Original Article

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Value of Pre-Operative Planning with Selecting the Most Functional Vessels by Ultrasound Vascular Mapping of Upper Limb for Haemodialysis Access Placement

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Abstract

Background: The increasing prevalence of end-stage renal illness, as well as its influence on health-care costs, has led in a greater emphasis on the provision of vascular access treatment. USG is an effective modality for evaluating (Haemodialysis) HD access since it is quick, easy to use, non-invasive, and affordable. With the advancement of high resolution USG machines, now it is feasible to gather data prior surgery, assisting in surgery planning. This study aimed to find the value of pre-operative planning with choosing the most functional vessels through mapping of the upper extremity by ultrasound for HD access creation, with the subsequent reduction in morbidity and hospitality cost after AV fistula placement. The objective of study is identifying correlation between Doppler USG findings and operational results (as assessed by anatomy, vessel size, patency, and wall morphology). **Subjects and Methods:** This research comprised 35 patients who were referred from Narayana Medical College's urology and nephrology departments for HD creation. The research took place between November 2019 and November 2021. The doppler results were then compared to the surgery findings and outcome. Doppler vessel sizes and per operative surgical results of vessel diameter were recorded and compared to identify differences. The correlation was used to identify access points selected and the type of access executed. The disparities discovered between US and operative results were also analyzed. **Results:** The findings of doppler USG were strongly correlated with operative findings. 94.2% accuracy is detected with preoperative Doppler USG for choosing potential sites for Hemodialysis access creation. 85.7% rise in AVF creation is observed when a physical examination is combined with Doppler USG. Summary: In this research, upper extremity vessels were sonographic ally assessed in 35 patients before AVF creation based on standard criteria & potential access sites were selected. Main purpose of this research was to determine the value of pre-operative planning with choosing the most functional vessels by ultrasound vascular mapping of the upper extremity for hemodialysis access placement, resulting in a reduction in morbidity, hospitality cost after AV fistula placement. The findings of Doppler USG were strongly correlated with operative findings. **Conclusion:** In patients whose physical examination was indeterminate, preoperative vascular mapping by Doppler USG by using various parameters such as vessel diameter, wall morphology, peak systolic flow, Spectral wave from, anatomical course, patency, depth from skin surface helped a lot in choosing potential sites for access creation.

Keywords: Haemodialysis, end-stage renal illness, arteriovenous fistula.

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Introduction

Arteriovenous access is the 'lifeline' for individuals with terminal stage kidney disease. Primary method of access for Hemodialysis(HD) is arteriovenous fistula (AVF). Complications following the surgery have been growing as major sources of morbidity with subsequent hospitalisation and higher expense to HD patients.

The viable HD access sites number is restricted per patient. As a result, steps to promote VA lifespan are required. Inadequate arteries utilised for surgery have been blamed for AVF failures. Pre-operative Doppler Ultrasound (USG) examination is a great alternative that may aid in the identification of appropriate vasculature and prevent AVF failures.

USG is an effective modality for evaluating HD access since it is quick, easy to use, non-invasive, and affordable. With the advancement of high resolution USG machines, now it is feasible to gather data prior surgery, assisting in surgery planning. With the rise in the number of AVFs over AVGs, enhanced anatomical knowledge provided from sonographic mapping may modify surgical management.

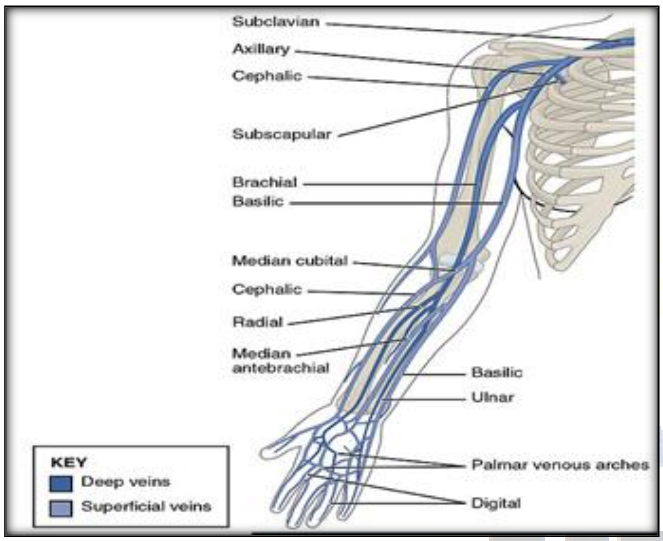
Doppler USG is especially useful in people with difficult-to-see veins, such as obese people, diabetics, the elderly, and in patients with prior access.

