Three Year Patency and Recurrence Rates of Revision Using Distal Inflow with a Venous Interposition Graft for High Flow Brachial Artery Based Arteriovenous Fistula

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Three Year Patency and Recurrence Rates of Revision Using Distal Inflow with a Venous Interposition Graft for High Flow Brachial Artery Based Arteriovenous Fistula

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WHAT THIS PAPER ADDS

To the authors' knowledge, this study is the first to report on mid-term patency and recurrence rates of the revision using distal inflow (RUDI) technique using a greater saphenous vein interposition graft in a homogenous group of haemodialysis patients with a high flow brachial-artery based arteriovenous fistula. Results suggest that a RUDI offers fairly good 3 year patency rates although re-interventions are often required. Furthermore, recurrence of high flow after RUDI is common as up to 50% develop flows >2 L/min within 3 years. High post-operative access flows predict recurrence.

Objectives: Upper arm arteriovenous fistulas (AVF) occasionally develop high flow. Revision using distal inflow (RUDI) effectively reduces flow of high flow accesses (HFA) in the short-term and is also popularised for treatment of haemodialysis access induced distal ischaemia (HAIDI). The long-term efficacy is unknown. The study's aim was to report on 3 year RUDI patency and recurrence rates for HFA with and without HAIDI.
Material and methods: This was a retrospective cohort study of patients with a HFA with or without HAIDI undergoing RUDI using greater saphenous vein (GSV) interposition between March 2011 and October 2017 at three facilities. AVFs were termed HFA if flow volumes exceeded 2 L/min on two consecutive measurements using dilution techniques. HAIDI was diagnosed as recommended. Following RUDI, follow up was not different from standard care in AVF patients. Data on post-operative flows and re-interventions were extracted from electronic patient files. Loss to follow up was avoided. Rates of patency and HFA recurrence were analysed.
Results: During the observation period, 21 patients were studied (7 females, 54 years ± 3). Fourteen had uncomplicated HFA whereas seven had additional HAIDI. Immediately post-operatively, flows decreased threefold (3120 mL/min ± 171 vs. 1170 mL/min ± 87, $p < .001$). Overall 3 year primary patency was 48% ± 12 (HFA, 55% ± 15 vs. HAIDI/HFA, 29% ± 17, $p = .042$). Secondary patency was identical in both groups (overall, 84% ± 9). Interventions were percutaneous transluminal angioplasty ($n = 12$, 9 patients), thrombectomy ($n = 7$, 3 patients), and revision with new interposition grafts ($n = 3$). After 3 years, 51% ± 12 were free of high flow (HFA, 32% ± 13 vs. HAIDI/HFA, 100%, $p = .018$). High immediate post-operative access flow predicted recurrence (OR 1.004 [1.000–1.007], $p = .044$). Patients with recurrence were 12 years younger than those without ($p = .055$).
Conclusion: RUDI with GSV interposition for HFA offers acceptable patency rates after 3 years although re-interventions are often required. High immediate post-operative flows and young age are associated with recurrent high flow.

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INTRODUCTION

Up to 4% of an average haemodialysis (HD) population with autologous arteriovenous fistulas (AVFs) develop a high flow access (HFA, >2 L/min) over time. Furthermore, haemodialysis access induced distal ischaemia (HAIDI) is not infrequent

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in the presence of a HFA.[1] Considering the ongoing shift from radial to brachial artery based AVFs, HFA incidence is expected to rise as elbow based accesses are associated with increased risk of unacceptably high flows compared with accesses originating from smaller calibre forearm arteries.[2–5] It is thought that HFAs often remain asymptomatic.[6] However, increasing evidence shows that HFAs may contribute to heart failure development in HD patients.[6–8] If flow reduction is indicated, various surgical procedures are available. In distal radial artery based HFAs, proximal radial artery ligation (PRAL) might be considered.[9] In contrast, brachial artery based HFAs may undergo venous outflow banding, effectively decreasing flow in the short term.[10] Although median-term results demonstrated recurrent high flow in up to half of the banded patients within 1 year.[11,12]

An alternative method for flow reduction is termed revision using distal inflow (RUDI). This approach has been popularised for treating both HFA and HAIDI in brachial artery based AVFs.[13] During RUDI, an interposition graft, for example greater saphenous vein (GSV) or polytetrafluorethylene (PTFE), anastomosed to a forearm artery reduces access flow.[14] RUDI effectively reduced flow after 1 year follow up, unless a basilic vein interposition graft was used.[15] Long-term efficacy and patency are unknown. The present study aimed to report on 3 year RUDI patency and recurrence rates for HFA with or without HAIDI using GSV interposition.

