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REVIEW

Lower-extremity Arteriovenous Access for Haemodialysis: A Systematic Review

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Abstract *Background:* The lower extremity is increasingly used as an access site in end-stage renal disease patients. However, reports present conflicting results, creating confusion regarding the feasibility and outcomes. Our objective is to review the available literature and analyse the patency rates and complications of various types of lower-extremity arteriovenous access.
Methods: An Internet-based literature search was performed using MEDLINE to identify all published reports on lower-extremity vascular access. The analysis involved studies comprising at least 10 arteriovenous accesses with both inflow and outflow vessels in the lower extremity, and reporting on patency rates and access-related complications. The weighted mean patency rates were calculated, and the chi-square (χ^2) test was used to evaluate the differences in the complication rates in the subgroups of patients identified.
Results: Three main types of lower-extremity vascular access were identified: the upper thigh prosthetic, the mid-thigh prosthetic and the femoral vein transposition arteriovenous access. There are limited data on saphenous vein loop grafts, which report poor results. The weighted mean primary patency rates at 12 months were 48%, 43% and 83%, respectively. The weighted mean secondary patency rates at 12 months were 69%, 67% and 93%, respectively. Access loss as a result of infection was more common in upper thigh and mid-thigh grafts than femoral vein transposition arteriovenous access (18.40%, 18.33% vs. 1.61%; $P < 0.05$). Ischaemic complications rates were higher in autologous than prosthetic arteriovenous access (20.97% vs. 7.18%, $P < 0.05$).
Conclusions: Lower-extremity vascular access has acceptable results in terms of patency, with femoral vein transposition having better patency rates than femoral grafts. Autologous access is associated with less infective complications, however, at the expense of increased ischaemic complications rates. Further research with randomised trials is required to assess the outcomes of lower-extremity vascular access.

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Permanent vascular access for haemodialysis is a key issue in the management of patients with chronic renal failure. Undoubtedly, the radial artery—cephalic vein arteriovenous fistula is the first procedure of choice for the incident end-stage renal disease patient, followed by secondary vascular accesses, such as proximal native fistulae or arteriovenous grafts in the upper extremities.[1] However, in the light of the ever increasing number of patients with end-stage renal disease, the ageing dialysis population and their prolonged longevity, surgeons are increasingly encountered with difficult access problems, such as exhausted upper extremity access sites and central venous outflow obstruction resulting from previous catheterisation. The constant evolution of angioaccess techniques in the presence of such circumstances has led to the development of arteriovenous access at different anatomic sites, such as the lower extremity. Femoral prosthetic arteriovenous access placed either in the upper thigh or in the mid-thigh in a loop configuration, as well as autogenous arteriovenous access using the transposed superficial femoral vein, have evolved as alternative access procedures in patients with difficult access problems. However, contradictory results in terms of outcome and complications, such as infection and steal syndrome, have been reported in the existing literature.

The purpose of this article was to systematically review and analyse the available literature regarding the surgical technique, patency rates and specific adverse events complicating lower-extremity vascular access, based on evidence derived from relevant studies.

Methods

Data sources and study selection. An Internet-based literature search was performed using the MEDLINE and SCOPUS electronic databases between January 1980 and January 2009. The literature search was confined to studies published in English. The keywords 'haemodialysis access', 'angioaccess', 'arteriovenous fistula', 'arteriovenous shunt surgical', and 'lower extremity', 'femoral' in all possible combinations were used to identify relevant abstracts. If there was any suggestion of the data looked for, the full texts of relevant articles were retrieved for further in-depth review. A second-level search included manual search of the reference lists of the retrieved articles. The literature search, study selection and data extraction were performed by two independent authors (GAA, MKL).

Studies were included in this review if the following criteria were fulfilled: (1) the study documented on the construction of either autologous or prosthetic arteriovenous haemodialysis access with both outflow and inflow vessels in the lower extremity, (2) the study comprised a series of at least 10 arteriovenous accesses placed in the lower extremity and (3) the study documented on the primary and/or secondary patency rates by using either life table or the Kaplan—Meier method, included the patients at risk and reported access-related complications.

