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Predictors of success of brachiocephalic fistula for hemodialysis in pediatric age group

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Abstract
Introduction: Arteriovenous fistula is the vascular access of choice in children on hemodialysis. However, creation and maintenance of arteriovenous fistula in children has unique challenges.
Aim of Study: To determine the predictors of success of brachiocephalic fistula for hemodialysis in pediatric age group.
Methods: This prospective study was conducted on (34) children (≤ 18 years of age) with end stage renal disease referred to the Vascular and Endovascular Surgery Department in Tanta University Hospitals for arteriovenous fistula creation for hemodialysis purpose from the beginning of April 2021 till the end of March 2023. Full history taking, clinical examination and duplex ultrasound vascular mapping was performed with minimal used arterial diameter of 2 mm and minimal vein diameter of 2.5 mm. All arteriovenous fistulae were created in end to side anastomosis with a continuous running suture using 7/0 prolene suture.
Results: 34 children were included in this study with mean age of 11.56±2.53 years ranging from 7-16 years and the mean weight was 32.29±9.18 Kg ranging from 18-54 Kg. 33 children (97.1%) had already started hemodialysis through temporary central venous catheters on presentation. The mean arterial diameter was 2.59±0.37 mm ranging from 2-4 mm. While the mean vein diameter was 3.21±0.50 mm ranging from 2.5-4.4 mm. Successful maturation occurred in 33 cases (97.1%) while primary failure occurred in 1 case due to failed maturation and thrombosis. After 1 year the primary patency rate was (82.4%). While secondary patency rate was (94.1%). No statistically significant correlations to (age, weight, etiology of renal failure, associated comorbidities, artery diameter, flow volume, vein diameter and arteriotomy length).
Conclusions: Success of brachiocephalic fistula in pediatric patients is predicted provided that preoperative child selection and duplex US vascular mapping is routinely used for evaluation of child vessels suitability with minimally used arterial diameter of 2 mm and minimal vein diameter of 2.5 mm, arteriotomy length of 3-5 mm with arteriovenous fistula creation in end to side anastomosis with a continuous running suture using 7/0 prolene suture, using metal dilators to overcome arterial spasm just before tying the last stitch and routine postoperative follow up for early detection of complications to achieve arteriovenous fistula maintenance.

Keywords: End stage renal disease, pediatric hemodialysis, arteriovenous fistula

Introduction

The number of children with end-stage renal disease (ESRD) is significantly increasing [1] and Hemodialysis (HD) was reported to be the most commonly used modality for renal replacement therapy [1]. Creation and maintenance of vascular access is the cornerstone for successful HD. In contrast to Central Venous Catheters (CVCs), Arteriovenous Fistula (AVF) is characterized by lower infection rates, less hospitalization, prolonged patency, adequate flow rates, smaller number of interventions and better dialysis efficiency [2]. However, Creation and maintenance of AVF in children needs high surgical experience using microsurgical techniques especially in younger children with smaller body size and lower-diameter blood vessels that are prone to vasospasm and need prolonged duration for maturation [3]. Several studies in adult population show that certain vessels criteria are associated with poor fistula maturation or failure such as arterial diameter < 2 mm or vein diameter < 2.5 mm [4, 5]. Published data in the use of an AVF for HD in children is sparse, and most of practiced guidelines are drawn from adults [6].

Aim of Study: To describe the clinical profile and predictors of success of brachiocephalic fistula for hemodialysis in pediatric age group.

Patients and methods: This prospective study was conducted on (34) children (≤ 18 years of age) with ESRD for HD recruited to the Vascular and Endovascular Surgery Department in Tanta University Hospitals from surrounding governments where there were no available expertise vascular surgeons in such cases from the beginning of April 2021 till the end of March 2023.
All children were subjected to Full history taking from patients, parents or relatives including age, sex, weight, primary etiology of ESRD, the dominant extremity, previous central lines, all previous HD access procedures, all comorbid conditions, and current medications.

