Revision using distal inflow versus distal revascularization and interval ligation in management of dialysis access steal syndrome

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Objective
Dialysis access steal syndrome (DASS) is a serious limb-threatening complication of arteriovenous access for dialysis. Redirection of arterial inflow includes distal revascularization and interval ligation (DRIL) and revision using distal inflow (RUDI); both allow improvement of ischemic symptoms while preserving the access. Although outcomes with the DRIL are well established, experience with the RUDI for DASS remains promising.
Aim
The purpose of this study was to evaluate the efficacy and outcome of RUDI in comparison with DRIL in the management of DASS.
Patients and methods
The present single-center randomized clinical study recruited 65 patients presented with DASS. A total of 40 patients presented with stage III and stage IV DASS during the study period. RUDI was performed in 19 patients and DRIL in 21 patients. The study was conducted at Vascular Surgery Departments, Zagazig University Hospitals, Egypt, from May 2016 to January 2021. The primary outcome in the present study was clinical symptom resolution and successful dialysis without pain. Other outcome parameters included duplex assessment of dialysis circuit flow rate and distal vessel peak systolic velocity, complications, primary patency, assisted primary patency, secondary patency, cumulative primary, and assisted primary patency as well as intervention-free survival during 12-month follow-up.
Results
In the DRIL group, patient demographics were as follows: mean age was 59.3 years, 16 were females, 13 were diabetics, and 15 were hypertensives, whereas in the RUDI group, the mean age was 56.9 years, 13 were females, 15 were diabetics, and 13 were hypertensives. There were no preoperative differences in patient comorbidities between the RUDI and DRIL. Indications for intervention were tissue loss (30%) or ischemic rest pain (70%). Resolution of ischemic symptoms with successful dialysis without pain, which occurred in 89.5% of RUDI patients and in 85.7% of DRIL patients (P=0.72), with regaining of radial pulsations. Ischemic rest pain persisted in two RUDI patients and three DRIL patients, who required access ligation to save the limb from progressive tissue loss. Two DRIL and three RUDI patients required partial or complete digital amputation after successful revascularization. Primary patency rates between RUDI and DRIL groups at 12 months (63.2 vs. 61.9%) were comparable (P=0.99), in addition to the primary-assisted patency rates at 12 months (73.7 vs. 71.4%; P=0.87). Secondary patency rates between RUDI and DRIL groups at 12 months (78.9 vs. 76.2%) were also comparable (P=0.83). Wound complications were documented in five (17%) patients, including two patients in DRIL and three patients in RUDI; all resolved with conservative management and antibiotics.
Conclusion
RUDI is a good alternative to DRIL in managing severe DASS symptoms and access preservation. RUDI avoids DRIL's complexity and risks with similar symptom resolution, patency, and complication rates.

Keywords:
arteriovenous fistula, dialysis access steal syndrome, distal revascularization and interval ligation, revision using distal inflow, steal syndrome

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Introduction

Arteriovenous fistula (AVF) is the access of choice (gold standard) for dialysis patients [1]. Management of AVF complications and their longevity is the main

target recently owing to an increase in the incidence of end-stage renal disease in association with longer life expectancy patients, necessitating more reliable, functional, cost-effective, and durable AVF [2].

Dialysis access steal syndrome (DASS) is one of the complications that not only threaten the durability of the AVF but also could result in significant morbidity and mortality [3].

It is defined as decreased perfusion distal to the access because of significant blood diverting into the access, leading to hand hypoperfusion and ischemia. Peripheral arterial resistance increases this blood shifting [4].

The diagnosis of DASS is determined by clinical and physiologic data. Ischemia severity is graded according to Tordois *et al*. [5].

Symptoms can be as minimal as cool extremity (stage I), pain during dialysis or exercise (stage II), and pain during rest (stage III), or, if not managed, steal can result in muscle atrophy and tissue loss in the form of ulcer or gangrene (stage IV). All patients with stage I ischemia are treated conservatively, as well as most patients with stage II. Patients with stage III and stage IV symptoms are routinely offered intervention [5].

DASS affects up to 30% of patients after the creation of an upper extremity access; however, DASS requiring intervention is uncommon, occurring in 1–2% of AVFs and in 2.7–8% of arteriovenous grafts [6].

Early diagnosis and treatment of moderate-to-severe DASS can prevent permanent motor dysfunction as well as severe ischemic neuropathy and tissue loss [7].