MATERIAL AND METHODS

Patients undergoing RUDI using GSV for a HFA in the upper arm with or without HAIDI in three Dutch hospitals (Máxima Medical Centre, MMC, Veldhoven; Maastricht University Medical Centre, Maastricht; Radboud University Medical Centre, Nijmegen) between March 2011 and October 2017 were studied, retrospectively. One year results of some of the patients who underwent RUDI using different interposition grafts ($n = 13$) have been published previously.[15] In the present cohort, RUDI was performed for three types of upper arm HFAs (brachiocephalic, BC-AVF; brachiobasilic, BB-AVF; Gracz-AVF).

Patients were included if they had a brachial artery based AVF for HD with access flows exceeding 2 L/min on at least two consecutive measurements (or >1.5 L/min with overt signs of venous congestion or cardiac failure), and if they had received RUDI using GSV interposition. Exclusion criteria were RUDI using non-venous interposition grafts, or radial artery transposition for HFA.

Each HFA patient was additionally screened for signs of concomitant ipsilateral hand ischaemia. An outpatient history and physical examination were performed, including hand inspection and palpation of the radial and ulnar artery. When the presence of hand ischaemia was likely, finger plethysmography was conducted (Vasoguard Nicolet 8 MHz, Scimet, Bristol, UK). HAIDI was diagnosed when one or more of the characteristic complaints (coldness, pain, cramps, loss of sensibility, diminished strength)[16,17] were reported and when the digital brachial index (DBI; ratio finger pressure to systemic pressure) was < 0.6.[17–19] Unreliable DBI values from incompressible arteries were omitted. Hand ischaemia was considered reversible (thus amendable to treatment) when access compression increased radial artery pulsations, and DBI values breached the ischaemic threshold (DBI > 0.6).[20] HAIDI was graded by analogy to the Fontaine classification as proposed in a recent consensus meeting.[21,22]

In one hospital (MMC), patients completed a hand ischaemic questionnaire (HIQ). This questionnaire scores severity (0, none — 10, extreme) and frequency (0, never — 10, always) of the five cardinal symptoms of hand ischaemia on a visual analogue scale. Subsequently, frequency and severity score per item are multiplied after which the five numbers are added up. Overall HIQ scores range from 0 (no symptoms associated with hand ischaemia) to 500 (maximal symptoms). HAIDI patients often score >100 points whereas HIQ scores are <50 in average HD populations without ischaemia.[23] Additional studies indicated that HIQ scores reflected the grade of ischaemia and effectiveness of surgical HAIDI revision.[10,24–26] In the present study, mean HIQ scores per group (HFA vs. HAIDI/HFA) were calculated after the diagnosis of HAIDI was confirmed or rejected by physical examination, medical history, and DBI measurements.

Each HFA patient was discussed in a multidisciplinary meeting with a nephrologist, vascular laboratory technician, vascular surgeon, radiologist, and access nurses. When required, a cardiologist was consulted. Once the team decided on performing RUDI, patients were informed of the procedure's specifics and consented verbally and in writing. The MMCs' ethics committee deemed that evaluation of the protocol was unnecessary as the study's aim was auditing of surgical results.

Operative protocol

GSV suitability was determined pre-operatively using Duplex analysis (diameter >3 mm). RUDI was essentially performed as previously described.[14] Patients underwent surgery in a day care setting under general anaesthesia. The AVF's venous portion on the upper arm was dissected close to the elbow anastomosis. A portion of the radial or ulnar artery in the proximal forearm was identified through a separate 5 cm longitudinal incision. A 5—10 cm segment of the upper leg GSV was harvested. Some 2—4 cm downstream from the brachial artery anastomosis, the venous portion of the AVF was transected. The venous stump on the brachial artery's side was ligated using 5/0 Prolene. The GSV was subsequently tunnelled as an interposition graft between the radial (or ulnar) artery (end to side, 6/0 or 7/0 Prolene) and the upper arm access vein (end to end or end to side, 5/0 Prolene). The distance between the newly constructed arteriovenous anastomosis and the brachial artery bifurcation was approximately 4—6 cm.

Data collection, definitions, statistical analysis

Two groups of HFA patients were identified. The HFA group demonstrated access flows >2 L/min without evidence of concomitant hand ischaemia. Conversely, the HAIDI/HFA group showed subjective signs of hand ischaemia with a DBI <0.6 in the presence of flows >2 L/min.