Physical examination including: Vital signs (pulse, temperature and blood pressure), arterial Examination (peripheral pulse examination, Allen test), venous Examination with and without tourniquet (size, continuity, distensibility, length, proximity to artery), scars of previous access procedures, distended neck veins and superficial subcutaneous venous collaterals. Furthermore, cardiac evaluation was routinely performed. Vascular mapping was performed for all children prior to surgery using duplex ultrasonography (Philips machine, Color Doppler, Linear array transducer 4-12 MHZ)). Veins were evaluated with and without tourniquet application for diameter, patency, continuity, distensibility, and indirect signs that suspect central veins occlusion. Also, peripheral arteries are evaluated for diameter, patency and blood flow volume.
An informed consent was taken by the legal guardian of the child for the operation after detailed description of the procedure. Ethical committee approval was performed with approval code: 34592/3/21. There were adequate provisions to maintain privacy of participants and confidentiality of data.
The choice of brachiocephalic fistula creation was individualized after examination and DUS vascular mapping with minimal arterial diameter of 2 mm and minimal vein diameter of 2.5 mm.

Procedure: All procedures were performed under general anesthesia. A single prophylactic intravenous antibiotic dose was given immediately before skin incision and magnifying loupe (Binocular magnifying loupe, Galilean X 3.5) was used in all cases. Careful and gentle dissection was performed with vein mobilization, ligation of side tributaries. Topical smooth muscle relaxant papaverine and mechanical dilators were used to overcome vessels spasm. Gentle vein dilation using heparinized saline injection while manually occluding the upper arm was performed. Flow control was achieved using fine non-traumatic vascular clamps. Arteriotomy was done to a length of approximately 1.5 times as arterial diameter usually up to 5 mm. All AVFs were created in end to side anastomosis with a continuous running suture using 7/0 prolene suture. Fig.1 Mechanical metal dilators were to dilate the artery distally then proximally just before tying the last stitch.

Post-operative care: Successful functioning AVF formation was confirmed by feeling a thrill or hearing bruit over the vein. The dressings were light and longitudinal. Older children who were compliant enough were encouraged to squeeze a rubber ball by their hands.

