Keyhole incision with inversion over a wire technique in brachiobasilic shunt

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Introduction
Brachiobasilic arteriovenous fistula (AVF) represents one of the most important accesses for hemodialysis; however, its transposition requires a long incision and extensive surgical dissection. In this study, we aimed to minimize the extent of surgery by using only keyhole incisions depending on a catheter-based technique.

Patients and methods
This work was designed as a single-center prospective study that included 30 patients indicated for brachiobasilic arteriovenous access.
After exposure and dissection of the basilic vein at the elbow, a 0.035 hydrophilic guidewire was introduced into basilic vein up to superior vena cava followed by a 6-Fr straight guiding catheter after fixing its tip to the basilic vein's transected end. The catheter was introduced gently inverting the basilic vein till a resistance was faced, representing a side branch, and a keyhole incision was performed to divide this branch. The basilic vein is then mobilized from an axillary incision and transposed in an anterolateral tunnel to be anastomosed with the brachial artery.

Results
Between April 2019 and April 2020 with follow-up to December 2020, 30 patients underwent the procedure. The mean operative time was 87.60±9.91 min, with primary patency of 86.7% and secondary patency of 93.3%.
Life table analysis showed that brachiobasilic AVF created with basilic veins more than or equal to 4 mm had a higher primary patency than that created with veins less than 4 mm in diameter.
Impairment of primary patency was significantly associated with increased age ($P=0.022$), diabetes mellitus ($P=0.035$), and patients on anticoagulant therapy ($P=0.004$). Two (6.7%) patients developed arm edemas, five (16.7%) patients had postoperative hematomas, three (10.0%) patients experienced infections, and no patient developed pseudoaneurysm, arterial steal, or nerve injuries.

Conclusion
Construction of arteriovenous fistulae using keyhole incisions and inversion of the vein over a wire provides a feasible technique with minimal complications and improved cosmetic outcomes.

Keywords:
arteriovenous fistula, brachiobasilic, keyhole, one stage, two stage

Introduction
Globally, there were 697.5 million cases of chronic kidney diseases that require an efficient provision of vascular access to ensure optimal outcomes form hemodialysis [1]. According to the most recent Kidney Disease Outcomes Quality Initiative (KDOQI) guidelines, it has been recommended that the radio-cephalic arteriovenous fistula (AVF) is the first choice as a vascular access in hemodialysis patients [2]. In conditions that these accesses were not feasible or failed, the options include brachial artery either autogenous vein or through prosthetic graft construction [2]. Autogenous AVFs are known for their better long-term patency and lower complication rates compared with prosthetic graft access [3].

There are usually two available autogenous brachial AVFs: brachiocephalic AVF and brachiobasilic arteriovenous fistula (BBAVF). Unlike cephalic vein, the basilic vein has the advantage of being a deep vein protected from damage caused by previous venipuncture and is often of good caliber. However, the basilic vein must be mobilized and superficialized during fistula formation; thus, the complexity of the procedure and complication rates are increased [4]. In 1976, Dagher et al. [5] first described transposition of the divided and well-mobilized vein by rotating it

anterolaterally through a subcutaneous tunnel in the arm. Since then, there have been two usual methods of BBAVF creation: a two-stage or one-stage operation. The two-stage procedure allows for maturation of the basilic vein first, which made the vein less liable to damage; however, it is associated with increased costs, infection rate, and anesthetic risks because it exposes the patient to two procedures [6].

On the contrary, the one-stage procedure was reported to be a reliable technique but the traditional method of a single long incision is associated with a high rate of hematoma formation, significant arm discomfort, ugly aggressive scar, and a high rate of wound complication, especially with diabetes, immunologic, nutritional and aging issues associated with end-stage renal disease [6].

So, there are many trials to minimize the vein harvesting techniques in these patients like using a segmental bridged incisions instead of large one incision, using laryngoscope or endoscopic techniques [7]. All these procedures try to avoid the perioperative complications and to improve the patency in comparison with the standard techniques [6].

In 2005, Jennings *et al.* [7] described the use of keyhole and inversion technique for autogenous brachiobasilic transposition through small skin incisions. This technique could be performed under local anesthesia and patients are discharged on the same day of the surgery.