Data on demographics, initial AVF type, surgery associated complications, access flows, and re-interventions were obtained from local electronic patient files (EZIS 5.2, ChipSoft B.V., Amsterdam, The Netherlands; SAP 7.30, SAP SE, Walldorf, Germany; EPIC Hyperspace 2017, Epic Systems Corporation, Verona, USA; Diamant, Diasoft B.V., Leusden, The Netherlands; ProDB, MedVision Ag., Unna, Germany). This approach may have introduced selection bias as patients who refused RUDI or who were considered unfit for surgery because of additional comorbidity were not studied.

Standard post-operative follow up (FU) was performed at the dialysis facilities by serial flow measurements (HD03, Transonic Systems IN, New York, USA) every 4–6 weeks as indicated by KDOQI.[27] Patients were discussed in weekly multidisciplinary meetings as dictated by possible complications such as substantial changes in access flows or for patient complaints. If required, duplex sonography (e.g. for decreased flow) or angiography (if stenosis was likely) was performed or the patient was invited to visit the outpatient vascular department. Essentially, FU in RUDI patients was identical to standard AVF care.

To estimate potential loss to FU possibly introducing attrition bias, a follow up index (FUI) was calculated following recent recommendations.[28] A complete FU period lasted for 3 years. RUDI status was determined at the end of October 2017. FU was terminated 3 years after RUDI surgery or following secondary patency failure, death, AVF ligation, or at October 31, 2017. Patients who had moved to another dialysis facility within the observation period were contacted and asked for permission to obtain data. Access flows shown as >4 L/min (maximum of HD03 Transonic System) were scored as such.

Primary, assisted and secondary patency rates were defined as recommended.[29] An access was deemed "recurrent HFA" when two consecutive flow measurements were >2 L/min. Time to recurrence was defined as number of weeks between RUDI and the first of two high flow measurements.

Statistical analyses were performed using SPSS version 24.0 (SPSS Inc., Chicago, IL, USA). Parameters were tested for normality and expressed as mean ± standard error of the mean (SEM). Survival was determined using Kaplan–Meier analysis and differences were analysed using Log–Rank Mantel–Cox test. Group differences were determined using Mann–Whitney *U* test. Wilcoxon Log–Rank test was used for paired comparisons. Kruskal–Wallis was used for multiple group comparisons. Using binary logistic regression, possible predictors of recurrent high flow (recurrence yes/no) were identified. Proportions were compared using Fisher Exact test and risk was expressed as odds ratio (OR) [95 CI]. A p value $< .05$ was deemed significant.

RESULTS

Each of the three facilities accommodates between 85 and 110 chronic HD patients and performs 100–200 access related operations annually. During the observation period, 29 RUDI procedures were conducted. Eight patients were excluded (interposition of PTFE, $n = 2$ or cephalic vein, $n = 1$; radial artery transposition, $n = 3$; HFA used for total parenteral nutrition, $n = 1$; HAIDI with flow < 2 L/min, $n = 1$). Prior to RUDI, six patients had undergone unsuccessful revision for HFA or HAIDI (banding, $n = 3$; side branch ligation, $n = 3$).

The study population thus consisted of 21 patients undergoing RUDI using a GSV interposition graft (7 females, mean age 54 years ± 3; Table 1). Nineteen patients had flows >2 L/min whereas two had flows >1.5 L/min in presence of venous congestion. All but one were on HD > 3 months, whereas one patient was in pre-dialysis stage. Prior to RUDI, access flows of BC-AVF ($n = 8$, 3230 mL/min ± 363), BB-AVF ($n = 6$, 3130 mL/min ± 299) and Gracz-AVF ($n = 7$, 2970 mL/min ± 215) did not differ ($p = .61$).

Fourteen patients had access flows >2 L/min without signs of HAIDI, whereas seven had concomitant hand ischaemia. Following AVF compression, DBI values of the HAIDI/HFA group breached the ischaemic threshold in all (DBI_{open} .48 ± .04 vs. $DBI_{compressed}$ .96 ± .07, $p = .028$; $n = 6$, incompressible arteries $n = 1$). Furthermore, the HFA group displayed lower HIQ scores compared with the HAIDI/HFA group (HIQ_{HFA} 27 ± 14, $n = 8$ vs. $HIQ_{HAIDI/HFA}$ 115 ± 30, $n = 7$, $p = .015$). Age, gender, comorbidity rates, initial AVF type or time between initial AVF construction and RUDI were similar (Table 1).