Anatomy of Veins[1,2,3]

The basilic vein, cephalic vein, & median antecubital veins, as well as their tributaries, are the upper extremity's superficial veins.

Anatomical changes in course of cephalic vein:

- An accessary vein connecting proximal & distal ends by passing through the cubital fossa.
- Large MCV carries majority of blood from CV into BV. In this situation CV in upper arm will be missing.
- Through by an anterior branch, CV may drain into external jugular vein.



Anatomy – Arteries[1,2,3]

Subclavian artery, Axillary artery, Brachial artery, Radial artery and Ulnar artery constitutes arterial system of upper limb.

Anatomical Variations - Practical Uses,[4]

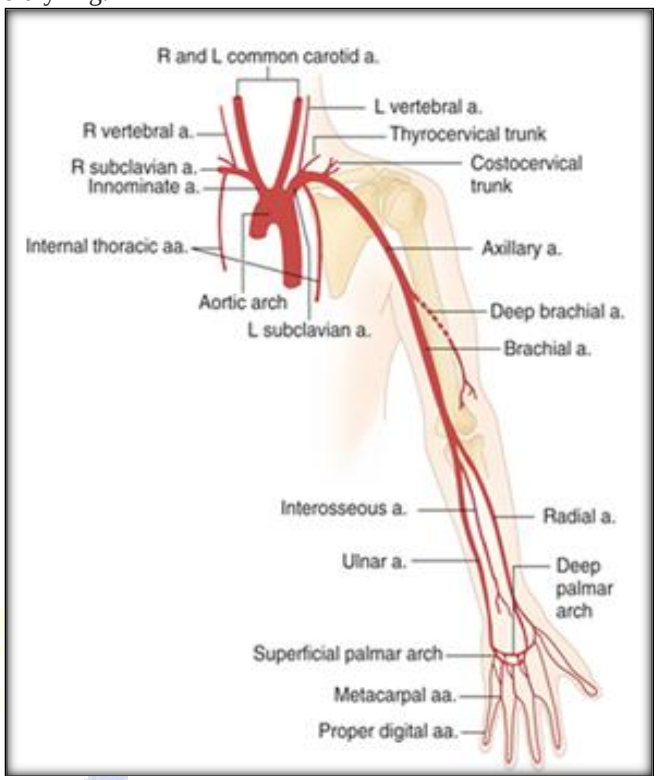
There are more than a dozen arterial variations in upper limb, most frequent of which is "high origin" - RA (12-20 percent). Superficial brachial, ulnar, and radial artery locations, as well as accessory brachial or other conceivable anatomical variations (0.5-7 percent). The superficial brachial artery (SBA), which originates from axillary artery and runs superficially to the median nerve, is another anatomic variant of upper arm. Double brachial artery is known as accessory brachial artery (ABA), and its occurrence is believed to be 0.5 to 2%.

Vascular Access

AVF & AVG are 2 types of long-term vascular access. The third form is a central venous catheter, which is intended for short-term usage.

Duplex Ultrasound Scanning Technique:

A high-frequency linear phased array probe is used for doing doppler ultrasound of upper extremity. Non-dominant upper limb & most distal site is selected initially, moving proximally depending on availability of good veins & disease-free arteries so that patient can do self- needling for home dialysis or write & perform other tasks while dialyzing.[5]



Criteria- successful AV Fistula creation: Arterial examination

Arterial diameter

The radial artery's typical diameter is between 2 and 3.[5] mm. Unfortunately, research on the effects of artery diameter and vascular quality on fistula success rates is scarce. A luminal diameter of < 1.6 mm was connected with early fistula failure according to Wong et al.[6] while a diameter of < 1.5 mm given 45 percent success rate according to Malovrh. Similarly, Lemson et al.[7] found that patients with unsuccessful forearm fistulas had considerably lower mean preoperative radial artery sizes than those with successful fistulas (1.9versus2.8 mm). Larger arterial diameter gives more AVF success rate.