Surgical interventions for symptomatic DASS are classified into three types: ligation of the access, operations that limit the flow through the access, and operations that redirect the arterial inflow. Redirection of arterial inflow includes distal revascularization and interval ligation (DRIL), revision using distal inflow (RUDI), and proximalization of the arterial inflow [8].

DRIL procedure has become the intervention of choice for preserving the arteriovenous access while relieving symptoms of steal syndrome. DRIL procedure has shown to be a durable intervention for DASS, and multiple recent large series have reported excellent long-term secondary patency rates approaching 80% at 5 years [9].

DRIL results in the arterial supply to the hand being dependent on an interposition bypass, either using a native or prosthetic graft. An alternative approach to restrict flow into the AV access involves revision of the arterial anastomosis to a more distal origin, such as the radial or ulnar artery (RUDI) [10,11].

RUDI has demonstrated some promising results and less complexity than DRIL; however, its efficacy has not been examined [12,13].

The aim of this study was to evaluate the efficacy and outcome of RUDI in comparison with DRIL in the management of DASS.

Patients and methods

Study design

This randomized prospective study was conducted at Zagazig University Hospitals in the period from May 2016 to January 2021. The study protocol was approved by the local ethical committee of Zagazig Faculty of Medicine, and all patients gave informed consent before participation in the study.

After AVF creation, patients had scheduled clinical follow-up by a vascular surgeon at 1, 3, 6, and 12 months, in addition to routine monitoring with duplex ultrasound-based access flow measurements every month during dialysis.

Inclusion criteria

Patients with brachiocephalic or brachiobasilic AVFs with symptoms consistent with significant hand ischemia (Tordois stage III and stage IV DASS) with absent forearm pulsations and Doppler confirmation were included.

Exclusion criteria

Patients with complicated AVF such as aneurysmal dilatation, cardiac overload, or venous hypertension were excluded from the study. Patients with low flow steal and patients with peripheral arterial disease were also excluded.

All patients underwent history taking, physical examination, and laboratory investigations. Doppler ultrasound for flow measurement before and after the procedure was performed.

Technical procedure

For distal revascularization and interval ligation

All patients had portable Doppler ultrasonography performed by the operating surgeon immediately preoperatively to enable marking of the pre-existing anastomosis, access vein, and brachial artery bifurcation and to locate the course and size of great saphenous vein.

The DRIL procedure is typically performed with general anesthesia or regional block. Marking the pathway of the arteriovenous conduit is recommended so as to avoid injury to the fistula from the incisions or tunneling.

A proximal incision is made in the upper arm along the sulcus, separating the biceps and the triceps muscles, at least 7 cm proximal to the AVF to prevent arterial bypass thrombosis from a low pressure sink from the AVF. The brachial artery is dissected free from the surrounding veins proximally and distally.

A distal longitudinal incision is made in the forearm, below the arterial anastomosis of the fistula. The target vessel is often the distal brachial, proximal ulnar, or proximal radial artery, depending on the level of the bifurcation and the dominance of the vessels based on the preoperative duplex mapping and flow volume assessment.

The artery proximal to the planned distal DRIL anastomosis is dissected free, which will be ligated after completion of the bypass.

The great saphenous vein as a conduit is harvested from the thigh to allow adequate size and length. The vein is gently dilated using heparinized saline to test for leaks before creation of the proximal anastomosis.

A tunnel is created between the two incisions. This is typically placed medially and deeper on the arm to avoid confusion with the fistula by the hemodialysis nursing staff.

A longitudinal arteriotomy is created in the proximal artery. Patients are treated with locally injected heparinized saline into the artery proximally and distally, without systemic anticoagulation. The anastomosis is completed end to side with 6–0 polypropylene (Ethicon, Somerville, New Jersey) running sutures.

After completing the proximal anastomosis, the integrity of all branch ligatures was checked again and then the vein was passed through the tunnel to avoid twists or kinks.

An end-to-side anastomosis was created between the vein graft and the distal target vessel with 6–0 or 7–0 polypropylene (Ethicon) running sutures.

After finishing the bypass, the artery proximal to the distal DRIL anastomosis was ligated with a 2–0 silk (Ethicon) ligature. Incisions were closed in at least two layers. The skin should be clearly marked to identify the location of the bypass graft and to distinguish it from the access vessel or graft, which can be used without interruption.