Table 1. Demographics of patients undergoing revision using distal inflow (RUDI) for high flow access (HFA) alone or in combination with haemodialysis access induced distal ischaemia (HAIDI/HFA).

	Overall ($n = 21$)	HFA ($n = 14$)	HAIDI/HFA ($n = 7$)	p value
Age (years, mean ± SEM)	54 ± 3	50 ± 4	58 ± 6	.30
Gender (male/female)	14/7	10/4	4/3	.64
Diabetes mellitus (%)	2 (10)	1 (7)	1 (17)	1.00
Peripheral arterial occlusive disease (%)	1 (5)	0 (0)	1 (14)	.33
Hypertension (%)	11 (52)	7 (50)	4 (57)	1.00
Coronary artery disease (%)	5 (24)	3 (21)	2 (29)	1.00
Type of AVF (BC/BB/Gracz)	8/6/7	7/4/3	1/2/4	N.A.
Time between AVF construction and RUDI (months, mean ± SEM)	44 ± 12	44 ± 11	43 ± 30	.25
HAIDI grade (2a/2b/3/4)	N.A.	N.A.	4/2/1/0	N.A.

SEM = standard error or the mean; AVF = arteriovenous fistula; BC = brachiocephalic; BB = brachiobasilic; Gracz = outflow via both cephalic and basilic vein; N.A. = not applicable.

In total, 15 patients (71%) reported complaints possibly associated with the HFA (e.g. throbbing headaches with palpitations, exertional dyspnoea, hand ischaemia). Echocardiography was performed in seven of these. Only one patient with very mild symptoms showed dilated atria and decreased left ventricular ejection fraction (40%), possibly related to cardiac overload because of the AVF. Additionally, five showed evidence of left ventricular hypertrophy.

RUDI configurations (artery-vein) were radio-cephalic ($n = 12$), radio-basilic ($n = 5$), ulnar-cephalic ($n = 2$), ulnar-basilic ($n = 1$), and brachial-cephalic ($n = 1$). Immediately post-operatively, flows were 2 L/min lower (3120 mL/min ± 186 vs. 1170 ± 87 mL/min, $p < .001$). Both pre- and post-operative flows in the HFA group were higher than in the HAIDI/HFA group ($p < .05$; Fig. 1).

Three accesses (14%) occluded in the first post-operative week. Two were successfully revised using the GSV of the contralateral leg and by thrombectomy, respectively. The third was abandoned. Two others developed a haematoma at the GSV donor site that healed conservatively. Wound infection or skin necrosis were absent. All patients were able to resume HD without temporary indwelling lines. One month after RUDI, one aneurysm of a venous stump was excised.

Overall primary patency rates after 1, 2, and 3 years were 71% ± 10, 54% ± 11, and 48% ± 12, respectively. Rates differed between the HFA group (93% ± 7, 67% ± 14, and 55% ± 15) and the HAIDI/HFA group (29% ± 17 at each time point, $p = .042$; Fig. 2A). 1, 2, and 3 year assisted patency rates were 76% ± 9, 71% ± 10, and 71% ± 10, and differed between groups (HFA 100%, 92% ± 8, and 92% ± 8 vs. HAIDI/HFA 29% ± 17, 29% ± 17, and 29% ± 17, $p < .001$).

Secondary patency rates (overall 95% ± 5, 90% ± 7, and 84% ± 9) were similar (Fig. 2B). During 12 angiograms in nine patients, 16 percutaneous transluminal angioplasties (PTA) of significant stenotic lesions were performed. Half of these were found in the GSV interposition conduit without involvement of either one of the two anastomoses (Fig. 3). Furthermore, three patients underwent seven thrombectomies. In two of these, the GSV was replaced by PTFE interposition during follow up. Patients in the HFA group had similar risks of undergoing PTA (HFA 5/14 vs. HAIDI/HFA 4/7; OR .42 [.07–2.66], $p = .397$) or thrombectomy (HFA 1/14 vs. HAIDI/HFA 2/7 OR .19 [.01–2.62], $p = .247$) compared with the HAIDI/HFA group.

Recurrence free survival over 3 years (overall 70% ± 10, 58% ± 12, and 51% ± 12) differed among both groups. The HFA group showed rates of 56% ± 14, 40% ± 14, and 32% ± 13 while no patient in the HAIDI/HFA group developed recurrent high flow ($p = .018$; Fig. 2C). After 28 ± 2 months of FU, flows were 1400 mL/min lower compared with pre-operative values ($p < .001$) but > 500 mL/min higher than immediately post-operatively ($p = .021$; Fig. 2D). Seven of nine patients with a recurrence were asymptomatic, whereas the eighth patient developed severe cardiac failure following myocardial infarction. This patient chose to cease HD. The ninth patient with initial flows >4 L/min, high post-operative flow, and an early recurrence suffered from cardiac failure. His AVF was ligated but cardiac complaints did not diminish. Gender, initial AVF type, and comorbidities did not influence patency or recurrence of high flow (data not shown).