Silva et al advocated minimum diameter 2 mm, which was later accepted by other researchers. There appears to be no link between artery diameter and fistula success above this threshold diameter.[8]

Arterial wall morphology

AVF blood flow rises when the feeding artery dilates throughout maturation, however, this may not happen in a sick artery.[9] Surgery may be problematic in case of calcification, which can be seen in B-mode. [9]. Individuals having ESKD, diabetes, or renovascular disease are highly likely to have radial artery wall alterations as a consequence of arterial disease.[10] At one year, Ku et al. discovered a statistically significant link b/w IMT & AVF failure owing to thrombosis / dialysis insufficiency (r = 0.358, P= 0.027).[11] Pre-existing artery disease is significant for AVF outcome, according to these researchers, and maybe diagnosed with USG. B-mode able to provide structural

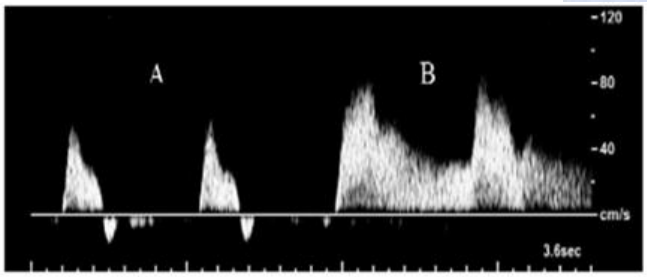
information on thickness & structure of artery wall (intima smoothness, wall thickening, & calcification).[12]

Arterial flow and velocity

The proper development of forearm fistulas requires adequate vascular input. Malovrh also found a mean preoperative flow rate of 54.5 ml/min in successful AVF and a mean flow rate of 24.1 ml/min in unsuccessful AVF. Lockhart observed no difference in preoperative PSV b/w adequate & insufficient fistulae and no increased failure rates with PSV of 50 cm/s, although Sedlach proposed a threshold PSV at least 50 cm/s for AVF success. The Lockhart investigation excluded arteries with diameter < 2 mm, which might be one cause. Arterial flow & PSV might be affected if diameter of artery exceeds this limit.[13]

Reactive hyperemia

By opening a hand that has been clenched for 2 minutes, reactive hyperemia can be created. The resistive index (RI) as well as variations in peak systolic and end-diastolic velocity are used to track changes in the waveform. When hyperemic RI of feeding artery was < 0.7, Malovrh discovered that 95.3 percent of AVFs were effective, but only 38.7% AVFs were effective when hyperemic RI was > 0.7. Wiese et al. showed that the basic quality of the artery wall and its capacity to dilate, rather than arterial diameter, determines AVF result in a preliminary study. Lockhart, on the other hand, discovered no variation in preoperative difference in RI b/w insufficient & adequate AVF, even when arteries smaller than 2 mm diameter were removed.[13]



Picture showing Radial artery waveform during clenched fist(A) and on releasing showing a hyperemic response(B)

Venous Examination

Venous appearance and suitability for cannulation

A normal vein contains an anechoic lumen, a thin & smooth wall, and is compressible. Patency is examined by repetitive intermittent compression with the probe placed in transverse section.[14]

The vein considered for AVF formation should have a sufficient length for future needle placement and should be < 6mm.[15]

Diameter & distensibility

Silva reported good AVF outcomes (8% early failure, 83% functional primary patency at 1 year) with minimum diameter of 2.5 mm.[16] Alexandru opera et al. noted that diameter >1.9mm has a 60% success rate. Exact criteria is not there but a diameter of at least 3mm is recommended.[9]

Vein- doppler scan

At optimal settings (correct angle, low pulse repetition frequency) scan should be done. Normal vein spectrum shows spontaneous flow. Normal subclavian vein gives a spectral pattern showing respiratory and cardiac phasicity. It indicates patency. Monophasic waveform in subclavian vein indicates occlusion of central veins.[17]

Key points - preoperative USG,[18]

1. Even if CV in upper arm is occluded or stenosed It might be possible to construct a forearm cephalic vein AVF if cephalic vein in forearm drains into brachial / basilic veins via an adequately sized MCV.
2. Area of focal stenosis at dividing points may limit AVF flow.
3. Veins depth from the skin surface is important.
4. Spectral waveform of brachial & radial arteries must be examined. Waveforms become monophasic & muted when the proximal blockage is present. The waveforms exhibit a typical triphasic pattern with distal obstruction, although the velocity might be lowered due to decreased outflow.

Aims and objectives:

1) This study aimed to find the value of pre-operative planning with choosing the most functional vessels through mapping of the upper extremity by ultrasound for HD access creation, with the subsequent reduction in morbidity and hospitality cost after AV fistula placement.
2) The objective of study is identifying correlation between Doppler USG findings and operational results (as assessed by anatomy, vessel size, patency, and wall morphology).

Subjects and Methods

This research comprised 35 patients who were referred from Narayana Medical College's urology and nephrology department for HD creation. The research took place between November 2019 and November 2021.

