wrist in the early post-operative period

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ABSTRACT

Background: In patients with a failed DRCF or unsuitable for DRCF, the current recommendation is to perform a brachiocephalic fistula. Proximal forearm radiocephalic fistulas are created less frequently. **Aims and Objectives:** The aim of the present study was to evaluate the outcomes of proximal forearm AV fistula placed at elbow and distal forearm AV fistula placed at wrist in terms of adequacy of blood flow in the early post-operative period. **Materials and Methods:** The present cross-section study was conducted on patients with end-stage renal disease with proximal or distal AV fistula at wrist for a period of 2 years at radiodiagnosis department. The patients were divided into two groups, those with proximal AVF and those with distal AVF. The Doppler ultrasound findings were analyzed and compared between the two groups to identify any differences that could be associated with the success or failure of the AVF. **Results:** The difference in mean arterial diameter between the proximal and distal groups may indicate that the proximal fistulas have a better chance of providing adequate blood flow for dialysis. The difference in TAV between proximal and distal group may indicate difference in the location and type of fistula and the blood vessels involved in them. **Conclusion:** Proximal forearm AV fistula is an appealing option to brachiocephalic fistulas in failed distal forearm AV fistula and patients who cannot obtain a distal radiocephalic fistula because to their much lower initial failure rate, higher patency rate, and reduced complication rate.

Key words: Proximal forearm AV fistula; Distal forearm AV fistula; Elbow; Wrist; End-stage renal disease

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INTRODUCTION

In a developing nation like India, chronic kidney diseases are a major health problem. The most viable long-term treatment option for patients with end-stage renal disease (ESRD) is renal transplantation; however, the rate of renal transplant activity falls short of the demand due to lack of financial support and a shortage of organ donors, both live and deceased. As a result, ESRD patients mostly present to hospitals for confirmation of diagnosis and to receive hemodialysis.

Autogenous arteriovenous fistula is the most preferred form of vascular access for haemodialysis.[1] It involves surgical creation of a direct connection between an artery and a vein in a patient's own body, which is then used to access the bloodstream for hemodialysis. The non-dominant upper limb is usually preferred for the creation of AV fistulas as it is associated with a lower risk of infections, peripheral vascular diseases and causes less discomfort to the patients.

To perform a successful hemodialysis, proper functioning of the AV fistula is crucial. An AV fistula is usually created

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a few months before starting hemodialysis to allow for proper maturation and healing of the fistula. The time required for maturation may vary depending on the size, location, and type of the fistula, as well as the overall health of the patient.

Determining the site and type of AV fistula is essential for its proper functioning, duplex ultrasound is considered the gold standard method for this purpose.

The examination allows the surgeon to see the anatomy of the blood vessels, their diameter, and the blood flow in the vessels. In duplex ultrasound, the arterial and venous diameters are measured, which is essential for the creation of an adequate AV fistula. An arterial diameter of more than 1.6 mm and venous diameter of more than 2 mm are considered adequate for AV fistula creation.

The kidney disease outcomes quality initiative has proposed specific criteria for the assessment of AV fistula maturation using ultrasound. These criteria include a blood flow rate of more than 600 mL/min, diameter of 0.6 cm, and depth from skin of <0.6 cm. These measurements are used to assess the maturity and readiness of the fistula for use in hemodialysis.

It is also important to note that while ultrasound is considered the gold standard for fistula assessment, other methods like physical examination and blood flow measurement by transonic flowmetry can also be used to complement the ultrasound assessment.[2]

The most common types of AV fistulas created are the radiocephalic AV fistula at the wrist and the brachiomedian (brachiobasilic) near the elbow joint. The radiocephalic AV fistula is created by connecting the radial artery and cephalic vein at the wrist, while the brachiomedian fistula is created by connecting the brachial artery and basilic vein near the elbow joint.