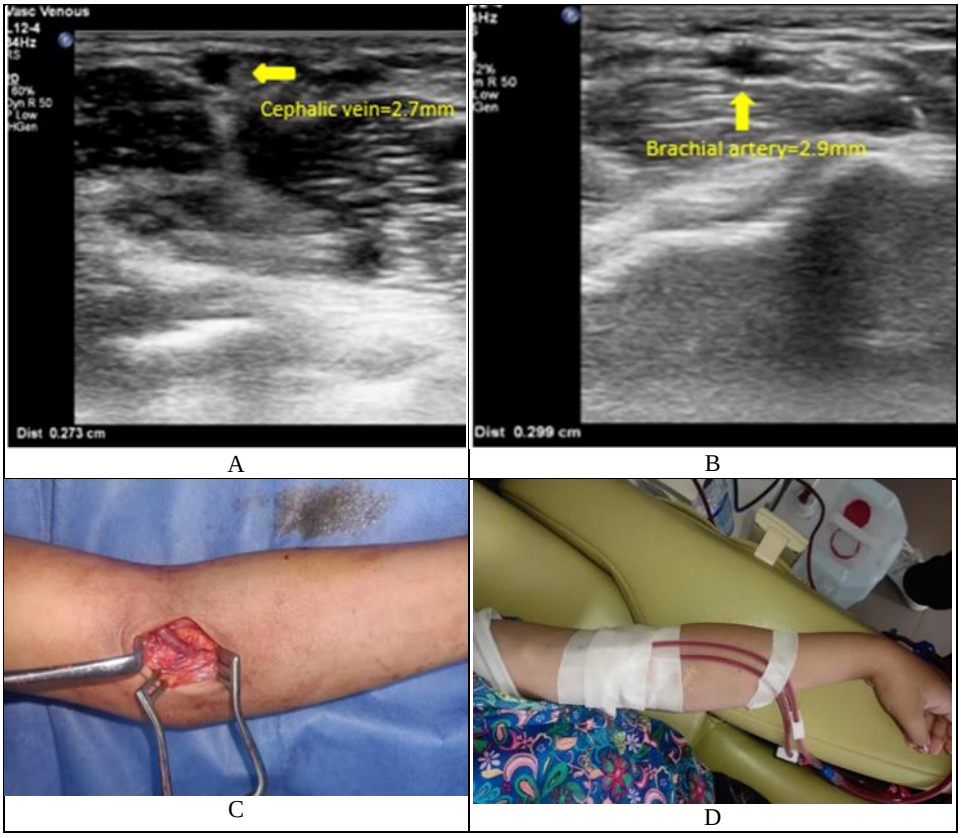

Fig 1: A) DUS showing cephalic vein diameter of 2.7 mm. B) DUS showing brachial artery diameter of 2.9 mm. C) brachiocephalic fistula creation with end to side anastomosis. D) 2 needle cannulation of cephalic vein.

After approximately 6 weeks, AVF maturation was assessed by vein palpation, feeling of thrill over it while its diameter, depth, and volume flow rate were evaluated using DUS. Vein diameter of 4 to 5 mm and blood flow of 400-500 ml/min were established criteria that indicate AVF maturation. All AVFs were annulated using 17-gauge needles. Initially using single needle for few sessions, then using both the arterial and venous needles.

Follow-Up: Children with AVF were evaluated approximately 6 weeks and at regular intervals of 3, 6, 9, 12 months after creation for: Clinical examination and assessment by DUS examination for (patency, maximum vessel diameter and volume flow rate).
Primary patency is the time interval from AVF formation till any intervention performed to maintain or reestablish patency. Primary assisted patency is the time interval from the time of AVF formation till AVF thrombosis, including interventions performed to maintain the function of an AVF. While secondary patency is the time interval from AVF formation till failure (including procedures performed to re-establish function).

Results

This prospective study was conducted on 34 children, 21 cases (61.76%) were males and 13 cases were female (38.24%). The mean age was 11.56±2.53 years ranging from 7-16 years. 24 children (70.6%) ≤12 years old and 10 children (29.4) > 12 years old. The mean weight was 32.29±9.18 Kg ranging from 18-54 Kg. The most common cause of ESRD was congenital anomalies of the kidney and urinary tract 18 (52.9%), followed by glomerulonephritis 6 (17.6%), recurrent urinary tract infections 5 (14.7%), hemolytic uremic syndrome 3 (8.8%) and 2 (5.9%) children were referred to unknown etiology.
3 children (8.8%) were associated with systemic lupus erythromatosus (SLE), 4 children (11.8%) with hypertension (HTN), 1 child (2.9%) with growth retardation, 4 children (11.8%) with cardiomegaly, 3 children (8.8%) with diabetes mellitus (DM) and 1 child (2.9%) was associated with familial Mediterranean fever (FMF).
33 children (97.1%) were on maintenance HD through a CVC for a mean duration of 1.90±1.6 months prior to AVF creation. Two children (5.9%) had history of a previous AVF creation (one case had history of previous brachiocephalic fistula in the other limb and the case had history of radiocehalic fistula in the same limb.
The mean arterial diameter was 2.59±0.37 mm ranging from 2-4 mm. While the mean vein diameter was 3.21±0.50 mm ranging from 2.5c4.4 mm. Twenty-three AVF (67.6%) were created in the left non dominant side. While 11 AVF (32.4%) were created in the right side. Mean operative time was 49.12±8.21 minutes with 32 children (94.1%) had intraoperative felt thrill and two children had no intraoperative felt thrill and this was supposed to be due to intraoperative hypotension. There was immediate post operative bruit along the vein in both cases and thrill appeared later on after recovery.
The mean follow up period was 10.7±5.7 months ranging from 1.5-24 months. Successful maturation occurred in 33 cases (97.1%) while primary failure occurred in 1 case due to failed maturation and thrombosis. The mean AVF creation to cannulation time was 49.1±10.2 days ranging from 40-90 days.
The most common complications were hematoma and ecchymosis (44.1%), thrombosis (11.8%) and pseudoaneurysm formation (8.8%) followed by stenosis (8.8%), true aneurysm (8.8%) and infection (2.9%). Fig 2, 3, 6.