Criteria for inclusion

Patients who were scheduled for upper limb AVF construction.

Exclusion Criteria

1. Patients who are morbidly obese
2. AV Grafts that have previously failed
3. Upper limb that is deformed or scarred
4. Raynaud's syndrome, an artery condition affecting the upper limbs.
5. Renal transplantation from a living donor is imminent.

Surgical Correlation

The doppler results were then compared to the surgery findings and outcome. Doppler vessel sizes and per operative surgical results of vessel diameter were recorded and compared to identify differences.

The correlation was used to identify access points selected and the type of access executed. The disparities discovered between US and operative results were also analyzed.

Research - Design

Prospective hospital-based research.

Statistical analysis method

Following are the methods of statistical analysis used in present study. 1) Chi-Square test 2) Pearson's Correlation test.

Ethical approval

Ethical approval has been obtained.

Observations during study- Abnormal findings:

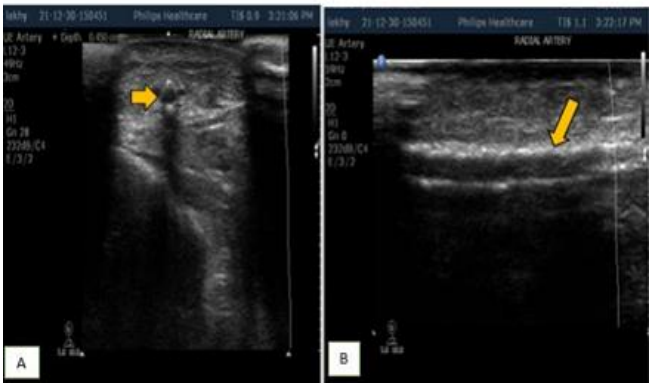


Figure 1: A) and B) transverse and longitudinal sections showing atheromatous changes in the form of wall calcifications in Radial artery.

Figure 2: Narrowed calibre of cephalic vein at wrist

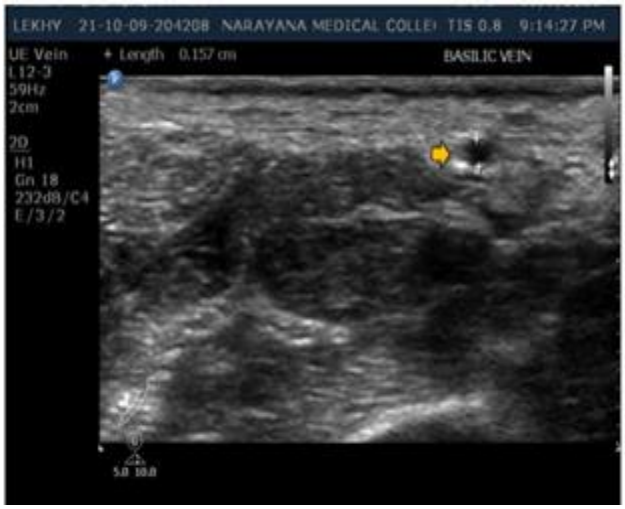


Figure 3: Narrowed calibre of basilic vein.

Figure 4: showing narrowed calibre of Radial artery.