Outcome measures and data abstraction. The primary outcome measures were primary and secondary patency rates, which were determined according to the reporting standards, set by the Committee of Reporting Standards for arteriovenous haemodialysis accesses.[2] Secondary outcome measures were special adverse events complicating lower-extremity haemodialysis access. The severity of arteriovenous access complications was graded according to the Reporting Standards document.[2]

Data abstracted (where available) from the individual studies were: study design, access configuration, number of patients and arteriovenous accesses created, patient demographic data, primary/secondary patency rates, access-related infection rate, grade of infection, access-related ischaemic complication and amputation rate, and other access-related complications. Data extraction was performed from the text, tables or graphs of the relevant studies.

Statistical analysis. Data retrieved from each relevant paper were entered into a purpose-designed database using SPSS® 15 for Windows® (SPSS Inc., Chicago, IL, USA). Data were aggregated and presented as means with ranges. The mean primary and secondary patency rates were averaged, weighting the data of each study by the number of arteriovenous access created. The mean patency values were calculated for 12 and 24 months following access construction. Values were calculated for these time periods, only if there were at least two studies to report for this time period. The chi-square (χ^2) test was used to evaluate the differences in the complication rates in the subgroups of patients identified. All statistical tests were two tailed, and a P value <0.05 was considered statistically significant. The relationship between the access configuration and complications was assessed using the odds ratio (ORs) and 95% confidence intervals (CI).

Results

Literature search results

The systematic review of the literature identified 32 papers with reference to outcome of lower-extremity vascular access. Seventeen articles were excluded from further analysis because either the inflow or outflow vessels were outside the lower extremity (the so-called exotic vascular procedures), they did not fulfill the preset criteria in terms of the size of the study series, or because of inadequate reported data.[3—19] Fifteen studies were entered into the final analysis, from which reliable data regarding primary and/or secondary patency rates and complications could be retrieved (Table 1).[20—34] The year of publication ranged from 1988 to 2006, with 67% of the studies published after 2000. Of these 15 studies, two were prospective, 10 retrospective, whereas the type of study was not reported in three papers. No randomised controlled trials comparing lower-extremity vascular access with that of upper extremity or the various configurations of lower-extremity vascular access (e.g., autologous and prosthetic) were identified.

Surgical technique of formation of lower extremity vascular access

Broadly divided, two types of lower-extremity vascular access were identified: the autologous and the prosthetic

Table 1 Study description and outcome

Author	Year	Type of study	Access configuration	Number of patients	Number of accesses	Age
Englesbe et al.[20]	2006	Retrospective	Upper thigh prosthetic AV access	30	30	48 (mean)
Scott et al.[21]	2006	Retrospective	Mid-thigh prosthetic AV access	38	46	57 (mean)
Cull et al.[22]	2004	Retrospective	Upper thigh prosthetic AV access	91	116	58 (median)
Hazinedaroğlu et al.[23]	2004	Prospective	Upper thigh prosthetic AV access	15	17	61 (mean)
			Femoral vein transposition	15	15	56 (mean)
Gradman et al.[24]	2004	NR	Femoral vein transposition	22	22	48 (mean)
Miller et al.[25]	2003	Prospective	Upper thigh prosthetic AV access	NR	63	NR
Flarup et al.[26]	2003	NR	Mid-thigh prosthetic AV access	11	14	56 (median)
Tashjian et al.[27]	2002	Retrospective	Upper thigh prosthetic AV access	73	73	62 (mean)
Gradman et al.[28]	2001	Retrospective	Femoral vein transposition	25	25[a]	55 (mean)
Vogel et al.[29]	2000	Retrospective	Upper thigh prosthetic AV access	134	134[b]	56 (mean)
Korzets et al.[30]	1998	Retrospective	Upper thigh prosthetic AV access	35	37	55 (mean)
Khadra et al.[31]	1996	Retrospective	Upper thigh prosthetic AV access	61	74	50 (mean)
Taylor et al.[32]	1996	Retrospective	Upper thigh prosthetic AV access	39	45[c]	58 (mean)
Bhandari et al.[33]	1995	Retrospective	Upper thigh prosthetic AV access	46	49	49 (mean)
Slater et al.[34]	1988	NR	Upper thigh prosthetic AV access	21	22	50 (mean)