Patients with a recurrence demonstrated higher immediate post-operative access flows (1390 mL/min ± 114 vs. 980 mL/min ± 95, $p = .016$) and were 12 years younger than the non-recurrence group (46 ± 3 years vs.58 ± 5 years, $p = .055$). Following correction for age (OR .951 [.878–1.030], $p = .220$), post-operative flow (OR 1.004 [1.000–1.007], $p = .044$) predicted onset of recurrence

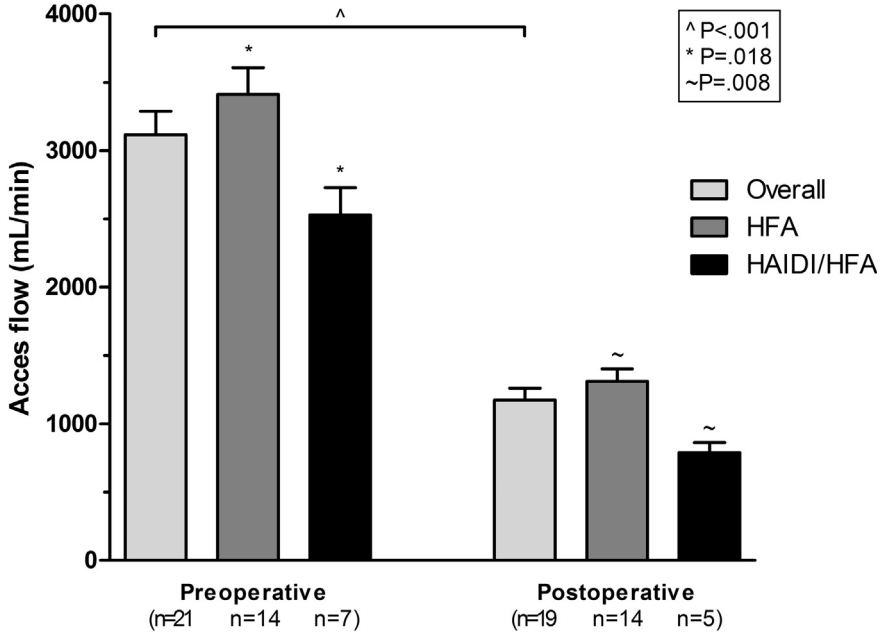

Figure 1. Mean access flows prior to revision using distal inflow (RUDI) and within 1 week after RUDI for high flow access (HFA, $n = 14$) and high flow access with concurrent haemodialysis access induced distal ischaemia (HAIDI/HFA, $n = 7$). Missing post-operative flows HAIDI/HFA group: failed RUDI, $n = 1$; pre-dialysis patient $n = 1$.