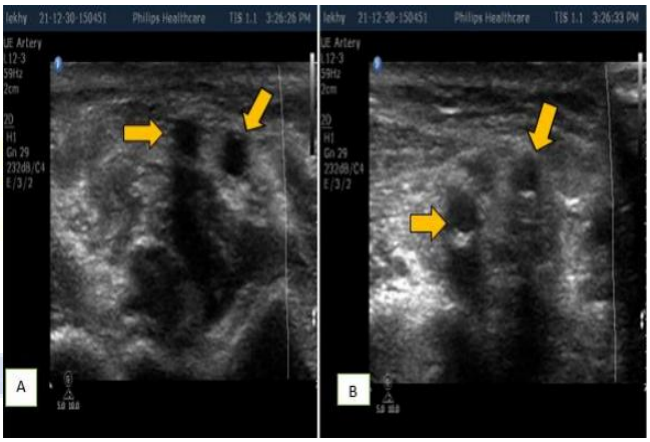
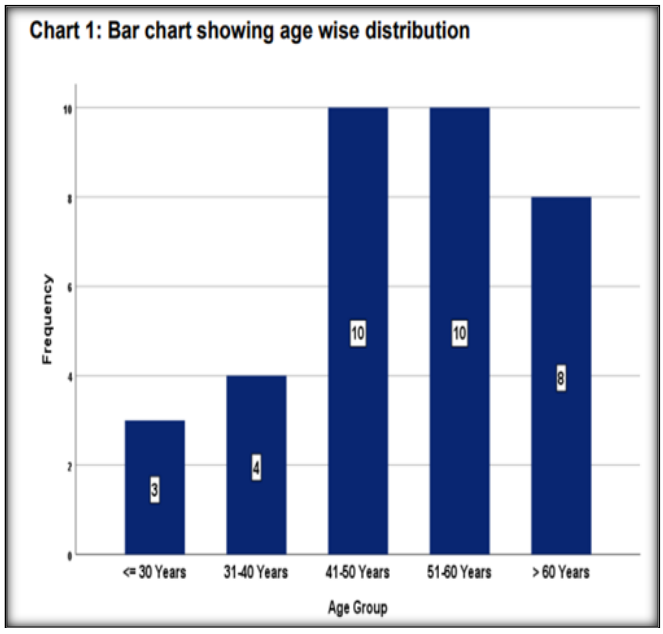
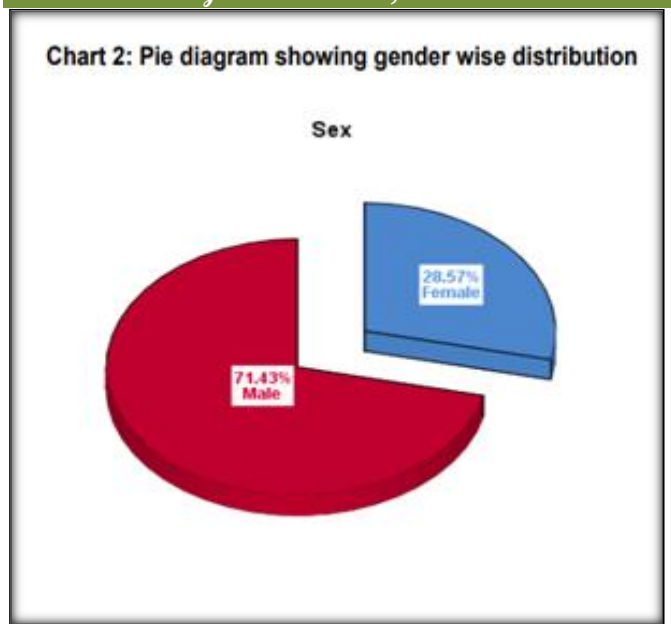
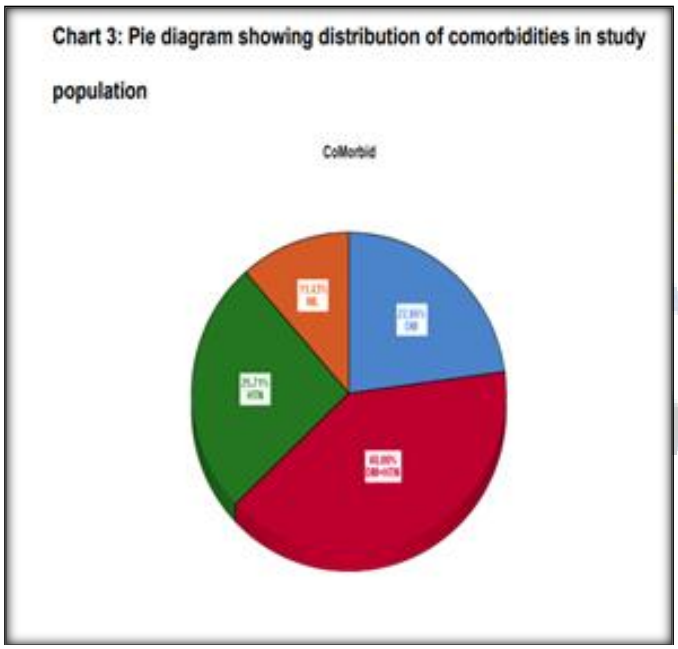