Males (%)	Diabetes (%)	Obesity (%)	Primary patency	Secondary patency	Grade 2 infection rate (%)	Ischaemic complication rate (%)	Amputation rate (%)
43	33	50[d]	NR	41 (12m)/26 (24m)	27	3[f]	7
42	36	NR	40 (12m)/18 (24m)	68 (12m)/43 (24m)	21	13	NR
37	44	27[e]	34 (12m)/19 (24m)	68 (12m)/54 (24m)	41	11	9
27	0	NR	38 (12m)/25 (24m)	NR	24	18	0
13	0	NR	87 (12m)	NR	7	33	0
55	32	NR	93 (12m)/85 (24m)	100 (12m)/94 (24m)	0	0	0
43	31	NR	NR	62 (12m)/39 (24m)	11	0	0
55	9	NR	54 (12m)/18 (24m)	64 (12m)/18 (24m)	7	0	0
44	NR	NR	71 (12m)/63 (24m)	83 (12m)/83 (24m)	NS	1	1
28	60	56[e]	73 (12m)	86 (12m)	0	32	4
60	19	NR	NR	62 (12m)	10	NR	NR
40	23	NR	NR	73 (12m)/65 (24m)	3	11	3
34	NR	NR	NR	77 (12m)/62 (24m)	14	3	1
41	NR	NR	52 (12m)/47 (24m)	NR	11	16	7
52	NR	NR	NR	85 (12m)/82 (24m)	NS	NR	NR
NR	NR	NR	NR	81 (24m)	9	NR	NR

NR, not reported; NS, not specified; m, months.
[a] 7 composite prosthetic-transposed SFV fistulae.
[b] 126 loop, 8 cross-femoral.
[c] 39 PTFE, 6 bovine.
[d] BMI > 40.
[e] BMI > 30.
[f] Perioperative only.

arteriovenous fistulae. The latter may be further subdivided into two types according to the site of the prosthetic graft. In the upper thigh prosthetic arteriovenous access, a polytetrafluoroethylene (PTFE) graft is interposed between the common femoral or superficial femoral artery and the common femoral, superficial femoral or long saphenous vein, and is placed in a loop configuration in the subcutaneous plane of the anterior aspect of the thigh.[31] A modification of this technique is placement of the graft along a subcutaneous loop channel over the anterior mid-thigh region just proximal to the patella, and anastomosing it to the superficial femoral artery and vein just proximal to the adductor canal.[14] Suprapubic cross-over femoro-femoral arteriovenous graft to the contralateral femoral vein has also been described.[29] The autogenous lower-extremity arteriovenous fistula is based on the construction of the transposed superficial femoral/popliteal vein in a similar configuration to the transposed basilic vein; the vein is mobilised from the knee joint to its junction to the common femoral vein, divided distally and anastomosed to the superficial femoral artery just proximal to the adductor hiatus, after having been placed in a subcutaneous tunnel over the anterior thigh, lateral to the skin incision.[13] Construction of a loop-composite PTFE-transposed superficial femoral vein has also been used when the aforementioned configuration is not feasible.[28] Furthermore, another type of autogenous lower extremity arteriovenous fistula is the saphenous vein loop arteriovenous fistula. In this form of vascular access, the greater saphenous vein is mobilised, ligated distally (usually at the level of the knee joint), placed in a loop subcutaneous tunnel over the anterior aspect of the thigh and anastomosed to the common femoral artery.[16] Of our selected papers for further analysis, 11 studies examined patients having undergone upper thigh prosthetic arteriovenous access,[20,22,23,25,27,29–34] two studies reported on mid-thigh loop arteriovenous grafts[21,26] and another three papers documented their experience with transposed superficial femoral vein.[24,23,28] Articles reporting on the saphenous vein loop fistula included limited numbers of accesses with inadequate data and, therefore, could not be entered in the analysis.[16–19] One paper prospectively evaluated upper thigh arteriovenous graft versus transposed superficial femoral vein.[23]

Outcome-patency rates

The total number of arteriovenous accesses created in the lower extremity was 782; of these, 660 were upper-thigh arteriovenous grafts, 60 were mid-thigh grafts and 62 were femoral vein transposition arteriovenous fistulae. The patients' demographic characteristics are shown in Table 1. It is evident that many of the studies failed to provide adequate data regarding patient demographics.