For revision using distal inflow

The technique for creation of the RUDI is based on that originally described by Minion *et al.* [11] but with several modifications developed by one of the study authors. Preoperative mapping and assessment of the proximal radial and ulnar arteries was performed in all patients to determine hand perfusion and arterial dominance. Selection of the distal artery inflow placement was preferentially for an adequate nondominant vessel, with the dominant artery reserved for hand perfusion. The pre-existing anastomosis exposed through curvilinear incision, and cephalic or basilic vein was mobilized and controlled. A second counter incision was made in the proximal forearm, and the radial or ulnar artery was exposed over a short length 5 cm of the brachial bifurcation. The original venous outflow is ligated. The great saphenous vein as a preferred conduit is harvested from the thigh to allow adequate size and length. The arterial anastomosis is then completed with running 7–0 polypropylene (Ethicon) sutures to the proximal radial or ulnar artery, and then the graft is tunneled subcutaneously to 4–5 cm proximal to the arterial anastomosis and anastomosed end to side with the venous outflow.

Follow-up

Follow-up assessments occurred at 1 week, 1, 3, 6, and 12 months. Clinical follow-up included clinical symptom resolution, including resolution or improvement in pain, healing of ischemic ulcers or amputations, and successful dialysis without pain. Duplex follow-up was done to evaluate dialysis circuit flow rate and measure the peak systolic velocity (PSV) of distal arteries.

Study end points and outcome measures

The primary end point of the study was clinical symptom resolution, including resolution or improvement in pain, healing of ischemic ulcers or amputations, and successful dialysis without pain. Secondary end points included duplex assessment of the dialysis circuit flow rate and distal vessel PSV, complications (wound infection, bleeding, thrombosis, or amputation), AVF primary patency, assisted primary patency, secondary patency, cumulative primary, and assisted primary patency as well as intervention-free survival during 12-month follow-up.

Primary patency is defined as uninterrupted patent and functional dialysis circuit till repeating surgical and/or percutaneous procedures during a given time period. Assisted primary patency is defined as a patent and

functional dialysis circuit after repeating surgical and/or percutaneous revision of procedures during a given time period. Secondary patency is defined as a patent and functional dialysis circuit regardless of the number of repeating surgical, percutaneous procedures, and/or surgically abandoned during a given time period.

Cumulative primary patency is defined as the total time the dialysis circuit remains patent, till repeating surgical and/or percutaneous procedures during a given time period. Cumulative assisted primary patency is defined as the total time the dialysis circuit remains patent, after repeating surgical and/or percutaneous revision of procedures during a given time period. Intervention-free survival is defined as the total time the dialysis circuit remains patent, regardless of the number of repeating surgical, percutaneous procedures surgically abandoned during a given time period.

Randomization

Simple randomization and concealment was achieved using computer-generated random numbers and the sealed envelope technique. Envelopes were opened in the operating room after confirmation of suitable anatomy. Enrolled patients were allocated to the studied groups in a 1: 1 ratio. Randomization, allocation, and concealment were supervised by an independent researcher who was not aware of the nature of the study.