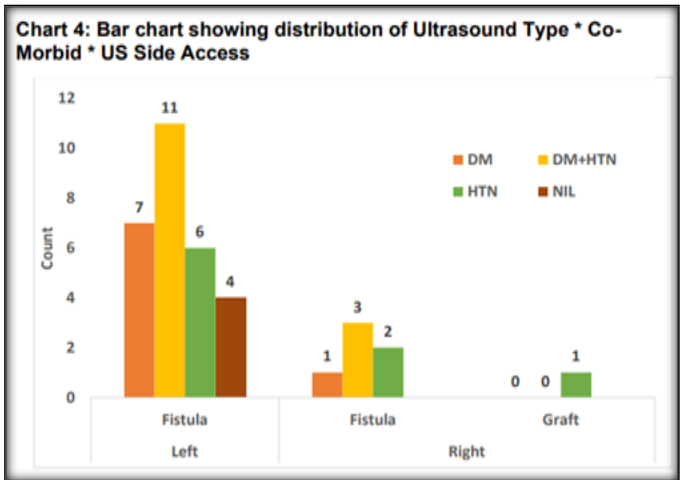
Figure 5: A) and B) showing presence of both ulnar and radial arteries at elbow and above elbow respectively- High Brachial artery bifurcation- Anatomical variant.

Results









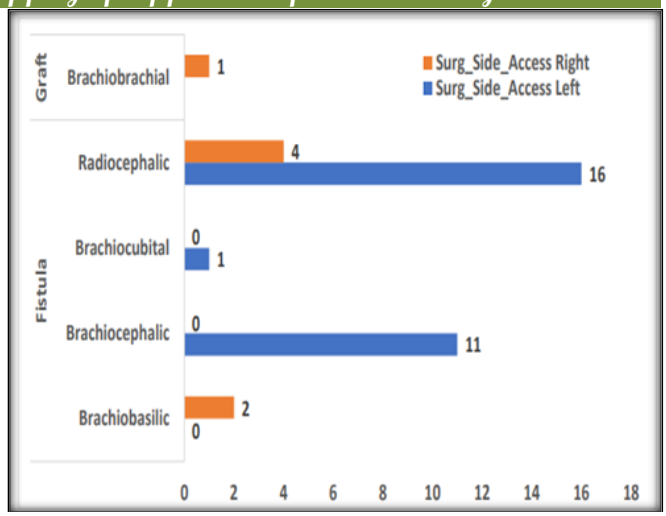


Chart 5: Bar diagram showing distribution of type and site of access against right and left side of access

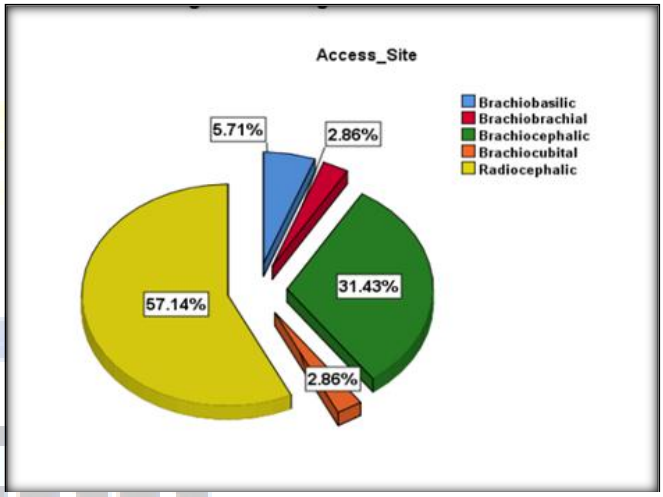


Chart 6: Pie diagram showing distribution of site of access

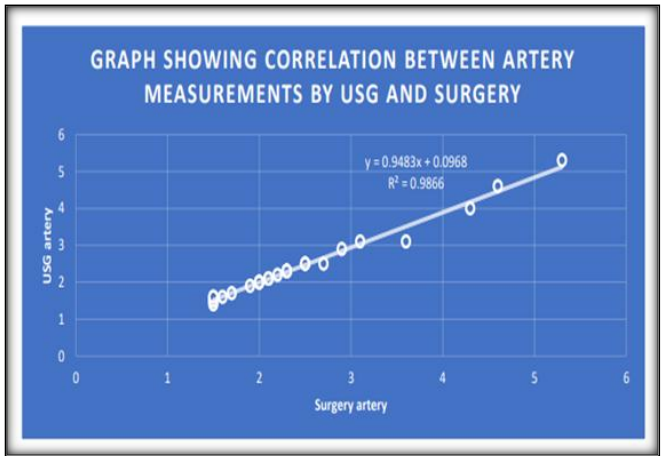


Chart 7: Graph showing correlation between Artery measurements by USG and Surgery

Pearson's correlation Coefficient, r=0.9933.
N= 35
P= 0.00001(<0.05)
The correlation is statistically significant.