For all types of lower-extremity arteriovenous access, the primary patency rates at 12 months ranged between 34% and 93%, with a weighted mean of 53%; the primary patency rates at 24 months ranged between 18% and 85%, with a weighted mean of 37%. Similarly, the secondary patency rates at 12 months ranged between 41% and 100%, with a weighted mean of 71%, whereas the secondary patency rates at 24 months ranged between 18% and 94%, with a weighted mean of 60% (Table 2). The corresponding weighted mean patency rates calculated separately for upper-thigh prosthetic, mid-thigh prosthetic and transposed femoral vein arteriovenous accesses are presented in Table 2. It is evident that the 12-month patency rates of femoral vein transposition arteriovenous fistulae are better than those of both upper- and mid-thigh grafts, with weighted mean primary patency rates of 83% versus 48% and 43%, respectively, and weighted mean secondary patency rates of 93% versus 69% and 67%, respectively.

Specific adverse events complicating lower-extremity vascular access

The most commonly encountered complications associated with lower-extremity arteriovenous access were infection and distal limb ischaemia secondary to steal syndrome (Table 1). Other less frequently reported complications were aneurysmal dilatation—pseudoaneurysm, venous hypertension, congestive cardiac failure, lymphocoele and seroma formation.

The most feared complication, particularly associated with prosthetic arteriovenous access construction in the lower extremity, is infection. Because the reported outcomes with regard to infection were conflicting, and in an effort to enable meaningful comparisons between studies, recommended standards for reports dealing with arteriovenous haemodialysis access were used to grade severity of infection.[2] Therefore, all infections reported to have been managed with non-operative means were classified as grade 1, whereas infections resulting in loss of the arteriovenous access were classified as grade 2. Our analysis found that access loss as a result of infection tended to be more common in upper-thigh and mid-thigh grafts than femoral vein transposition arteriovenous access, which reached statistical significance (18.40%, 18.33% versus 1.61%; $P < 0.05$) (Table 3). No difference between upper- and mid-thigh arteriovenous grafts was found with regard to infection (Table 3). Furthermore, when calculated for the total number of prosthetic and autologous arteriovenous access, infection rates were higher in the former group at a statistical significance (18.39% versus 1.61%, $P < 0.05$) (Table 3). No limb loss (grade 3 infection) resulting from access-related infection has been reported. Infection-related death has been reported by one study only, reporting a rate of 4%.[22]

Steal syndrome resulting in limb ischaemia was also a commonly described complication associated with lower-extremity vascular access construction, especially in elderly, diabetic patients with long-standing end-stage renal disease. However, some studies failed to provide adequate data regarding the severity of steal syndrome, thus complicating the grading process. Ischaemic complications rates were found to be higher in femoral vein transposition as compared with prosthetic arteriovenous grafts (20.97% vs. 7.18%, $P < 0.05$) (Table 3), whereas no statistically significant difference was found between upper and mid-thigh prosthetic arteriovenous access (6.81% vs. 10.00%, $P = 0.397$) (Table 3). The amputation rate as a result of lower-extremity arteriovenous access creation ranged between 0% and 7% (Table 1).

Table 2 Weighted mean patency rates

Access configuration	Upper thigh prosthetic AV access		Mid-thigh prosthetic AV access		Femoral vein transposition		Total lower extremity AV access	
Treatment time (months)	12	24	12	24	12	24	12	24
Number of papers (references)	4 (22, 23, 27, 32)	4 (22, 23, 27, 32)	2 (21, 26)	2 (21, 26)	3 (23, 24, 28)		9 (21, 22, 23, 24, 25, 26, 27, 28, 32)	7 (21, 22, 23, 24, 26, 27, 32)
Number of accesses	251	251	60	60	62		373	333
PP	48	37	43	18	83	—	53	37
Number of papers (references)	8 (20, 22, 25, 27, 29, 30, 31, 33)	8 (20, 22, 25, 27, 30, 31, 33, 34)	2 (21, 26)	2 (21, 26)	3 (23, 24, 28)		12 (20, 21, 22, 24, 25, 26, 27, 28, 29, 30, 31, 33)	11 (20, 21, 22, 24, 25, 26, 27, 30, 31, 33, 34)
Number of accesses	576	464	60	60	47		683	546
SP	69	61	67	37	93	—	71	60

PP, primary patency; SP, secondary patency.