Although the use of autogenous brachiobasilic transpositions has been investigated in various studies, there has been significant disparity in published patency and complication rates [8,9]. The aim of this study was to evaluate use of catheter-based technique with only keyhole incisions in autogenous brachiobasilic transposition AVFs.

Patients and methods

This study was designed as a single-center prospective study in which BBAVF was performed in 30 patients with end-stage renal disease at the vascular surgery unit of Menoufia University Hospitals, Menoufia, Egypt. This study was approved by Menoufia University Hospitals' ethical committee. A written informed consent from all participants was obtained before procedures. The study was performed between April 2019 and April 2020, and follow-ups of patients were carried out until December 2020.

Inclusion criteria included all patients who were planned for brachiobasilic shunting.

Exclusion criteria included patients with heart failure, coagulopathy, peripheral arterial diseases, basilic diameter less than 3 mm, and history of synthetic shunt on the same limb.

Surgical technique

This technique started by basilic vein exposure and dissection at cubital fossa. A straight, stiff, 0.035-inch, 180-cm-long hydrophilic guidewire was introduced through the vein and advanced under fluoroscopic guidance till its tip reached the superior vena cava. A 6-Fr straight guiding catheter was advanced over the wire, with its tip fixed to the vein by sutures (Fig. 1). Then, gentle pushing of the catheter proximally over the wire was done to invert the vein (as an intussusception). Pushing forward was kept till facing a resistance, and the site of resistance was determined accurately as it was mostly the site of the side branch (Fig. 2).

A single skin incision was made over the resistance about 0.5–1 cm with direct division of the side branch

Figure 1

Fixation of the catheter to the tip of the vein in the cubital fossa.

Figure 2

Division of a side branch.

(Fig. 2). The endothelium always remains intraluminal throughout the procedure.

Externalization of the basilic vein was performed through a short axillary incision (Figs 3 and 4).

After full mobilization of the basilic vein, it was checked for any leak, prepared as usual, and tunneled subcutaneously, and then it was anastomosed to the brachial artery in the cubital incision (Fig. 5).

Data collection
Data were gained from each patient about age, sex, anticoagulant treatment, previous hemodialysis access, hypertension, diabetes, or smoking. Vein diameter was assessed by duplex and reported. Operation time was also recorded.

All surgical outcome definitions were in accordance with the Society for Vascular Surgery reporting guidelines [10]. Arm edema, hematoma, infection, pseudoaneurysm, or arterial steal were assessed and recorded if present. Primary patency was defined as the interval between fistula formation and initial failure without any intervention. Secondary patency was defined as the interval between fistula formation and eventual failure despite all interventions to maintain patency [11].

Statistical analysis
The collected data were organized, tabulated, and statistically analyzed using SPSS, version 24 (IBM Corp., Armonk, New York, USA).

Discrete variables were presented as numbers (counts) and percent. Continuous variables presented as mean and SD. Data were analyzed by using χ^2 test and Fisher's exact test. AVF performance was calculated by life tables (Kaplan–Meier with log-rank evaluation). Statistical significance was defined as a confidence interval more than or equal to 95%, and P value was considered significant if less than 0.05.

Results
Demographic characteristics of the study cohort
The present study included 30 patients, where 53.3% were males, with a mean age of 52±27 years. Overall, 20% of patients had previous access, 30.0% were diabetic, 36.7% were hypertensive, and 33.3% were smokers. In addition, 70.0% of patients had a vein diameter more than 4 mm and 10.0% were on anticoagulant treatment. The average operation time of the study was 87.60 min, with a range between 73 and 103 min (Table 1).

Relationship between demographic characteristic of the study cohort and primary patency
Impairment of primary patency was significantly associated with increased age (P=0.022), diabetes mellitus (P=0.035), small vein diameter (P=0.035), and anticoagulant therapy (P=0.004) (Table 2).