Fig 2: Infected pseudoaneurysm over brachiocephalic fistula in 3 years old child

Fig 3: Infected pseudoaneurysm over brachiocephalic fistula in 8 years old child

In total, 7 reinterventions were performed: 2 pseudoaneurysm repair, 1 AVF ligation, two cases percutaneous transluminal angioplasty (one for subclavian vein stenosis and the other for cephalic vein stenosis) and 2 cases of thrombectomy (one thrombectomy with aneurysmorrhaphy and the other one with redo proximal anastomosis). The Primary Patency rate was (94.1%) (88.2%). (88.2%), (82.4%) at 3, 6, 9, 12 months respectively. While secondary patency rate was (97.1%) (94.1%) (94.1%) (94.1%) at 3, 6, 9, 12 months respectively. Fig.4, 5
There were insignificant correlations between duration of primary, secondary patency and (age, weight, etiology of renal failure, associated comorbidities artery diameter, flow volume, vein diameter and arteriotomy length).Table (1).

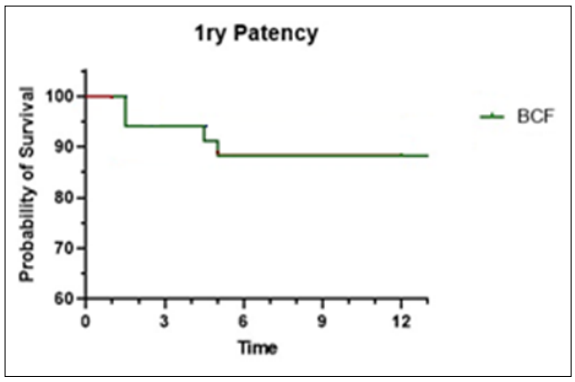

Fig 4: Kaplan Meier curve for duration of primary patency in BCF. BCF: brachio-cephalic fistula

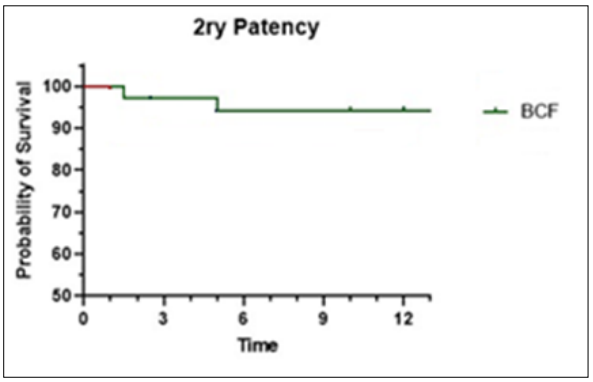

Fig 5: Kaplan Meier curve for duration of secondary patency in BCF. BCF: brachio-cephalic fistula

Table 1: Correlation between duration of primary patency and duration of secondary patency and age, weight, etiology of renal failure, associated comorbidities, artery diameter, flow volume, vein diameter and arteriotomy length

		Duration of primary patency	Duration of secondary patency
Age	P-Value	0.990	0.053
Weight	P-Value	0.705	0.377
Etiology of renal failure	P-Value	0.235	0.132
Associated comorbidities	P-Value	0.125	0.521
Artery Diameter	P-Value	0.916	0.680
Flow volume	P-Value	0.816	0.754
Vein Diameter	P-Value	0.275	0.403
Arteriotomy length	P-Value	0.542	0.432