Statistical analysis

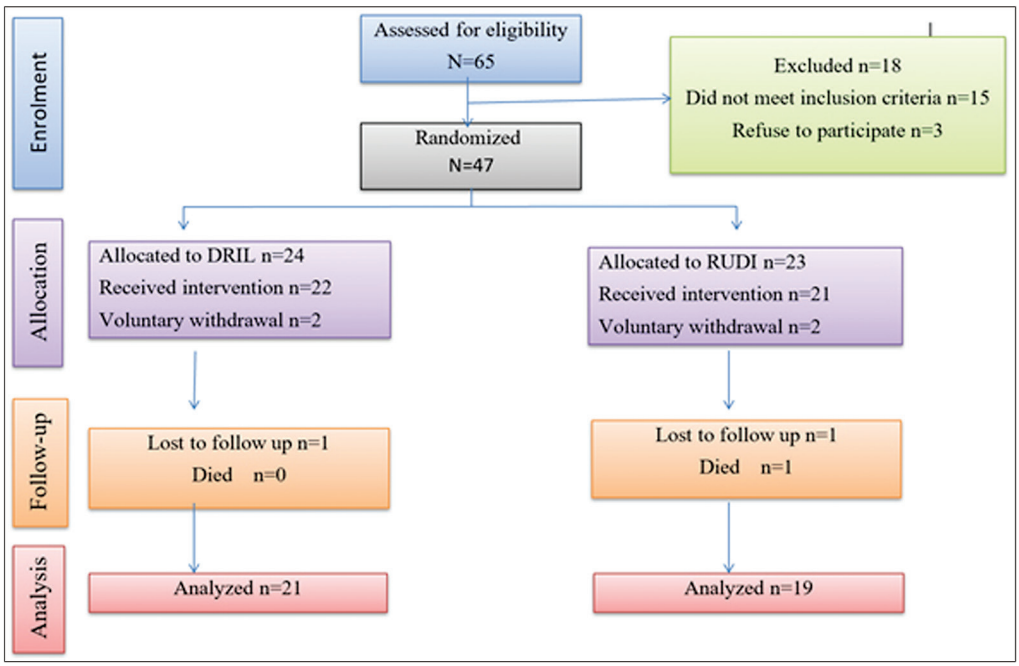
Data were collected with respect to thorough history, basic clinical examination, and laboratory investigations, and outcome measures were coded, entered, and analyzed using Microsoft Excel software. Statistical analysis was done using IBM SPSS statistics for windows, Version 20.0 (Armonk, NY: IBM Corp.). Qualitative data were represented as numbers and percentages, whereas quantitative ones that were continuous were represented by mean and SD. Difference and association of qualitative variables were tested by χ^2 test. However, differences between quantitative independent groups were tested by t test. P value was set at less than 0.05 for significant results and less than 0.001 for highly significant results.

Results

We screened 65 consecutive patients with DASS for eligibility. A total of 47 patients with stage III or stage IV DASS were recruited and equally randomized. Two patients in each group were excluded owing to voluntary withdrawal. One patient was lost to follow-up at each group, in addition to one patient who died in the RUDI group. All of these patients were excluded. Only 40 patients completed the study (21 in the DRIL group and 19 in the RUDI group) until the end of follow-up period after 12 months (Fig. 1).

Table 1 shows demographic data and DASS risk factors. The mean age for the DRIL group was 59.3 years and that of the RUDI group was 56.9 years. Females represented 76.2 and 68.4% for DRIL and RUDI groups, respectively. Risk factors between the RUDI and DRIL groups were comparable. The most common risk factors included diabetes (61.9 and 78.9%) and hypertension (71.4 and 68.4%) in DRIL and RUDI

Figure 1



CONSORT (The Consolidated Standards of Reporting Trials) chart illustrating study protocol.

groups, respectively, and dyslipidemia (63.2%) in the RUDI group.

Indications for intervention were comparable in both groups, with 12 (30%) patients presenting with tissue loss (ischemic ulceration, gangrene, or digit necrosis) as the primary indication for intervention and 28 (70%) with ischemic rest pain. There was no statistically significant difference between RUDI and DRIL groups (31.6 vs. 28.6%, respectively (*P*=0.83; Table 2) for ischemic tissue loss.

Mean dialysis duration using the original fistula before any revision showed no statistically significant difference between RUDI and DRIL groups (8.15 ± 2.37 and 9.76 ± 3.36 months, respectively; *P*=0.752; Table 2). The conduit used in both groups was saphenous vein. The distal target artery for the RUDI was the proximal radial artery in 13 (68.4%) and the ulnar in six (31.6%). The DRIL was performed using a brachial artery as the distal target artery in 14 (66.7%), the proximal radial artery in three (14.3%), and the ulnar in four (19%) (Table 3).

Table 1 Demographic data distribution between studied groups

	DRIL group	RUDI group	t/χ^2	*P*
Age	59.33 ± 8.64	56.94 ± 10.36	0.158	0.799
BMI	29.95 ± 5.16	31.94 ± 4.67	0.03	0.897
Sex [*n* (%)]				
Female	16 (76.2)	13 (68.4)		
Male	5 (23.8)	6 (31.6)	0.36	0.56
Diabetes mellitus [*n* (%)]				
Negative	8 (38.1)	4 (21.1)		
Positive	13 (61.9)	15 (78.9)	0.37	0.55
Hypertension [*n* (%)]				
Negative	6 (28.6)	6 (31.6)		
Positive	15 (71.4)	13 (68.4)	0.30	0.58
Coronary artery disease [*n* (%)]				
Negative	12 (57.1)	11 (57.9)		
Positive	9 (42.9)	8 (42.1)	0.002	0.96
Smoking [*n* (%)]				
Negative	13 (61.9)	16 (84.2)		
Positive	8 (23.8)	3 (15.8)	0.40	0.52
Dyslipidemia [*n* (%)]				
Negative	11 (52.4)	7 (36.8)		
Positive	10 (47.6)	12 (63.2)	0.97	0.32
Peripheral arterial disease [*n* (%)]				
Negative	12 (57.1)	9 (47.4)		
Positive	9 (42.9)	10 (52.6)	0.38	0.53
Total				
n (%)	21 (100.0)	19 (100.0)		

DRIL, distal revascularization and interval ligation; RUDI, revision using distal inflow.

