ORIGINAL ARTICLE

Comparison of Outcomes between Upper Arm Loop and Straight Arteriovenous Grafts in Hemodialysis Patients

Nutvara Deeratanasrikul, MD[1], Saritphat Orrapin, MD[1], Thoetphum Benyakorn, MD[1], Boonying Siribumrungwong, MD, PhD[1]

[1] Division of Vascular Surgery, Department of Surgery, Faculty of Medicine, Thammasat University Hospital, Thammasat University, Pathum Thani, Thailand

Objective: The effectiveness of different configurations of upper arm arteriovenous grafts (AVGs) in hemodialysis remains controversial. This study aimed to compare outcomes between upper arm straight AVGs (AS-AVG) and loop AVGs (AL-AVG).

Materials and Methods: A retrospective study included all upper arm AVGs performed for hemodialysis between January 2018 and December 2022. An AS-AVG was selected if the cubital brachial artery diameter was greater than 4 mm; otherwise, an AL-AVG was chosen. Postoperative and long-term complications, as well as primary patency, were compared between the two groups. Multivariable regression analyses were used to account for potential confounding factors due to imbalanced baseline characteristics.

Results: Two hundred eleven patients were included, with 127 (60%) receiving AS-AVGs and 84 (40%) receiving AL-AVGs. Baseline characteristics were not significantly different between the groups, except for a high proportion of males in AS-AVG (37% versus 57%, p=0.003). The rates of postoperative and long-term complications (i.e., infection, stenosis, thrombosis, and hemodialysis access-induced distal ischemia) were not significantly different between the groups. The primary patency rates were also comparable. The 1-year primary patency is 67% (95% CI 53 to 77) for AL-AVG and 73% (95% CI 62 to 81) for AS-AVG. However, the operation time for AL-AVG was significantly longer, taking approximately 15 minutes (95% CI 8 to 22, p<0.001) more than AS-AVG.

Conclusion: The outcomes between AS-AVG and AL-AVG are not significantly different in terms of effectiveness and safety. Further study is needed to confirm the results. This conclusion specifically applies to patients with a cubital brachial artery diameter greater than 4 mm, indicating that both graft types may be viable options.

Keywords: Hemodialysis; Arteriovenous graft; Patency; Configuration; Loop; Straight; Ischemia

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Arteriovenous fistula (AVF) is recommended as the first choice for vascular access for hemodialysis in patients with end-stage renal disease due to its longer patency and lower access-related complications compared to arteriovenous graft (AVG). However, when patients' anatomy or conditions limit the creation of AVF, AVG becomes a favorable option[1].

For upper extremity AVG, evidence supporting the choice of sites between the forearm and upper arm remains controversial[1]. Some studies have demonstrated poorer patency rates in the forearm than in the upper arm AVG[2,3]. While recent data showed that patency did not differ[4]. However, forearm AVG should be considered before upper arm AVG when feasible to preserve the upper arm vein for future access creation[1].

Regarding graft configuration, a forearm loop graft was superior to a forearm straight graft, due to inflow from the distal forearm artery, especially in today's era, when a significant number of patients are diabetic, which can affect the quality of the distal forearm artery. However, data comparisons between upper arm AVG configurations remain controversial.

Although most studies found no significant differences in primary patency between upper arm straight and loop graft configurations[4,5], some demonstrated significantly better secondary patency with the loop configuration and less hemodialysis access-induced distal ischemia (HAIDI)[5,6]. Therefore, the present study compared outcomes between upper arm straight (AS-AVG) and loop AVG (AL-AVG). The primary objective was to compare primary patency, while secondary objectives were operative outcomes and complications between groups.

Correspondence to:

Siribumrungwong B.

Division of Vascular Surgery, Department of Surgery, Faculty of Medicine, Thammasat University Hospital, Thammasat University, Pathum Thani 10120, Thailand.