The mean duration of follow up was 14±6 months (range, 8–20 months). Two (6.7%) patients developed

Figure 3
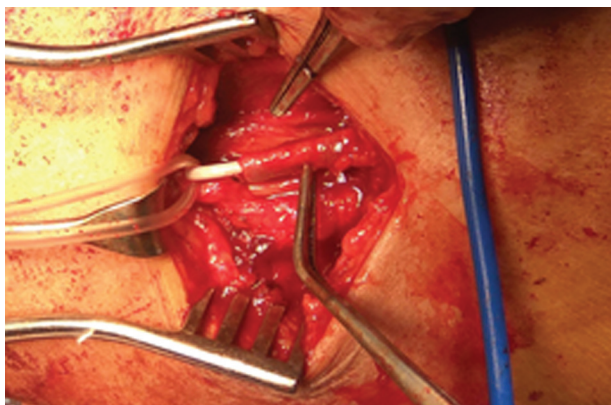
Advancement of the catheter till a resistance was faced and then a keyhole incision is made to divide a side branch.

Figure 4

Extracting the vein through an axillary incision and preparation of the vein for tunneling and anastomosis.

Figure 5

Extracting the vein through an axillary incision and preparation of the vein for tunneling and anastomosis.

Table 1 Demographic characteristics of the study cohort

Parameters	Patients (N=30) [n (%)]
Age	
Mean±SD	52.27±14.56
Median	53.50
Minimum–maximum	24.00–77.00
Sex	
Male	16 (53.3)
Female	14 (46.7)
Previous access	
No	24 (80.0)
Yes	6 (20.0)
Hypertension	
No	19 (63.3)
Yes	11 (36.7)
Diabetes mellitus	
No	21 (70.0)
Yes	9 (30.0)
Smoker	
No	20 (66.7)
Yes	10 (33.3)
Vein diameter	
Less than 4 mm	9 (30.0)
More than 4 mm	21 (70.0)
Anticoagulant	
No	27 (90.0)
Yes	3 (10.0)
Operation time	
Mean±SD	87.60±9.91
Median	89.50
Minimum–maximum	73.0–103.0

Table 2 Relationship between demographic characteristic of the study cohort and primary patency

Parameters	Primary patency [n (%)]		P value
	No (N=4)	Yes (N=26)	
Age			
Mean±SD	67.0±7.35	50.0±14.1	0.022
Median	65.0	49.0	
Minimum–maximum	61.0–77.0	24.0–74.0	
Sex			
Male	2 (50.0)	14 (53.8)	0.886
Female	2 (50.0)	12 (46.2)	
Previous access			
No	3 (75.0)	21 (80.8)	0.788
Yes	1 (25.0)	5 (19.2)	
Hypertension			
No	1 (25.0)	18 (69.2)	0.087
Yes	3 (75.0)	8 (30.8)	
Diabetes mellitus			
No	1 (25.0)	20 (76.9)	0.035
Yes	3 (75.0)	6 (23.1)	
Smoking			
No	3 (75.0)	17 (65.4)	0.704
Yes	1 (25.0)	9 (34.6)	
Vein diameter			
Less than 4 mm	3 (75.0)	6 (23.1)	0.035
More than 4 mm	1 (25.0)	20 (76.9)	
Anticoagulant treatment			
No	2 (50.0)	25 (96.2)	0.004
Yes	2 (50.0)	1 (3.8)	
Operation time			
Mean±SD	84.0±10.42	50.0±14.1	0.702
Median	83.50	49.0	
Minimum–maximum	75.0–94.0	24.0–74.0	

arm edemas, five (16.7%) patients had hematomas, one (3.3%) patient develop stenosis, three (10.0%) patients experienced infections, whereas no cases experienced pseudoaneurysm, arterial steal, or nerve injuries during the study period. The primary patency was 86.7%, whereas secondary patency was 93.3% (Table 3).

Relationship between complications and surgical outcomes of the study cohort and primary patency
There was a statistically significant association between the complications of the included patients involving arm edema, hematoma, secondary patency, infection, and impaired primary patency (P<0.01) (Table 4).

Relationship between complications and surgical outcomes of the study cohort and vein diameter
Small vein diameter was significantly associated with arm edema (P=0.025), hematoma (P=0.008), secondary patency (P=0.025), and infection (P=0.005) (Table 5).

Relationship between vein diameter and primary patency
Life table analysis showed that BBAVF created with basilic veins more than or equal to 4 mm had a higher

primary patency than that created with veins that were less than 4 mm in diameter. However, this difference did not reach statistical significance (P=0.273) (Fig. 6).