Discussion

A steady increase in the number and age of patients undergoing chronic haemodialysis has emphasised the need to evaluate potential alternate access sites to maintain long-term vascular access. The lower extremity is increasingly used as an access site in end-stage renal disease patients. However, reports on several types of lower-extremity arteriovenous access present conflicting results, thus creating confusion regarding the indications, feasibility and outcomes. Our attempt was to perform an analysis of the available literature in order to shed light onto these aspects of lower-extremity vascular access.

The search of the pertinent literature often detected retrospective case series, with only one prospective comparative study of lower versus upper extremity and another one of upper-thigh prosthetic versus femoral vein transposition arteriovenous access having been identified.[25,23] No randomised controlled trials exist comparing various types of lower-extremity arteriovenous access or upper- and lower-extremity arteriovenous access. The latter undertaking might possibly be performed only in selected groups of end-stage renal disease patients. The majority of the authors of the reviewed papers converge on the fact that vascular access in the lower extremities should only be attempted in selected patients, when all other access sites in the upper extremities have been exhausted, there is severe pathology in the central vein trunks, and, possibly, in patients who are not suitable candidates for peritoneal dialysis. Nevertheless, some authors used patient's preference as one of the criteria for lower-extremity arteriovenous access construction, since it allows two-handed self-cannulation, leaves both hands free during dialysis and provides a better cosmetic appearance, especially for young women with the dialysis site hidden under their skirts.[31,33]

Table 3 Complication rates in prosthetic arteriovenous access

	Upper thigh prosthetic AV access	Mid-thigh prosthetic AV access	*P* value	OR (95% CI)
Infection[a]	99/538 (18.40%)	11/60 (18.33%)	0.990	0.995 (0.500—1.983)
Steal	31/455 (6.81%)	6/60 (10.00%)	0.397	1.484 (0.592—3.720)
	Upper thigh prosthetic AV access	Femoral vein transposition	*P* value	OR (95% CI)
Infection[a]	99/538 (18.40%)	1/62 (1.61%)	0.001	0.073 (0.010—0.531)
Steal	31/455 (6.81%)	13/62 (20.97%)	0.000	3.543 (1.738—7.222)
	Mid-thigh prosthetic AV access	Femoral vein transposition	*P* value	OR (95% CI)
Infection[a]	11/60 (18.33%)	1/62 (1.61%)	0.002	0.073 (0.009—0.585)
Steal	6/60 (10.00%)	13/62 (20.97%)	0.095	2.388 (0.842—6.767)
	Prosthetic	Autologous	*P* value	OR (95% CI)
Infection[a]	110/598 (18.39%)	1/62 (1.61%)	0.001	0.073 (0.010—0.530)
Steal	37/515 (7.18%)	13/62 (20.97%)	0.000	3.427 (1.707—6.881)

[a] Grade 2 infection.

Our analysis has found that autologous femoral vein transposition arteriovenous fistula has better primary and secondary patencies as compared with upper- and mid-thigh prosthetic arteriovenous accesses. This finding consolidates the results of the only existing prospective study comparing upper-thigh prosthetic and femoral vein transposition arteriovenous fistula in a non-randomised fashion.[23] Furthermore, from the existing literature, it appears that the outcomes of lower-extremity arteriovenous access are not significantly inferior to upper-extremity vascular access, with femoral vein transposition presenting comparable or even better results in terms of patency.[25,35,36] Besides, one should take into consideration that the dialysis population of the studies reporting on lower-extremity vascular access is possibly different than upper-extremity dialysis patients, with the former being on longer-term haemodialysis with exhausted upper-extremity access sites, of older age and, possibly, with more co-morbidities. However, to draw definite conclusions, further comparative studies with larger numbers of accesses and longer follow-up are required.