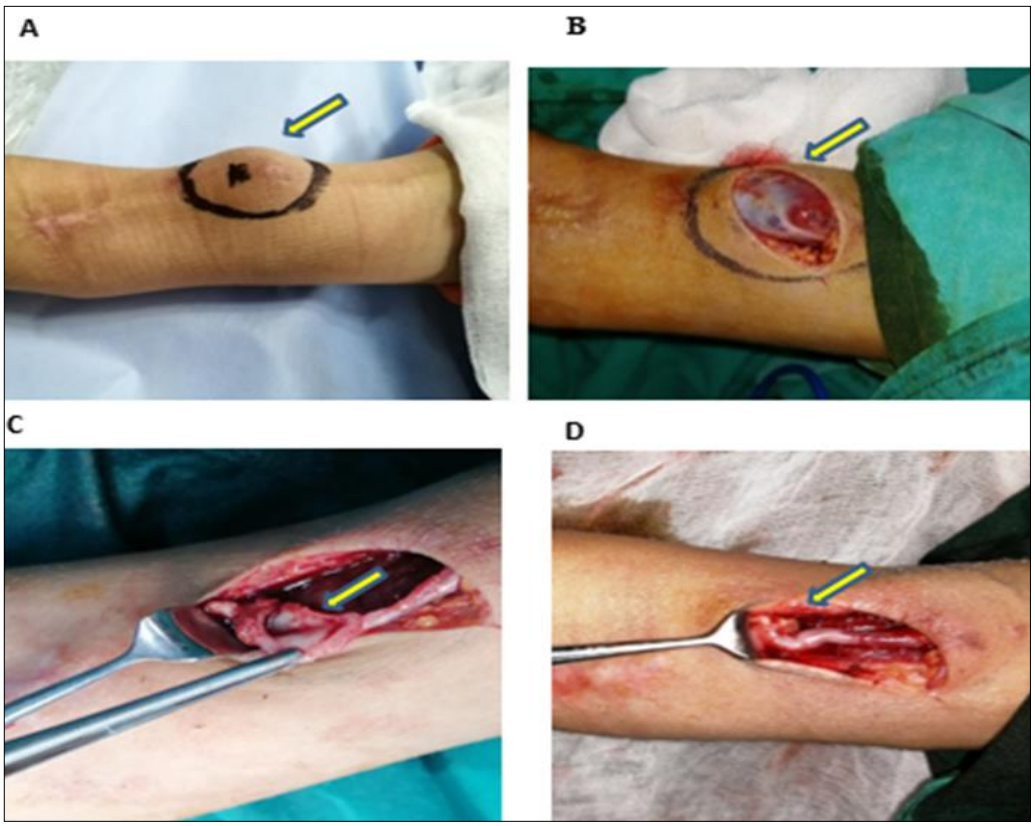

Fig 6: A) Cephalic vein pseudoaneurysm in 7 years old child. B) Cephalic vein pseudoaneurysm after exploration. C) Cephalic vein large perforation after exploration. D) Cephalic vein after primary repair

Discussion

In the present study, brachio-cephalic fistula was created in 34 cases. The mean age was 11.56±2.53 years ranging from 7-16 years. 24 children (70.6%) ≤ 12 years old and 10 children (29.4) > 12 years old and the mean weight was 32.29±9.18 Kg ranging from 18-54 Kg. Logically the smaller the vessels, the greater challenge in creation and cannulation a functioning AVF. Significant experience in AVF formation, in small children weighed <10 kg were reported. However, more attempts were required for children weighing less than 10 kg to achieve a functioning AVF compared to larger children [7].

In the same line, Bourquelot [8] in one of the largest series on AVFs in small children (<10 kg) reported that failure occurred in (52.7%) of children and received a new vascular access was attempted. Akturk et al., (2018) [9] reported a debate that needs to be discussed is if one would favor a micro-surgical technique in AVF at distal or at proximal site in children. AVF creation at wrist requires more expertise from the vascular surgeons aiming to preserve the proximal site for as a future AVF option. Moreover, distal AVFs have a less frequency of steal syndrome. However, relatively small radial level vessels, weak arterial inflow and low intravascular volume and usually limit this option especially in young children.