Discussion

The increasing number of patients requiring hemodialysis triggers a drive for innovation of different methods for arteriovenous access. The BBAVF is considered one of the best choices to avoid the potential adverse effects of prosthetic grafts. The anatomic inaccessibility, hematoma formation, basilic vein injury, high failure rate, and cosmetically disfiguring incisions are considered the main obstacles against this technique [12].

Since Dagher *et al.* [5] described the transposition of a well-mobilized vein by rotating it anterolaterally, there are several changes and modifications in the technique by either doing this through a two-stage or one-stage procedure in a trial to get better patient outcomes.

Tan *et al.* [6] showed a superior primary patency rate of 49.1% for the one-stage procedure compared with 40.4% for the two-stage procedure. However, Jun Yan Wee *et al.* [13] conducted a large systematic review with meta-analysis, which reported that the two-stage approach is associated with improved 2-year primary patency rates. However, they finally concluded that there is no difference in both

techniques in relation to primary and secondary patency rates at 12 months [13].

Regarding the complications like steal syndrome, hematoma, infection, pseudoaneurysm, stenosis, or postoperative thrombosis, many of the studies reported that there is no difference between the two techniques [9,13,14].

The one stage offers benefits of one-step surgery and can result in a shorter duration for maturation with low cost than the two stages [12]. Moreover, there are many trials nowadays to avoid the large single incision that is usually used with its hazards by using a minimally invasive technique like using multiple skin incisions, videoscopic approach, laryngoscope, or inversion over a wire [15].

On the contrary, Peter Gloviczki *et al.* [16] conducted a study using the single-stage technique through one or two large incisions where a higher rate of complications

Table 3 Complications and surgical outcomes of the study cohort

Parameters	Patients (N=30) [n (%)]
Arm edema	
No	28 (93.3)
Yes	2 (6.7)
Hematoma	
No	25 (83.3)
Yes	5 (16.7)
Infection	
No	27 (90.0)
Yes	3 (10.0)
Pseudoaneurysm	
No	30 (100.0)
Yes	0
Arterial steal	
No	30 (100.0)
Yes	0
Nerve injury	
No	30 (100.0)
Yes	0
Primary patency	
No	4 (13.3)
Yes	26 (86.7)
Secondary patency	
No	2 (6.7)
Yes	28 (93.3)
Follow up duration	
Mean±SD	14±6
Median	12
Minimum–maximum	8–20

Table 4 Relationship between complications and surgical outcomes of the study cohort and primary patency

Parameters	Primary patency (N=30) [n (%)]		P value
	No (N=4)	Yes (N=26)	
Arm edema			
No	2 (50.0)	26 (100.0)	<0.01
Yes	2 (50.0)	0	
Hematoma			
No	1 (25.0)	24 (92.3)	<0.01
Yes	3 (75.0)	2 (7.7)	
Infection			
No	1 (25.0)	26 (100.0)	<0.01
Yes	3 (75.0)	0	
Secondary patency			
No	2 (50.0)	0	<0.01
Yes	2 (50.0)	26 (100.0)	

Table 5 Relationship between complications and surgical outcomes of the study cohort and vein diameter

Parameters	Vein diameter [n (%)]		P value
	Less than 4 mm (N=9)	More than 4 mm (N=21)	
Arm edema			
No	7 (77.8)	21 (100.0)	0.025
Yes	2 (22.2)	0	
Hematoma			
No	5 (55.6)	20 (95.2)	0.008
Yes	4 (44.4)	1 (4.8)	
Infection			
No	6 (66.7)	21 (100.0)	0.005
Yes	3 (33.3)	0	
Secondary patency			
No	3 (33.3)	1 (4.8)	0.025
Yes	6 (66.7)	20 (95.2)	
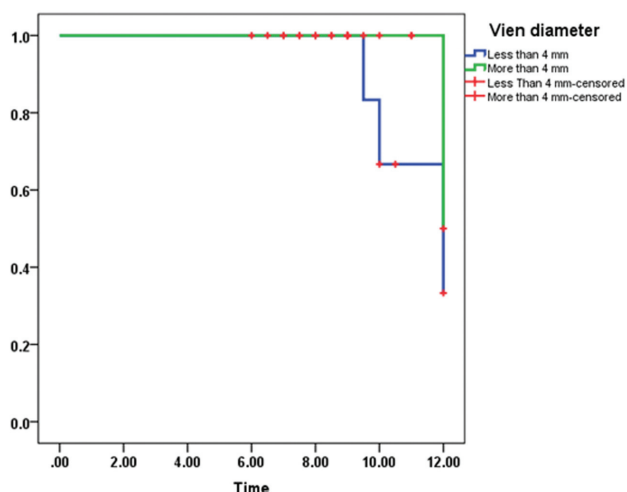
Life table analysis showed similar primary patency at 12 months postoperatively. However, it showed that BBAVP created with a basilic vein 4 mm or more in diameter to have a higher primary patency rate at 0, 3, 6, and 9 months, compared with those created with veins that were less than 4 mm in diameter. However, this difference did not reach statistical significance (P=0.273).