Table 2 Dialysis data distribution between studied groups

	DRIL group	RUDI group	t/χ^2	*P*
Dialysis duration (months)	9.76 ± 3.36	8.15 ± 2.37	0.318	0.752
Dialysis access side [*n* (%)]				
Left	8 (38.1)	5 (26.3)		
Right	13 (61.9)	14 (73.7)	0.63	0.42
Dialysis access type [*n* (%)]				
BB	6 (28.6)	4 (21.1)		
BC	14 (66.7)	14 (73.7)	0.30	0.86
RC	1 (4.8)	1 (5.3)		
Steal stage [*n* (%)]				
III	15 (71.4)	13 (68.4)		
IV	6 (28.6)	6 (31.6)	0.04	0.83
Total				
n (%)	21 (100.0)	19 (100.0)		

BB, brachiobasilic; BC, brachiocephalic; DRIL, distal revascularization and interval ligation; RC, radiocephalic; RUDI, revision using distal inflow.

Resolution of ischemic symptoms with successful dialysis without pain occurred in 89.5% of RUDI patients and in 85.7% of DRIL patients (P=0.72), with regaining radial artery pulsations and resuming PSV of 50–80 cm/s in either radial or ulnar artery, or both. Ischemic rest pain persisted in two patients with RUDI

Table 3 Target vessel distribution between studied groups

	Groups		χ^2	P
	DRIL group	RUDI group		
Target vessel [*n* (%)]				
Brachial a.	14 (66.7)	0		
Radial a.	3 (14.3)	13 (68.4)	20.6	0.00**
Ulnar a.	4 (19.0)	6 (31.6)		
Total				
n (%)	21 (100.0)	19 (100.0)		

DRIL, distal revascularization and interval ligation; RUDI, revision using distal inflow.
**<0.001 for highly significant results.

Table 4 Changes of peak systolic velocity and access flow rate between studied groups

	DRIL group	RUDI group	t	P
Preoperative radial PSV (cm/s)	19.28±6.60	20.05±6.71	0.364	0.718
Postoperative radial PSV (cm/s	49.28±10.17	52.47±8.48	1.069	0.292
P	0.00**	0.00**		
Preoperative ulnar PSV (cm/s)	14.23±4.12	14.47±4.41	0.175	0.862
Postoperative ulnar PSV (cm/s)	49.28±10.17	47.94±14.45	0.341	0.735
P	0.00**	0.00**		
Preoperative access flow volume (ml/min)	1539.04±150.7	1548.15±158.0	0.187	0.853
Postoperative access flow volume (ml/min)	739.47±215.83	714.04±222.8	0.358	0.738
P	0.00**	0.00**		

DRIL, distal revascularization and interval ligation; PSV, peak systolic velocity; RUDI, revision using distal inflow.
**<0.001 for highly significant results.

Table 5 Postoperative outcome and patency rate distribution between studied groups

	DRIL group	RUDI group	t/χ^2	P
Cumulative 1ry patency days	317.61±77.76	300.94±100.4	0.551	0.585
Intervention-free survival days	338.38±64.8	338.64±66.96	0.012	0.991
Technical success [*n* (%)]				
Negative	3 (14.3)	2 (10.5)		
Positive	18 (85.7)	17 (89.5)	0.12	0.72
Technical failure [*n* (%)]				
Negative	18 (85.7)	17 (89.5)		
Positive	3 (14.3)	2 (10.5)	0.12	0.72
Primary patency 6/12 [*n* (%)]				
Negative	5 (23.8)	5 (26.3)		
Positive	16 (76.2)	14 (73.7)	0.03	0.85
Primary patency 12/12 [*n* (%)]				
Negative	8 (38.1)	7 (36.8)		
Positive	13 (61.9)	12 (63.2)	0.007	0.93
Primary-assisted patency 6/12 [*n* (%)]				
Negative	4 (19.0)	4 (21.1)		
Positive	17 (81.0)	15 (78.9)	0.02	0.87
Primary-assisted patency 12/12 [*n* (%)]				
Negative	6 (28.6)	5 (26.3)		
Positive	15 (71.4)	14 (73.7)	0.02	0.87
Secondary patency 6/12 [*n* (%)]				
Negative	4 (19.0)	3 (15.8)		
Positive	17 (81.0)	16 (84.2)	0.07	0.78
Secondary patency 12/12 [*n* (%)]				
Negative	5 (23.8)	4 (21.1)		
Positive	16 (76.2)	15 (78.9)	0.04	0.83
Total				
n (%)	21 (100.0)	19 (100.0)		