In the present study, among 34 children, 33 children (97.1%) were on maintenance HD through a CVC for a mean duration of 1.90±1.6 months prior to AVF creation. Similar to our findings, Borzych-Duzalka, et al., (2019) [10] reported that 73% of children started HD through CVC possibly due to delays in diagnosis and referral.

The overall mean time of AVF maturation in the present study was 49.1±10.2 days ranging from 40-90 days. In the same context, Kamath et al., (2022) [11] reported fistula maturation time of median 7 weeks. In contrast to the current study, Karava et al, (2018) [7] reported median maturation time was 18.8 weeks. This could be explained by that in Karava study there was no limitation in vessels diameters, 72.9% of AVFs were created distally in the forearm, his patients' weight was less (13.5 Kg vs 32.29 Kg in our series) and his patients' median age was lower (3.2 vs 11.56 years in our series).

Overall, the most common complications in the current study were hematoma and ecchymosis (44.1%), thrombosis (11.8%) and pseudoaneurysm formation (8.8%) followed by stenosis (8.8%), true aneurysm (8.8%) and infection (2.9%). Onder et al. (2020) documented that the most common complication was stenosis in (31%), followed by thrombosis in (16%).

In total, 7 reinterventions were performed: 2 pseudoaneurysm

repair, 1 AVF ligation, two cases percutaneous transluminal angioplasty (one for subclavian vein stenosis and the other for cephalic vein stenosis) and 2 cases of thrombectomy (one thrombectomy with aneurysmorrhaphy and the other one with redo proximal anastomosis). In the same context Karava et al., (2018) [7] documented that 16 inreterventions were performed: six anastomosis revisions, four percutaneous transluminal angioplasties, and six thrombectomies.

The Primary Patency rate was (94.1%), (88.2%), (88.2%), (82.4%) at 3, 6, 9, 12 months respectively. While secondary patency rate was (97.1%), (94.1%), (94.1%), (94.1%) at 3, 6, 9, 12 months respectively. In the same line, Şişli, E (2019) [12] reported the primary patency rate at 1 year was 92.3% and the secondary patency rate was 96.2%.

Unexpectedly, we didn't find any significant correlation between duration of primary, secondary patency and (age, weight, etiology of renal failure, associated comorbidities, artery diameter, flow volume, vein diameter and arteriotomy length). This could be due to following the basic expected measures of success such as preoperative duplex US vascular mapping with minimally used arterial diameter of 2 mm and minimal vein diameter of 2.5 mm and arteriotomy length of approximately 3-5 mm. Arteriovenous fistula is sensitive to blood pressure (BP) levels to maintain adequate volume flow and patency, in the present study there was no cutoff point for blood pressure to decide AVF creation, also there was no significant correlation between AVF patency and blood pressure. In the same line, Matoussevitch, V. et al., (2015) [13] stated that there was no significant correlation between AVF patency, maturation time and child weight or age and also AVF success was independent of the type of AVF (distal vs. proximal). However, for formation of a successful AVF, preoperative individualisation in child selection, particularly the type and location of AVF is mandatory.

Conclusions

AVF for hemodialysis is feasible in pediatric age group with good outcomes and low complications provided that better choice of the child and availability of well-trained vascular surgeons.

Success of brachiocephalic fistula creation in pediatric patients is predicted with primary patency rate of 82.4% and secondary patency rate of 94.1% after 1 year provided that preoperative child selection and duplex US vascular mapping is routinely used for evaluation of child vessels suitability with minimally used arterial diameter of 2 mm and minimal vein diameter of 2.5 mm, arteriotomy length of 3-5 mm with AVFs creation in end to side anastomosis with a continuous running suture using 7/0 prolene suture, using metal dilators to overcome arterial spasm just before tying the last stitch and routine postoperative follow up for early detection of complications to achieve AVF maintenance.

Conflict of Interest: Not available

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