The primary failure rate of an AV fistula might range from 47% to 60%.[3] Al-Jaishi et al., found 40% main failure in a meta-analysis of 43 trials.[4] Jennings (2006) showed that proximal forearm radiocephalic fistulas had a 91% primary patency rate, which was greater than DRCF.[5]

The distal types of AV fistulas, such as the radiocephalic, are preferred over the proximal types, such as the brachiomedian, for several reasons. One of the main reasons is that distal fistulas have a lower complication rate than proximal fistulas. Keeping all the above things in mind, the present study was undertaken to evaluate the difference between proximal forearm AV fistula placed at elbow and distal forearm AV fistula placed at wrist in terms of adequacy of blood flow in the early post-operative period (<1 week).

Aims and objectives

The aims of this study were to compare adequacy of blood flow between proximal forearm AV fistula placed at elbow and distal forearm AV fistula placed at wrist in terms of adequacy of blood flow in the early post-operative period.

MATERIALS AND METHODS

The present cross-section study was conducted on patients with ESRD with proximal or distal AV fistula at wrist or at proximal forearm for hemodialysis for a period of 2 years at radiodiagnosis department. The study design included a comparison of Doppler ultrasound findings with the patients' clinical outcomes and the adequacy of the fistulas for dialysis. The Institutional Ethical Committee Clearance was obtained before beginning of the study. The patients were divided into two groups, those with proximal AVF, and those with distal AVF. The Doppler ultrasound findings were analyzed and compared between the two groups to identify any differences that could be associated with the success or failure of the AVF.

The sample size for the present study was derived from:

$$n = (Z_{\alpha/2}+Z_{\beta})^2 * (p_1(1-p_1)+p_2(1-p_2))/(p_1-p_2)^2,$$

where $Z_{\alpha/2}$ is the critical value of the normal distribution at $\alpha/2$ (for a confidence level of 95%, α is 0.05 and the critical value is 1.96), Z_{β} is the critical value of the normal distribution at β (for a power of 90%, β is 0.1 and the critical value is 1.28) and p_1 and p_2 are the expected sample proportions of the two groups.

According to a study done by Bhalodia et al.,[6] primary maturation failure of proximal fistulas was 32% and distal fistulas was 59%. The sample size for each group was 70.

Data collection procedure

An ultrasound scanner capable of examination with B-mode and Doppler mode. Linear array probes with a frequency of 7 MHz or higher for B-mode, and 5 MHz or higher for Doppler was used i.e. Doppler alongwith linear array probes.

The arm arteries were followed longitudinally with directional color Doppler, from the distal part of the subclavian artery to the radial and ulnar arteries; segments with abnormal color Doppler are further assessed with B-mode and spectral Doppler to identify a stenosis or occlusion.

Using B mode imaging, color Doppler ultrasound and spectral Doppler techniques to collect the following data for comparison of the AV fistulas:

1. Diameter of the feeding artery and the draining vein
2. Diameter at the narrowest part of the fistula
3. Time averaged velocity of flow through the fistula
4. Flow volume through the fistula as calculated by the formula.

Statistical analysis

The analysis was carried out for 140 patients with post-operative Doppler evaluation of their newly created AVF. The association was analyzed using frequency analysis, percentage analysis, and Chi-square test. P<0.05 was taken as significant. Microsoft Excel and SPSS v20.0 software was used for data entry and analysis.

RESULTS

In the present study, the mean arterial diameter was measured in both proximal and distal forearm fistula groups. The mean arterial diameter in the proximal forearm fistula group was 3.84 mm with a standard deviation of 0.70 mm. In the distal forearm group, the mean arterial diameter was 2.19 mm with a standard deviation of 0.26. This suggests that the proximal forearm fistulas had a slightly larger diameter on average compared to the distal forearm fistulas. There was statistically significance difference of mean arterial diameter between proximal forearm fistula group and distal forearm group (P<0.001) (Table 1).

The arterial diameter is an important factor to consider when evaluating the adequacy of AV fistulas. Adequate arterial diameter is necessary for the fistulas to provide sufficient blood flow for dialysis. The difference in mean arterial diameter between the proximal and distal groups may indicate that the proximal fistulas have a better chance of providing adequate blood flow for dialysis.