The most prohibitive reported shortcomings associated with lower-extremity vascular access are infection and ischaemic complications. The main concern of placing a prosthetic material for vascular access in proximity to the groin is reported by most authors. In an attempt to avoid placement of a prosthetic material in the potentially contaminated area of the groin and preserve proximal femoral vessels for later use, the upper-thigh loop technique was further modified by placing the graft along a subcutaneous loop channel over the anterior mid-thigh region, increasing the distance to the groin and the urogenital area.[14,21,26] However, our analysis revealed no difference in infection rates between the upper- and the mid-thigh groups of arteriovenous access. Several authors have also proposed the autologous transposed superficial femoral vein transposition in order to avoid infectious complications associated with prosthetic access.[11–13] In the present analysis, infection tended to be more common in upper-, mid-thigh and the overall prosthetic than autologous lower-extremity arteriovenous access. In addition, several preventive measures have been proposed to keep infection rates at low levels, including perioperative prophylactic antibiotics and meticulous attention to aseptic technique at the time of cannulation.[30,31,37]

Lower limb ischaemia resulting from access-related arterial steal is another dreaded complication, particularly likely to occur in diabetic patients with generalised arterial occlusive disease. It seems that the advantage of autologous lower-extremity arteriovenous access in terms of infection is offset by the high ischaemic complication rates compared with prosthetic arteriovenous grafts. The reported incidence of ischaemic complications resulting from lower-extremity vascular access construction seems to be higher than the reported rates in the upper-extremity proximal arteriovenous accesses.[38,39] It has been suggested that preoperative screening for peripheral arterial disease with a detailed clinical evaluation and duplex ultrasound scanning and/or arteriography, when required, be performed in all patients scheduled for lower-extremity vascular access construction.[25,28,30] Gradman et al. in their initial report had a high incidence of ischaemic limb complications, whereas after carefully selecting patients and selectively performing femoral vein tapering, the incidence of this complication declined.[24] It seems that in non-diabetic young patients without evidence of peripheral arterial disease, the femoral vein transposition arteriovenous fistula should be possibly preferred. Management of steal syndrome resulting in distal lower limb ischaemia consisted of either closure ligation of the access or arterial reconstruction and amputation. Venous hypertension is a less frequently described complication, usually resulting from previous undetected venous outflow obstruction, which may be managed with endovenous means.[40]

There is limited evidence in the literature with regard to the saphenous vein loop on the thigh as an alternative lower-extremity arteriovenous access.[16–19] These studies are limited by the small numbers of accesses, which excluded them from the present analysis. All of these studies report dismal results, especially in terms of complication rates. The most recent study documented a functional fistula for haemodialysis in 71.4% (five out of seven accesses constructed). Furthermore, all patients developed stenoses in the loop of the arteriovenous fistula, treated with either angioplasty or open surgery. An earliest report with a larger series of patients demonstrated that the saphenous vein loop to the femoral artery arteriovenous fistula had worse primary patency rates and a higher pseudoaneurysm rate than forearm fistulae.[41] It seems that the use of the saphenous vein loop arteriovenous fistula in the thigh is not a satisfactory solution for long-term haemodialysis.

In the interpretation of the results of the present analysis, one should take into consideration that relatively low numbers of mid-thigh prosthetic and femoral vein transposition arteriovenous access as compared to upper-thigh prosthetic vascular access were included in the analysis. Our literature search identified two studies only reporting on the mid-thigh prosthetic loop grafts fulfilling our selection criteria, and another three studies reporting on autologous femoral vein transposition. Furthermore, these reports come from centres having a special interest in these difficult-access patients, which means that their results may not be applicable to all units. Referral of such difficult vascular access haemodialysis patients to specialist centres might be required to achieve comparable results and provide patients with the best possible care.

Conclusions

Lower-extremity vascular access is increasingly used as an alternative access site in patients unsuitable for upper-extremity arteriovenous access creation. Our review has shown that it has acceptable results in terms of patency, with femoral vein transposition having better patency rates than femoral grafts. Autologous access was also found to be associated with less infective complications compared with prosthetic arteriovenous access, however, at the expense of increased ischaemic complications rates. It seems that the type of lower-extremity vascular access should be chosen, taking into account the patient's co-morbidities, such as peripheral arterial disease, and their immunological status. However, because of the retrospective nature of most of the studies included in this systematic review and the great

variability in the reporting outcomes, our results should be approached with caution. Further research with randomised controlled trials is required to consolidate our results.

Conflict of Interest

None.

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None.

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