Phone: +66-89-9606259

Email: boonying22@gmail.com

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Materials and Methods

A retrospective cohort study of all patients who underwent upper arm straight and loop AVG at Thammasat University Hospital between January 2018 and December 2022 was included. The study was approved on January 20, 2023, by the Ethics Committee of the Faculty of Medicine, Thammasat University (MTC-EC-SU-0-228/65). The study was not registered in the clinical trial registry due to its retrospective nature. The study was done without any artificial intelligence.

Preoperative ultrasound mapping was performed by the operating surgeons in all cases at the outpatient clinic using outer-to-outer diameter measurements with a 12 MHz probe on the Philips EPIQ CVx ultrasound machine. In cases with no suitable vein for AVF and forearm AVG creation, upper arm AVG would be considered. All operations were done by experienced vascular surgeons. There were some practice differences among surgeons in choosing between AS-AVG and AL-AVG. BS and SO would choose AS-AVG first if the diameter of the cubital brachial artery is greater than 4 mm[7]. Otherwise, AL-AVG was chosen, whereas TB chose AL-AVG in every case.

Regarding the operations, non-ringed 6 mm polytetrafluoroethylene (PTFE) grafts were applied in all cases. In AS-AVG, the inflow was the brachial artery just proximal to the elbow crease, while in AL-AVG, the inflow was the brachial artery of the proximal arm. Both operations use the basilic or brachial veins as outflow veins. The outflow vein should be at least 4 mm in diameter.

Data from all patients who underwent AS-AVG or AL-AVG during the study period were collected from an electronic hospital information system. Baseline characteristics included age, sex, BMI, underlying diseases (i.e., cerebrovascular disease, coronary artery disease, congestive heart failure, and peripheral artery disease), antiplatelet use, active smoking, and history of previous catheter placement and ipsilateral access creation. Outcomes included operative data, postoperative and long-term complications (infection, bleeding, stenosis, thrombosis, pseudoaneurysm, and HAIDI), functioning AVG use, and primary patency. Missing data was minimized via phone calls.

Primary patency was defined as the interval from the time of access placement to any intervention designed to maintain or reestablish patency or to access thrombosis or the time of measurement of patency. Postoperative complications were complications that occurred within 30 days after the operation, whereas long-term complications were complications that occurred more than 30 days after the operation[8].

HAIDI was classified according to the clinical presentation of the patients as: Grade 1 is coolness, decreased pulse, pale or cyanotic nail; Grade 2a is tolerable pain, cramps, paresthesia during hemodialysis or exercise; Grade 2b is intolerable pain, cramps, paresthesia during hemodialysis or exercise; Grade 3 is rest pain or motor dysfunction of fingers or hands; Grade 4a is tissue loss; Grade 4b is extensive tissue loss that need amputation[9].

Categorical data were presented as percentages, while continuous data were presented as mean ± standard deviation (SD) or median (interquartile range, IQR), depending on the distribution. Chi-square and independent t-tests were applied to analyze categorical and continuous data, respectively. Pairwise deletion was used to manage missing data. Multivariable logistic and linear regression, and Cox proportional hazards model analyses were used to adjust for the unbalanced baseline characteristics as indicated. Outcomes were presented as odds ratios, mean differences, and hazard ratios, along with their 95% confidence intervals (CIs), depending on the data type. Analysis was done using Stata Statistical Software, version 16 (StataCorp LLC, College Station, TX, USA), and a p-value of less than 0.05 was considered statistically significant.

Results

Two hundred eleven patients underwent upper arm AVG during the study period. Of which 127 (60%) were AS-AVG, and 84 (40%) were AL-AVG. Baseline characteristics are compared between AVG types in Table 1. Mean age and body mass index were not significantly different between groups. The proportion of patients with hypertension, diabetes, cerebrovascular disease, coronary artery disease, congestive heart failure, and peripheral artery disease was also not significantly different. However, the AS-AVG group had a significantly higher proportion of males (57% versus 37%, p=0.003).