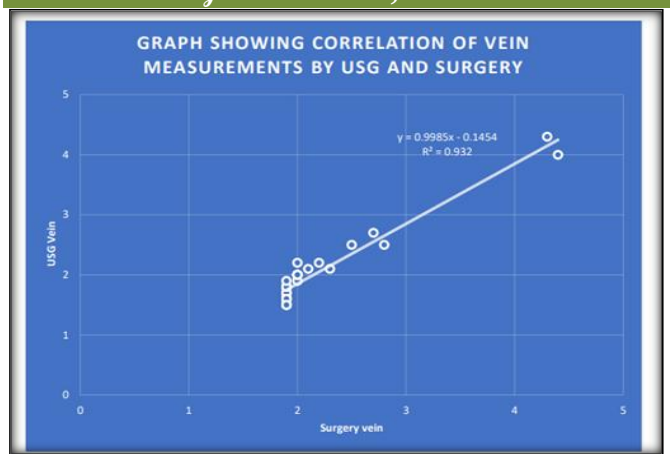


Chart 8: Graph showing correlation between Vein measurements by USG and Surgery

Pearson's correlation Coefficient, r=0.9654.
N= 35
P= 0.00001(<0.05)
The correlation is statistically significant.

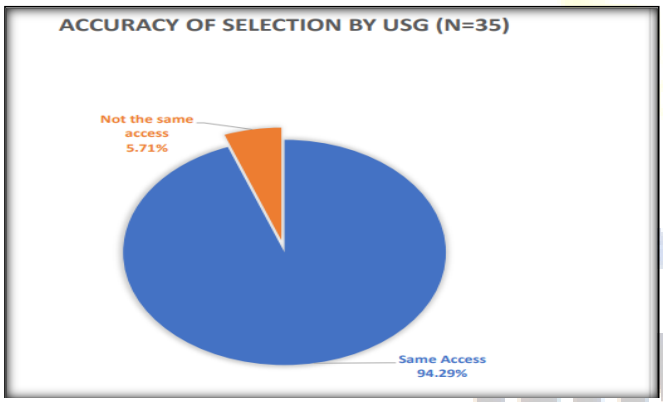


Chart 9: Pie diagram showing accuracy of selection by USG

Table 1: Percentage of accuracy of selection by USG

Accuracy of selection by US (n=35)	Number	Percentage
Same Access	33	94.29%
Not the same access	2	5.71%
Total	35	100.00%

Discussion

Age distribution: Moreover half of the patients in this research (57.2%) were between the ages of 40 and 60.
Sex distribution: In the present study, 35 patients underwent pre-operative vascular mapping. 25 (71.4%) were males and 10 (28.5%) were females.
Comorbidities: Out 0f 35 patients, 8 were diabetic,9 were hypertensive and 14 were both diabetic and hypertensive and 4 have no comorbidity.
According to Miller et al,[19] The rate of fistula adequacy was lower in diabetics than nondiabetics, and it was lower in older patients (age >65) than younger patients (age < 65). It was also lower in overweight patients (BMI >27 kg/m^2) as compared with patients at or below their ideal body.
According to Alexandru opera et al.[20], findings suggest that a preoperative VD ≥1.9 mm and AD ≥ 1.5 mm, as measured by DUS, have a successful maturation rate over 60% and that the maturation rate increases with increase in vessel diameter.
In this study, the minimum arterial diameter taken was 1.5mm and the vein was 1.9mm.
In the current investigation, 35 individuals were evaluated physically. During the evaluation, 4 (11 percent) of the patients had good anatomy. In 31 cases, the results were inconclusive. Under physical examination, people with good forearm anatomy following the test, ultrasonography confirmed the results. Of the 31 individuals with negative or indeterminate vascular outcomes, on physical evaluation. 30 (85.7%) of the vessels were appropriate by the USG for native upper limb fistulas one case is unfavourable to AVF. AVG was done for that individual.
The vessel diameter is the main parameter to create effective AVF. The mean diameter of RA measured by USG & surgery in a research by Malvroh et al[12] was 2.3 + 0.66 (range: 1.4–3.2) & 2.1+ 0.58 (range: 2.1-2.8), respectively.
The mean diameter of RA in patients who were candidates for radiocephalic fistula was 2.37 mm, whereas the mean diameter of BA in patients with upper arm fistulas was 3.13 mm, according to a study by Kaushal et al.[21] Forearm fistulas had a mean venous diameter of 2.69, while upper arm fistulas had a mean venous diameter of 3.18.
The diameter of RA assessed by ultrasound & surgery was 2.4 ± 0.5 & 2.6 ± 0.5, respectively, in a research by KC Aishwarya et al.[18]

- The mean diameter of RA evaluated by USG & surgery in the present research was 2.2 ± 0.78 and 2.0 ± 0.47, respectively.
- There was a strong relationship between USG measurements and surgery.