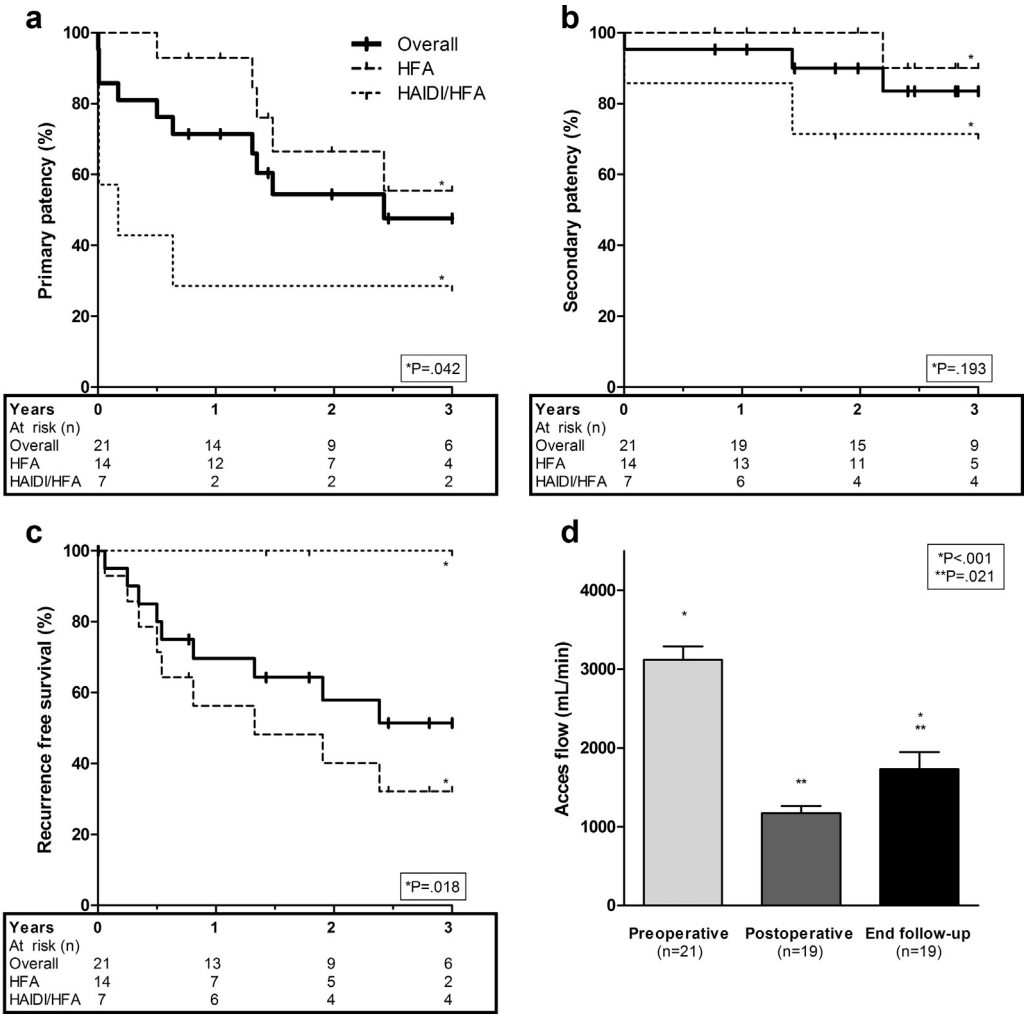

Figure 2. Kaplan–Meier analysis of patency and recurrence rates and flow development over time in 21 dialysis patients that underwent revision using distal inflow (RUDI) for high flow access (HFA) with or without haemodialysis access induced distal ischaemia (HAIDI/HFA). (A) Primary patency. (B) Secondary patency. (C) Recurrence free survival. (D) Mean access flow prior to RUDI, within 1 week after RUDI and at the end of follow up of secondary patency 28 months ± 2 after the procedure.

($R^2 = .48$) in a binary regression model (recurrence yes/no). Six of seven HAIDI/HFA patients reported total recovery of hand ischaemia after the procedure.

Complete data search meant that loss to follow up was avoided. Of the 12 patients with a FU shorter than 3 years, two had died with patent accesses, RUDIs failed in three additional patients, whereas three others underwent ligation after successful renal transplantation. The final four patients underwent RUDI after October 2014, thus FU was terminated at October 31, 2017. Therefore, a FUI of 1.0 was attained with a mean FU of 28 ± 2 months.

DISCUSSION

The number of haemodialysis (HD) patients with an autologous arteriovenous fistula (AVF) developing a high flow access (HFA, >2 L/min) are expected to rise because of a contemporary shift favouring upper arm over wrist AVFs.[2] Flow reduction is advised as the systemic effects of HFA induced cardiovascular overload may occasionally be detrimental. Banding, a previously recommended flow reducing technique, is beneficial in the short term but high flow often recurs.[12] Most patients undergoing revision using distal inflow (RUDI) were still free of high flow after 1 year,[15] but the efficacy of this technique is unknown beyond this time period. The aims of the present study were to investigate long-term rates of access patency and high flow recurrence after RUDI. To the authors' knowledge, it is the first to report on these rates in a homogenous group of HD patients with an upper arm HFA undergoing RUDI using only the greater saphenous vein (GSV) as the interposition conduit.

There is increasing evidence suggesting that RUDI offers optimal patency rates in treating both hand ischaemia and HFA. For instance, one study demonstrated 78% 3 year patency rates in patients with hand ischaemia.[30] A second study found 87% 1 year secondary patency rates in 29 patients with hand ischaemia or HFA.[13] A third study using PTFE interposition grafts reported 77% secondary patency rates after 16 months.[5] Conversely, one study in seven patients with hand ischaemia showed failure rates well above 40% within 8 months.[31] The present results indicate that the overall mid-long term (3 year) access patency of RUDI for HFA using GSV is fairly good and well over 80%.