The mean diameter of the arteries and veins was 4.4 mm (SD 1.23) and 4.9 mm (SD 2.04) in AL-AVG and 4.4 mm (SD 1.07) and 5.4 mm (SD 2.03) in AS-AVG, which were not significantly different. The only baseline characteristic that was different was the proportion of males, which was 37% in AL-AVG and 57% in AS-AVG (p=0.003). The median follow-up time was 1.5 years (IQR 0.8 to 2.6) for AL-AVG and 1.6 years (IQR 1.0 to 3.1) for AS-AVG.

Table 1. Baseline characteristics comparison between upper arm straight arteriovenous graft (AS-AVG) and upper arm loop arteriovenous graft (AL-AVG)

Variables	AL-AVG (n=84)	AS-AVG (n=127)	p-value
Age (years); mean±SD	58±15	59±13	0.607
Sex; n (%)			0.003
Male	31 (37)	73 (57)	
Female	53 (63)	54 (42)	
BMI (kg/m^2); mean±SD	23.7±5.2	23.5±4.1	0.700
Hypertension; n (%)	78 (93)	118 (93)	0.988
Diabetes; n (%)	41 (49)	64 (50)	0.822
Cerebrovascular disease; n (%)	5 (6)	17 (13)	0.084
Coronary artery disease; n (%)	7 (8)	16 (13)	0.373
Congestive heart failure; n (%)	5 (6)	7 (6)	0.678
Peripheral artery disease; n (%)	2 (2)	7 (6)	0.446
Previous hemodialysis catheter; n (%)	58 (69)	92 (72)	0.595
Previous ipsilateral access creation; n (%)	19 (23)	17 (13)	0.081
Native AVF	14 (74)	13 (77)	0.847
AVG	5 (26)	4 (24)	
Alcohol drinking; n (%)	11 (13)	24 (19)	0.267
History of tobacco use; n (%)	12 (14)	26 (20)	0.252
Current tobacco use	4 (33)	4 (15)	0.207
Access side; n (%)			0.391
Right	18 (21)	38 (30)	
Left	66 (79)	89 (70)	
Preemptive access; n (%)	18 (21)	31 (24)	0.616
Vessel diameter (mm); mean±SD			
Artery	4.4±1.23	4.4±1.07	0.909
Vein	4.9±2.04	5.4±2.03	0.093
Arteriotomy (mm); mean±SD	7.3±1.87	7.0±1.52	0.517
Venotomy (mm); mean±SD	10.3±3.68	10.5±2.75	0.768
Perioperative medication; n (%)			
Antiplatelet use	26 (31)	45 (35)	0.500
• Aspirin	22 (85)	36 (80)	0.552
• Clopidogrel	3 (12)	4 (9)	
• Dual antiplatelet therapy	1 (4)	5 (11)	
Statin use	52 (62)	76 (60)	0.764
Anticoagulant use	3 (4)	6 (5)	0.685

AVF=arteriovenous fistula; AVG=arteriovenous graft; BMI=body mass index; SD=standard deviation

Table 2. Operative time and postoperative complications comparison between upper arm straight arteriovenous graft (AS-AVG) and upper arm loop arteriovenous graft (AL-AVG)

Variables	AL-AVG (n=84)	AS-AVG (n=127)	p-value
Operative time (minutes); mean±SD	122 (26)	107 (25)	<0.001
Postoperative complications (within 30 days); n (%)			
Infection	4 (5)	3 (2)	0.341
Bleeding	0 (0)	4 (3)	0.101
Early thrombosis	1 (1)	3 (2)	0.541
HAIDI	5 (6)	7 (6)	0.892
• Grade 1	2	5	
• Grade 2a	2	-	
• Grade 2b	-	2	
• Grade 3	1	-	
• Grade 4a	-	-	
Long-term complications; n (%)			
Stenosis	19 (23)	31 (24)	0.765
Thrombosis	24 (29)	35 (24)	0.873
Pseudoaneurysm	5 (6)	3 (2)	0.181
Infection	9 (11)	9 (7)	0.356
HAIDI	0 (0)	3 (2)	0.156
• Grade 1	-	1	
• Grade 2a	-	1	
• Grade 4a	-	1	
Death; n (%)	7 (8)	21 (17)	0.086