The study found that the mean diameter (average size) of the veins in the proximal fistula group was 4.37 mm, with a standard deviation (measure of how much the individual measurements varied) of 0.75 mm. In the distal forearm fistula group, the mean diameter of the veins was found to be 2.68 mm, with a standard deviation of 0.34 mm. There was statistically significance difference of mean diameter of the veins between proximal forearm fistula group and distal forearm group (P<0.001) (Table 2).

The study found that in the proximal forearm fistula group, the mean diameter of the narrowest part of the fistula was 2.4 mm, with a standard deviation of 0.60. This means that on average, the narrowest part of the fistula in this group measured 2.4 mm, and the individual measurements varied by up to 0.60 mm. In the distal forearm fistula group, the mean diameter of the narrowest part of the fistula was found to be 1.99 mm, with a standard deviation of 0.75. This means that on average, the narrowest part of the fistula in this group measured 1.99 mm, and the individual measurements varied by up to 0.75 mm. There was statistically significance difference of mean diameter of the narrowest part of the fistula between proximal forearm fistula group and distal forearm group (P<0.05) (Table 3).

The study found that the mean TAV through proximal fistula group was 174.94 mm/s and in the distal forearm group, it was 191.51 mm/s. This means that on average, the blood flow velocity in the proximal fistula group is 174.94 mm/s and in the distal forearm group, it is 191.51 cm/s. The difference in TAV between proximal and distal group may indicate difference in the location and type of fistula and the blood vessels involved in them. There was no statistically significance difference of mean TAV between proximal forearm fistula group and distal forearm group (P=0.43) (Table 4).

The study found that the mean flow volume through the proximal fistula group was calculated to be 413.13 mL/min, which is higher than the mean flow volume in the distal forearm fistula group, which was 321.43 mL/min. This means that on average, the amount of blood flowing through the fistulas in the proximal group is higher than in the distal group. The difference in flow volume may indicate difference in the location and type of fistula and the blood vessels involved in them. There was statistically significance difference of mean flow volume between proximal forearm fistula group and distal forearm group (P<0.01) (Table 5).

DISCUSSION

In the present study, the majority of patients (61.4%) were examined by Doppler ultrasound on the same day of the surgery, which is a common practice in the post-operative evaluation of AVF. This allows for early detection of any issues or complications that may affect the fistula's development and maturation. In addition, 44 patients (31.4%) were examined 1 day after the surgery, which allows for detection of complications that may have occurred during the first 24 h after the surgery. Finally, ten patients (7.1%) were examined 2 days after the creation of the fistula, which allows for detection of complications that may have developed during the first 48 h after the surgery. This approach of examining patients at different intervals post-surgery allows for a comprehensive evaluation of the fistula and detection of complications at an early stage.

Table 1: Mean diameter of artery in distal and proximal fistula

Type of fistula	Mean	Number of patients	SD
Distal forearm	2.19	70	0.26
Proximal forearm	3.84	70	0.70
Total	3.01	140	0.98

t-value=18.5, *P*<0.001

Table 2: Mean diameter of vein in distal and proximal fistula

Type of fistula	Mean	Number of patients	SD
Distal forearm	2.68	70	0.34
Proximal forearm	4.37	70	0.75
Total	3.52	140	1.02

t-value=17.17, *P*<0.001

Table 3: Mean diameter of the narrowest part of fistula

Type of fistula	Mean	Number of patients	SD
Distal forearm	1.99	70	0.60
Proximal forearm	2.43	70	0.75
Total	2.21	140	0.71

t-value=3.83, *P*<0.05

Table 4: Mean TAV in proximal and distal fistula

Type of fistula	Mean	n	SD
Distal forearm	191.51	69	120.67
Proximal forearm	174.94	69	129.77

t-value=0.78, *P*=0.43

Table 5: Mean flow volume through the proximal and distal fistula

Type of fistula	Mean	Number of patients	SD
Distal forearm	321.43	70	103.03
Proximal forearm	413.14	70	99.49

t-value=5.36, *P*<0.01

In our study, we evaluated the mean arterial diameter in both proximal and distal forearm fistula groups. The mean arterial diameter for the proximal forearm fistula group was found to be 3.84 mm, with a standard deviation of 0.70 mm.