DRIL, distal revascularization and interval ligation; RUDI, revision using distal inflow.

and three patients with DRIL, requiring ligating to save the limb from progression of tissue loss (Table 5).

Mean access flow data demonstrate a significant decreased between preoperative and postoperative values in both groups ($P<0.001$). Preoperative flow rates for patients undergoing RUDI or DRIL were comparable (1548.15±158.0 vs. 1539.04±150.7 ml/min, respectively; $P=0.853$). However, mean postoperative access flow rates were lower in the RUDI group than in the DRIL group (714.04±222.8 vs. 739.47±215.8 ml/min, respectively; $P=0.738$) (Table 4).

Total hand amputation is not encountered; however, two DRIL and three RUDI patients underwent partial or complete digit amputation after successful revision with DRIL or RUDI. The amputation stumps healed successfully in all patients. Seven additional patients with digital necrosis are treated conservatively without amputation, that is, four DRIL and three RUDI (Table 6).

A total of 12 reinterventions were performed during the study period, with six in each group. Successful endovascular angioplasty for juxta-anastomotic outflow stenosis was performed in one DRIL patient. Surgical revision with interposition grafting for long-segment stenosis was performed in one patient with RUDI, and thrombectomy for graft thrombosis in four patients in each group, being successful in two patients from each group.

Primary patency rates between RUDI and DRIL at 6 months (73.7 vs. 76.2%) and 12 months (63.2 vs. 61.9%) were comparable ($P=0.85$ and 0.93, respectively; Table 5), in addition to primary-assisted patency rates at 6 months (78.9 vs. 81%) and 12 months (73.7 vs. 71.4%; $P=0.87$ and 0.87, respectively; Table 5). Secondary patency rates between RUDI and DRIL at 6 months (84.2 vs. 81%) and 12 months (78.9 vs. 76.2%) were also comparable ($P=0.78$ and 0.83 respectively; Table 5). Primary patency of the brachial artery bypass in the DRIL group at 12 months was 95%, with one bypass requiring balloon angioplasty to dilate a distal anastomotic stenosis. No brachial artery bypass thrombosis was encountered during the study period and brachial artery bypass secondary patency rate reached 100%.

Kaplan–Meier survival analysis with log-rank comparison revealed no statistically significant differences between the studied groups regarding cumulative primary and assisted primary patency as well as intervention-free survival (Figs 2–4).

Wound infection occurred in five (17%) patients, including two DRILs and three RUDIs. All patients resolved with conservative management and antibiotics, and no graft required excision for infectious complications. Rates of overall fistula thrombosis with abandonment were comparable in both groups (Table 6).