HAIDI=hemodialysis access-induced distal ischemia; SD=standard deviation

HAIDI grade 1 and 2a were treated conservatively; grade 2b, 3, and 4a were managed with intervention

Operative time and postoperative complications were compared between groups (Table 2). AL-AVG had significantly longer operative time than AS-AVG, 15 minutes (95% CI 8 to 22, p<0.001). Postoperative complications included infection, bleeding, early thrombosis, and HAIDI, which were not significantly different between groups. All early graft infections were successfully treated conservatively with intravenous antibiotics.

Long-term complications were also not significantly different between groups (Table 2). Nine (11%) in the AL-AVG and nine (7%) in the AS-AVG had AVG infection that necessitated graft removal (p=0.356). Three (2%) of AS-AVG later developed HAIDI, while no cases of AL-AVG developed HAIDI later. These differences were not significant. Both groups showed no significant differences in mortality after the procedure. No death occurred related to AVG complications.

The severity of HAIDI was also not significantly different between groups (Table 2). For postoperative HAIDI, two of seven (29%) in AS-AVG were Grade 2b that needed intervention [one that had distal revascularization and interval ligation (DRIL), and one that had band ligation], and one of five (20%) in the AL-AVG developed HAIDI Grade 3a, which was managed by a DRIL procedure. The proportion of total HAIDI cases that need intervention between groups was not statistically different (p=0.541).

The primary patency of AL-AVG and AS-AVG was not significantly different, as demonstrated in Figure 1 (p=0.121). The multivariable Cox proportional hazard model, which adjusts for

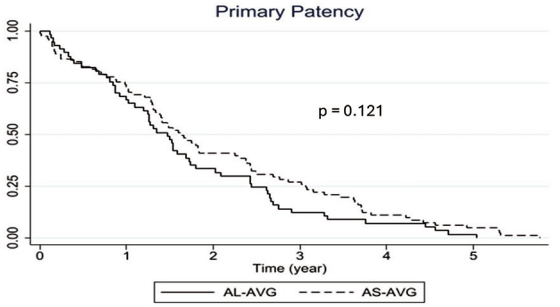

Figure 1. Primary patency rate between upper arm straight arteriovenous graft (AS-AVG) and upper arm loop arteriovenous graft (AL-AVG).

differences in sex proportions in the analysis, also demonstrated similar results (hazard ratio of 0.73, 95% CI 0.51 to 1.05, p=0.087) by using AL-AVG as a reference. Sex was also not significantly associated with primary patency (p=0.370). The one- and two-year primary patency rates were 67% (95% CI 53 to 77) and 33% (95% CI 22 to 46) for AL-AVG, and 73% (95% CI 62 to 81) and 41% (95% CI 30 to 51) for AS-AVG, respectively.

Discussion

The results of the present study demonstrated that primary patency in AS-AVG and AL-AVG were not significantly different. Moreover, postoperative and long-term graft complications and mortality did not differ significantly between groups. All deaths were unrelated to AVG complications. However, AL-AVG creation had longer operative times of about 15 minutes than AS-AVG. Sex was not associated with the patency and postoperative complications.

The findings presented align with previous studies indicating that the configuration of upper arm AVG is not significantly associated with graft patency[4,10]. However, they contrasted with the results of Khoshnev et al.[5], who reported a trend of higher primary patency of AL-AVG at 1-year follow-up (31% versus 55.5%, p=0.058) and significantly higher secondary patency of AL-AVG than AS-AVG at 2-year follow-up (37.9% versus 66.7%, p=0.044). The authors attributed the higher secondary patency to the longer AL graft lengths compared to AS.