This indicates that the proximal forearm fistulas tend to have a slightly larger diameter on average when compared to the distal forearm fistulas.

A study done by Farrington et al., found a moderate correlation between pre-operative arterial and venous diameters (R=0.38, P<0.001) and a weaker correlation between pre-operative arterial diameter and brachial arterial blood flow (R=0.28, P<0.001). The study also evaluated the relationship between clinical and demographic characteristics with pre-operative arterial diameter, venous diameter, and brachial artery blood flow. They found that upper arm AVF location was associated with greater pre-operative arterial and venous diameters.[7]

In the present study, it was found that the mean diameter of the veins in the proximal fistula group was 4.37 mm, with a standard deviation of 0.75 mm. In the distal forearm fistula group, the mean diameter of the veins was found to be 2.68 mm, with a standard deviation of 0.34 mm.

In our study, the mean diameter of the narrowest part of the fistula was measured in both proximal and distal forearm fistula groups. In the proximal forearm fistula group, the mean diameter of the narrowest part of the fistula was 2.4 mm with a standard deviation of 0.60. This suggests that on average, the narrowest part of the fistula in this group measured 2.4 mm, and the individual measurements varied by up to 0.60 mm. In contrast, in the distal forearm group, the mean diameter of the narrowest part of the fistula was 1.99 mm with a standard deviation of 0.75. This suggests that on average, the narrowest part of the fistula in this group measured 1.99 mm, and the individual measurements varied by up to 0.75 mm. This means that the proximal forearm fistulas had on average a larger diameter for both veins and narrowest part of the fistulas when compared to the distal forearm fistulas.

In addition, the study also measured the time-average velocity (TAV) and flow volume through the fistulas. In the proximal forearm fistula group, the mean TAV was calculated to be 174.94 cm/s and in the distal forearm group, it was 191.51 cm/s. This suggests that the TAV in the distal forearm group is higher than in the proximal forearm group.[8]

The mean flow volume in mL/min through proximal fistula group was calculated to be 413.13 mL/min, which is higher than in the distal forearm fistula group, where the mean flow volume was 321.43 mL/min. This suggests that the flow volume through the fistulas in the proximal forearm group is higher than in the distal forearm group.[8]

In a study done by Albayrak et al., it was found that the flow volume and TAV through the proximal forearm fistulas were higher compared to distal forearm fistulas. In addition, the study found that well-developed RCF fistulas may ultimately reach flow volumes of 600–1,200 mL/min, which is a result of both vasodilation and vascular remodelling.[9]

CONCLUSION

Early identification and prompt treatment of AVF-related complications are essential for optimizing the success of

the procedure. It is crucial for health-care providers to monitor patients closely for signs of complications and to take appropriate action in a timely manner. This can help to minimize the impact of the complications and increase the chances of successful fistula use.

Proximal forearm AV fistula is an appealing option to brachiocephalic fistulas in failed distal forearm AV fistula and patients who cannot obtain a distal radiocephalic fistula because to their much lower initial failure rate, higher patency rate, and reduced complication rate.

Limitations of the study

1) Early infection at the operative site
2) Early AV fistula thrombosis
3) Locallised collection like haematoma, seroma at the operative site
4) Pseudoaneurysm formation.

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PK- Concept and design of the study, prepared first draft of manuscript and revision of the manuscript; **ASG-** Statistical analysis, interpreted the results; reviewed the literature and manuscript preparation; **VRL-** Concept, statistical analysis and interpretation, preparation of manuscript and revision of the manuscript.

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