was reported in comparison with the present technique results regarding upper limb edemas (12.2 vs. 6.7%), vascular steal syndromes (12.2 vs. 0%), and less rate of complications regarding hematoma formation (10.5 vs. 16.7%) and infection rate (3.5 vs. 10%). Furthermore, the present technique recorded a higher primary patency at 12-month follow-up (86.7 vs. 66.3%) and a secondary patency (93.3 vs. 75.9%) in comparison with the technique used by Peter Gloviczki *et al.* [16].

Leone *et al.* [17] conducted a videoscopic approach to harvest the basilic vein for BBAVF in 21 patient as a one-stage through two small incisions. The mean operative time was 159 min, which was longer than the present technique (87.6 min), with no major difference between the two techniques regarding patency and complications. However, the significant cost of disposables, endoscopic equipment, and the surgeon's ability to learn the procedures remain the potential barriers to extend this technique for vascular access. In addition to the technical problems in the form of thermal injury to the vein, carbon dioxide embolization and the formation of intraluminal clot will stand against the postoperative patency of the AVF [5].

In agreement with the present work, Jennings *et al.* [7] used laryngoscope to mobilize the basilic vein through two small incisions, one in the axilla and the second just proximal to the cubital fossa. This study includes 47 patients during a 20-month follow-up period. The primary and secondary patency rates were 80 and 92%, respectively, and they did not report any cases

with hematoma formation or vascular steal, which correlate with other minimally invasive techniques. Diabetes mellitus is considered a major risk factor that affected the primary patency of the access, as the present study recorded that three of four patients who experienced impairment of primary patency were diabetic (P=0.035). This finding correlates with a meta-analysis conducted by Yan *et al.* [18].

In agreement with the present study findings, Hill and colleagues used the same technique with a mean operative time of less than 90 min, with 66% primary patency and secondary patency of 72%. However, Hill and colleagues reported that two patients developed postoperative hematomas and one patient developed arm edema in comparison with five patients and two patients, respectively, in our study. Furthermore, Hill and colleagues reported a case of ulnar nerve palsy that occurred immediately after surgery and resolved spontaneous. No cases of pseudoaneurysm or arterial steal were recorded in both studies. Their life table analysis showed that basilic veins with 4-mm diameter or more had a higher primary patency than the veins with diameter less than 4 mm in 8-month follow-up (80 vs. 50%) [7]. The present work also reported the same finding regarding the vein diameter, as large veins were associated with a higher patency rate, but this did not reach statistical significance in our study.

Preoperative duplex scanning must be considered for proper patient selection for the keyhole technique. Inversion procedure is not preferred to be performed in cases for which the vein diameter is less than 4 m because of the better manipulations, easy invagination over the wire, less rate of avulsed side branches, and better maturation of the larger-diameter veins.

Recommendations
A small sample size and the review of a single-center outcomes are considered the main limitations of this study. We recommend processing a large multicentric randomized study to evaluate and compare between different minimally invasive techniques regarding the patency and postoperative complications. A preoperative duplex scan in recommended to detect the size of the vein and the site of side branches.

Conclusion
Transposition of BBAVF using keyhole and inversion over a wire technique is considered a feasible surgical procedure as it had low rate of complications and higher primary and secondary patency rates.

Thus, despite being rarely performed for BBAVF, this technique may be used as an alternative to the traditional single-incision technique, and it can give comparable results to other minimally invasive techniques, provided that the basilic vein is of good quality and 4 mm or more in diameter.

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Conflicts of interest
There are no conflicts of interest.

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