However, the discrepancy in results may be influenced by differences in graft sizes (6 mm versus 8 mm) and diabetes prevalence (33% versus 14%) between the groups compared. The authors did not present secondary patency data in the present study because it did not accurately reflect the relationship between graft configuration and patency, primarily because most patients did not undergo interventions due to financial constraints. The primary patency of the patients was comparable to the results from the systematic review and meta-analysis of patency of PTFE AVG, which reported 41% (95% CI 35 to 47) at 1-year follow-up[11].

In the present study, the authors found that the incidence and severity of HAIDI did not differ between AS-AVG and AL-AVG. This contrasts with the findings of Kudlaty et al.[6], which indicated that clinically significant HAIDI occurred only in AVG with a straight configuration. The difference in results may be attributed to our case selection. The authors performed AS-AVG specifically in patients with a brachial artery diameter greater than 4 mm. This selection criterion may also have resulted in a significantly higher proportion of males in the AS-AVG group in the present study.

AL-AVG had 15 minutes longer operative time than AS-AVG, indicating greater procedural difficulty or complexity, with no difference in efficacy or safety between the two procedures. Therefore, both procedures were safe and effective. The choice remains dependent on anatomical suitability, individual patient factors, and surgeon preference, following the principle of the distal-to-proximal approach to preserve sites for future access creation as part of a succession plan.

There are limitations to this study. The study was a single-center, retrospective study that may have introduced selection bias and limited its generalizability. However, multivariable regression analysis was applied to reduce the possible confounding of unbalanced baseline characteristics on the outcome. In addition, the limited number of patients included might lead to low power to detect significant differences in results. Another possible bias was performance bias related to the surgeon's technique, judgment, and perioperative care, as only one surgeon performed a single type of operation.

Conclusion

AS-AVG and AL-AVG are both effective and safe procedures for hemodialysis patients, with no significant differences in patency or complications. Further study using a more rigorous methodology should be conducted to confirm the results. This conclusion specifically applies to patients with a cubital brachial artery diameter greater than 4 mm for AS-AVG, indicating that both graft types may be viable options for hemodialysis patients.

What is already known about this topic?

When considering AVGs for hemodialysis patients, both forearm and upper arm AVGs achieve similar patency rates when the anatomy is suitable. Therefore, forearm AVGs should be prioritized over upper arm AVGs to preserve future access options. Additionally, forearm AVGs with a loop configuration exhibit better patency compared to those with a straight configuration. However, the effectiveness of loop versus straight configurations in upper arm AVGs remains a topic of debate.

What does this study add?

This study demonstrated comparable patency between loop and straight configurations of upper arm AVG. Early postoperative complications and long-term complications, particularly HAIDI, were also non-significantly different between groups. However, the upper arm loop AVG configuration had a longer postoperative time than the straight configuration.

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Authors' contributions

ND contributed to the conception and design of the study, the acquisition of data, the data analysis and interpretation, the drafting of the manuscript, and the final approval of the version to be published. SO and TB contributed to the critical revision of the manuscript and final approval of the version to be published. BS contributed to the conception and design of the study, the acquisition of data, the data analysis and interpretation, the drafting of the manuscript, the revision of the manuscript, and the final approval of the version to be published. All authors have read and approved the final manuscript and agree to be accountable for all aspects of the work.

Data availability statement

The datasets of this article are available by manual requests to the corresponding author.

Ethics approval and consent to participate

This study was approved by the Ethics Committee of the Faculty of Medicine, Thammasat University (MTC-EC-SU-0-228/65), on January 20, 2023.

Clinical trial registration

The study was not registered to the clinical trial registry due to its retrospective nature.

Use of artificial intelligence

The study was done without any artificial intelligence.

Funding disclosure

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Conflicts of interest

The authors declare no conflict of interest.

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