According to KC Aishwarya et al,[18] the mean diameter of CV at the wrist was 2.1± 0.39 by USG & 2.0± 0.33 by surgery, respectively.[20]
The mean diameter of CV at the wrist was 1.8± 0.3 and 1.8 ± 0.26 by USG and surgery, respectively, in the current study.
Four anatomical variations were identified by the USG in a research by Kaushal et al,[21] Two patients had high brachial artery bifurcation, one had cephalic vein duplication, and one had cephalic vein hypoplasia at the arm.
The US identified one anatomical variation in the current study. It was high bifurcation of brachial artery.
With deep understanding of anatomical variations, results in decrease of negative surgical exploration rates. Malvroh et al,[12] discovered a 0% negative surgical exploration rate. Allon et al,[22] identified an 11% (28 of 256) negative surgical exploration rate. According to Kaushal et al,[21] a single case, i.e., a 2% negative surgical exploration rate. The variations in venous branching around the cubital fossa region were attributed to this. The current study found a 5.71 percent rate of negative surgical exploration.
Schillinger et al. observed a 50% stenosis or occlusion rate at the site of subclavian cannulation. Kaushal et al,[21] in patients having history of central venous access through the

subclavian route 4 out of the 5 patients (80%) had either complete or partial thrombus in 71 deep venous system. USG might provide indirect evidence of thrombosis in central veins & also direct visualization of thrombus in peripheral veins. So it supports usage of USG in routine pre-op evaluation for AV access. However, in these cases, the value of angiography cannot be over-emphasized. This was suggested by Schillinger et al. In this research, there was no observation of stenosis or occlusion at the site of subclavian cannulation in patients who had a history of central venous access.

In the present research, Access sites created were 57.14% Radiocephalic, 31.43% Brachiocephalic, 5.7% Brachiobasilic, 2.8% Brachiobrachial, and 2.8% Brachiocubital.

In the present research 80% non-dominant arm was used for AV access creation. 20% Dominant arm used.

Wong et al.[6] observed that accessory veins within 5 cm distance from the anastomosis location might impair the functioning of the fistula. The walls of a typical vein are thin and regular, and the lumen is anechoic. To allow venipuncture, it must be sufficiently linear (over a distance of at least 8-10cm) and lie less than 6mm below the skin surface.[6]

Subclavian & internal jugular veins spectrum shows changes in velocity with respiratory & cardiac activity. It is an indirect indicator of patency in ipsilateral innominate vein and superior vena cava. Monophasic flow is indicative of steno-occlusion. In any case, phlebography should be performed for confirming suspicion of steno-thrombotic lesion involving a central vein.

Sedlacek M et al,[23] for a successful fistula, a PSV of 50 cm/sec was found to be necessary. Another study, Lockhart et al,[24] found no change in pre-operative PSV b/w successful & unsuccessful fistulae, as well as with PSV of 50, there is no rise in failure rate of arteries larger than 2mm in diameter 40. As a result, above 2 mm diameter, arterial flow & PSV may be irrelevant in predicting fistula outcomes.

According to a study by KC Aishwarya et al,[18] if depth of vein is > 0.5 cm, surgeon should consider transposition.

In a research by KC Aishwarya et al.[18] 95% of USG chosen accesses matched with surgical accesses.

In the current analysis, 94.29 percent of USG-selected accesses were matched with surgical accesses.

In a research by KC Aishwarya et al,[18] The creation of fistulae exceeded the grafts, with 48 fistulae & 12 AVGs, assisting in the maximisation of native AVFs.

In the present research, 1 graft and 34 fistulae were created thereby preoperative USG helped in increasing the AVFs.

Conclusion

- In patients whose physical examination was indeterminate preoperative vascular mapping by Doppler USG has helped a lot in increasing AVF creation.
- Doppler USG preoperative mapping also selects most possible sites for HD access creation.
- Preoperative mapping with Doppler USG has 94.2% accuracy in choosing potential sites for the successful creation of hemodialysis access.
- The current research found a 5.71 percent rate of negative surgical exploration.
- Anatomical variation picked up by USG i.e., HBAB has helped in surgical planning.
- There is a strong correlation between diameters estimated by Ultrasound and surgery.
- Various parameters such as vessel diameter, wall morphology, peak systolic flow, Spectral wave form, anatomical course, patency, depth from skin surface helped a lot in choosing potential sites for access creation.

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