Discussion

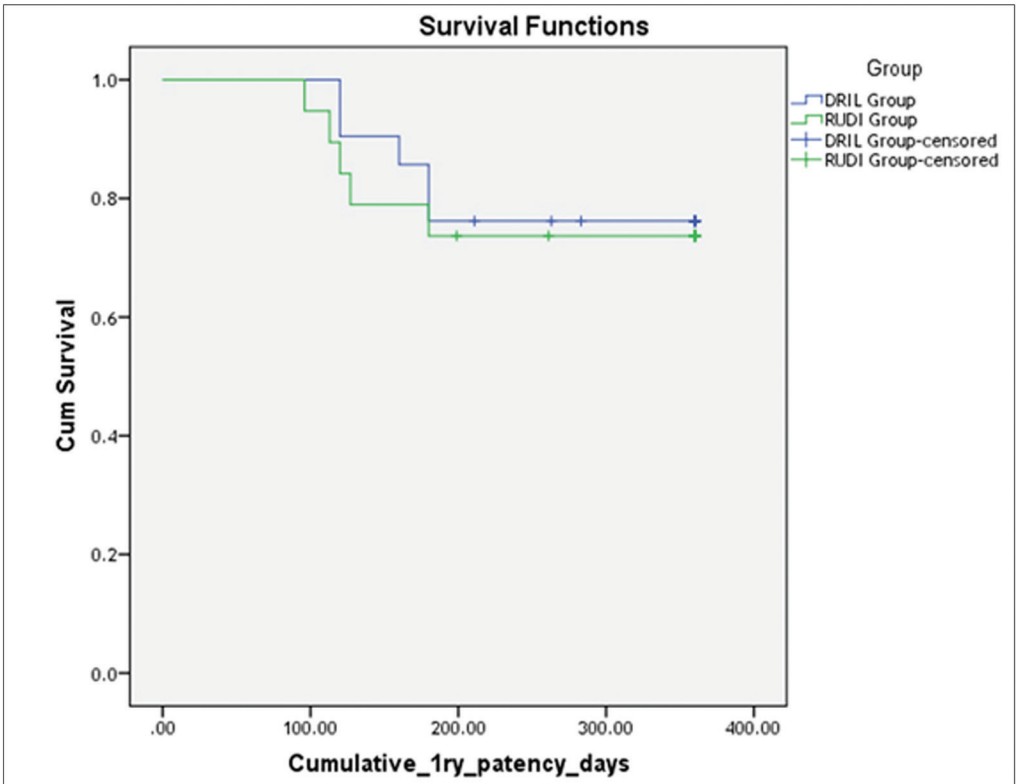
Storey *et al*. [13] first described steal syndrome associated with vascular access for dialysis following a Brescia Cimino fistula between the radial artery and the distal cephalic vein [13,14]. The incidence of upper extremity DASS is higher in brachiocephalic

Table 6 Complication distribution between studied groups

	Groups		χ^2	*P*
	DRIL group	RUDI group		
Wound infection [*n* (%)]				
Negative	19 (90.5)	16 (84.2)		
Positive	2 (9.5)	3 (15.8)	0.35	0.55
Stenosis [*n* (%)]				
Negative	20 (95.2)	18 (94.7)		
Positive	1 (4.8)	1 (5.3)	0.005	0.94
Thrombosis [*n* (%)]				
Negative	17 (81.0)	15 (78.9)		
Positive	4 (19.0)	4 (21.1)	0.02	0.87
Bleeding [*n* (%)]				
Negative	20 (95.2)	17 (89.5)		
Positive	1 (4.8)	2 (10.5)	0.47	0.48
Amputation [*n* (%)]				
Negative	19 (90.5)	16 (84.2)		
Positive	2 (9.5)	3 (15.8)	0.35	0.55
Ligation [*n* (%)]				
Negative	16 (76.2)	15 (78.9)		
Positive	5 (23.8)	4 (21.1)	0.04	0.83
Total				
n (%)	21 (100.0)	19 (100.0)		

DRIL, distal revascularization and interval ligation; RUDI, revision using distal inflow.

Figure 2



Group	Mean			
	Estimate	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
DRIL Group	310.476	19.547	272.165	348.788
RUDI Group	298.737	23.753	252.180	345.293
Overall	304.900	15.280	274.952	334.848

Kaplan–Meier for primary patency survival.

or brachiobasilic AVF than radiocephalic AVF. This also suggests that use of the proximal radial artery as opposed to the brachial artery may result in a significantly lower incidence of steal. High-flow steal syndrome is supposed to be owing to wide anastomosis in the absence of peripheral arterial occlusive disease [15].