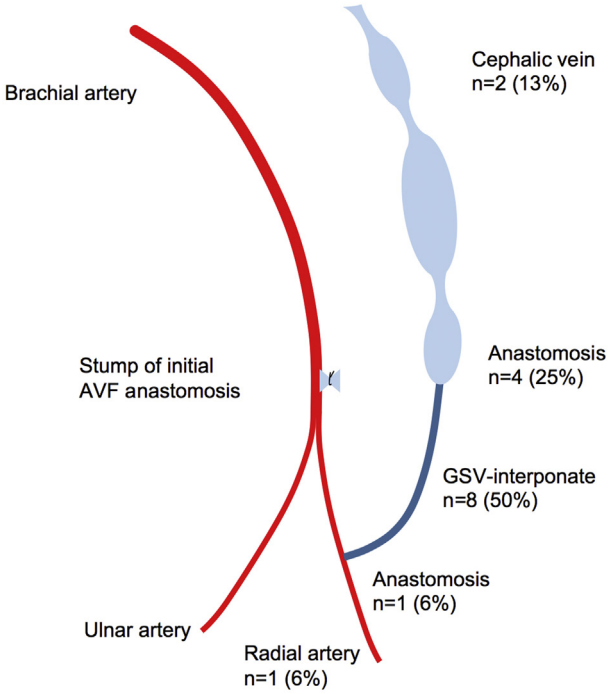

Figure 3. Schematic view of location of dilated stenosis sites, as seen during percutaneous transluminal angiography of arteriovenous fistulas (AVFs) after revision using distal inflow with greater saphenous vein (GSV) interposition.

However, as in all HD patients with an AVF, RUDI patients require ongoing close flow surveillance as only half remained free of (endovascular) interventions.

It is unclear whether the venous conduits used for RUDI are at risk of developing stenoses. One study in maturing radiocephalic AVFs indicated that most stenoses occur in the anastomotic area.[32] In brachiocephalic AVFs, only 4% of stenoses occurred at the anastomosis itself while almost one quarter developed in the portion of the cephalic vein directly adjacent to the anastomosis.[33] In the present study, over 40% of the patients developed a stenosis. Moreover, half of these stenoses developed in a portion of the GSV away from both anastomoses. Furthermore, almost 40% occurred in the upper arm venous outflow tract including its anastomosis. Conversely, the arterial anastomosis was seldom affected. If flow reduction occurs following RUDI, duplex analysis should especially focus on the GSV interposition graft.

One may question whether performing RUDI for asymptomatic high flows (>2 L/min) without routinely examining cardiac function is indicated. However, ejection fractions may be preserved even in the presence of extremely high flows (>10 L/min).[34] Additionally, several studies have shown that flows > 2 L/min or a "flow to cardiac output ratio" > 0.3 are important predictors for the development of high output cardiac failure[6,35] and that flows > 2 L/min might confer serious haemodynamic consequences.[36] As a proportion of the patients did report symptoms that were probably related to systemic overload, it is felt that a quite aggressive attitude towards high flows was indicated.

HD populations tend to have higher death rates compared with groups on peritoneal dialysis.[37] Furthermore, myocardial perfusion is chronically reduced in HD groups.[38] Moreover, left ventricular hypertrophy was attenuated after AVF ligation in patients who successfully underwent renal transplantation.[39,40] During the study period, one patient with recurrent HFA suffered a myocardial infarction and heart failure leading to death after HD cessation. This sequence of events can be regarded as circumstantial evidence of the importance of durable flow reduction. Conversely, AVF ligation after transplantation in another patient with recurrent HFA and signs of heart failure did not alleviate symptoms of dyspnoea and orthopnoea. One might speculate that the heart failure did not exist solely because of the HFA. Alternatively, cardiac reserves may have been exhausted already because of very high flows prior to RUDI, a relative high post-operative access flow and early recurrence. Interestingly, none of the other seven patients with recurrent HFA developed cardiac overload. As the mean age of the recurrence group was relatively low, it is likely that it takes time before a HFA exhausts cardiac reserves.

A limited number of techniques are promoted for flow reduction of HFAs. Banding is suggested as a minimally invasive treatment option for high output heart failure occurring in the presence of high flow.[10] Unfortunately, half of the banded patients demonstrated recurrent high flow after 1 year.[12] The present 1 year results demonstrate a two third recurrence free survival indicating that RUDI does perform better at this time point, although direct comparisons are absent. However, one recurrence for every two RUDIs after 3 years is disappointing. Immediate high post-operative flow and young age, factors also identified in a previous study, predicted recurrence.[12] It may be concluded that the optimal flow reducing technique resulting in durable stable access flows is yet to be discovered.

Several limitations should be addressed. The study is relatively small and retrospective. Furthermore, the generally accepted 0.6 DBI ischaemic threshold was challenged in a recent consensus meeting proposing a threshold of 0.4.[22] Patients who refused surgery or who were considered unfit may have introduced selection bias, possibly leading to under or overestimation of outcome measures. Moreover, the upper measurement limit of the access flow equipment is 4 L/min, precluding accurate determination in some patients possibly having higher access flows. Finally, potential loss to follow up may introduce attrition bias, distorting results.[28] However, a follow up index of 1.0 was attained in this retrospective study minimizing the risk on this type of bias.

In conclusion, the RUDI technique using a portion of GSV offers favourable long-term patency in HD patients with a brachial artery based AVF with high flow but meticulous follow up and maintenance are required. High immediate post-operative access flows and young age are associated with recurrent high flow.

CONFLICTS OF INTEREST

None.

FUNDING

None.

APPENDIX A. SUPPLEMENTARY DATA

Supplementary data related to this article can be found at https://doi.org/10.1016/j.ejvs.2018.03.014.

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COUP D'OEIL

Pseudoaneurysm of the Axillary Artery

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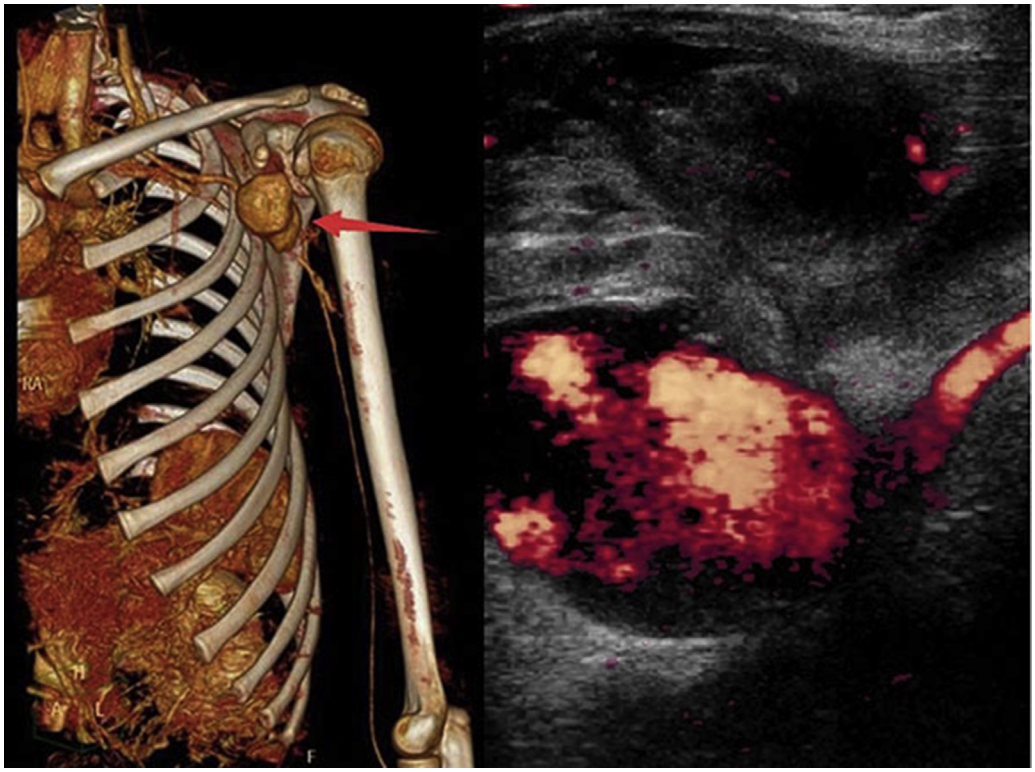

A 12 year old boy sustained a shoulder injury resulting in a left shoulder fracture dislocation. One year later, surgical exploration of the shoulder joint was performed to remove osteophytes. Soon after, a pulsatile mass developed at the left axilla. Computed tomography angiography (red arrow, panel A) and colour duplex sonography (panel B) demonstrated a 7 × 6 cm pseudoaneurysm of the axillary artery. The patient underwent great saphenous vein reconstruction of the damaged arterial segment. The patient is monitored with duplex ultrasound annually, and thus far blood flow and nerve function of the left upper extremity remain normal.

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