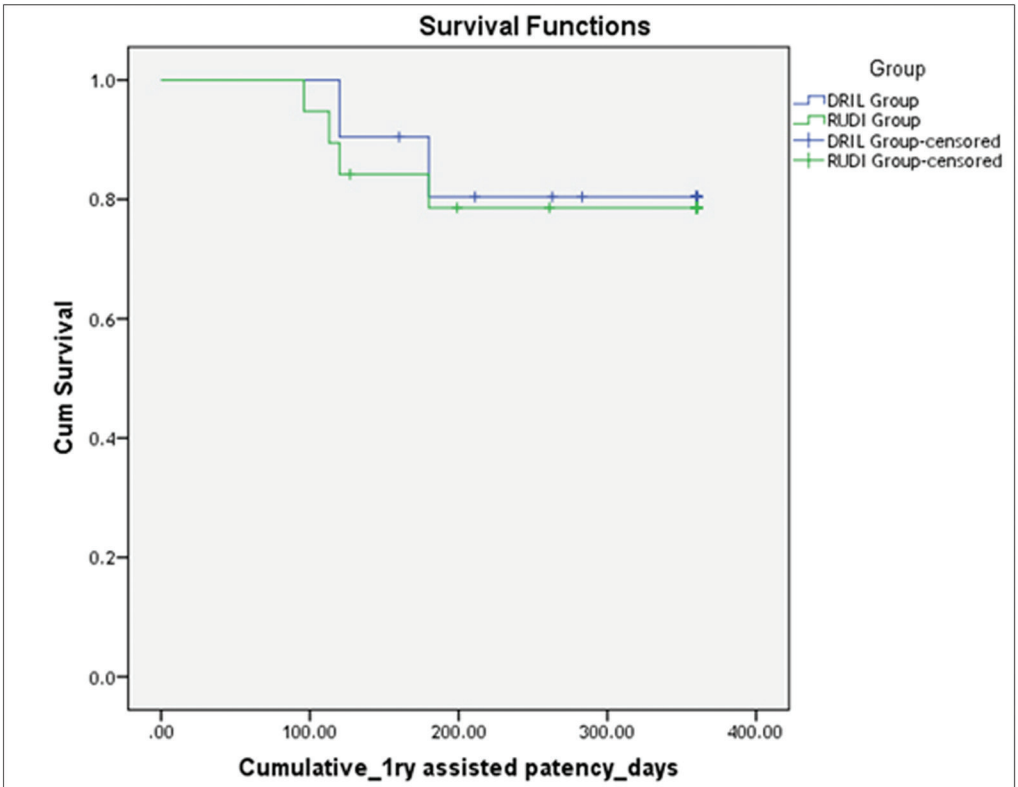
Schanzer *et al*. [16] first described the DRIL procedure. The DRIL procedure involves ligating the native vessel just distal to the AVF, with revascularization of the hand via an arterial bypass originating at least 5 cm proximal to the fistula [16,17]. RUDI originally described by Minion *et al*. [11] involves distalization of the fistula to the proximal radial or ulnar artery 2–3 cm distal to the brachial bifurcation with ligation of previous anastomosis [18]. This modified procedure attempts to avoid complexity of DRIL. It is a clinical entity that maintains the native arterial circulation. RUDI both lengthens the fistula and reduces the diameter [19].

Mechanisms by which steal symptoms and perfusion to the hand are improved by the RUDI and DRIL procedures are different [6]. DRIL relieves access-induced ischemia by a more complex mechanism. It involves both an alteration in relative resistances between the fistula and the distal vascular bed in addition to direct prevention of flow reversal by ligation of the distal brachial artery [20].

On the contrary, RUDI involves extension of the existing fistula to a lower-flow forearm vessel in which the incidence of ischemic steal is low [21]. The lower flow rate from a more distal access, in addition to longer access length and narrowing of the access (if the conduit is smaller than the native outflow vein), all cause improvement in steal symptoms, making the conduit particularly suitable for higher flow fistulas [22].

Findings of this study demonstrate that DRIL and RUDI procedures provide comparable symptom resolution and patency rates for selected patients with stage III and stage IV DASS. Improvements in distal perfusion are comparable after both procedures, as measured by mean preoperative and postoperative distal vessel PSV, and postoperative regain of radial

Figure 3



Group	Mean			
	Estimate	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
DRIL Group	319.048	18.551	282.688	355.407
RUDI Group	310.368	22.219	266.820	353.917
Overall	314.907	14.382	286.718	343.095

Kaplan–Meier for primary-assisted patency survival.

pulsations. Neither procedure is associated with excess wound infection or repeated intervention.

In our study, patient demographics included dyslipidemia, diabetes mellitus type II, female sex predominance, and hypertension. These are statistically significant risk factors for DASS.

In a study by Gupta *et al.* [12], coronary artery disease, diabetes mellitus type II, female sex, hypertension, and tobacco were statistically significant risk factors for DASS.

All cases in our study were operated on using saphenous vein conduit, to avoid heterogeneity and confusion of the results from different types of conduit.

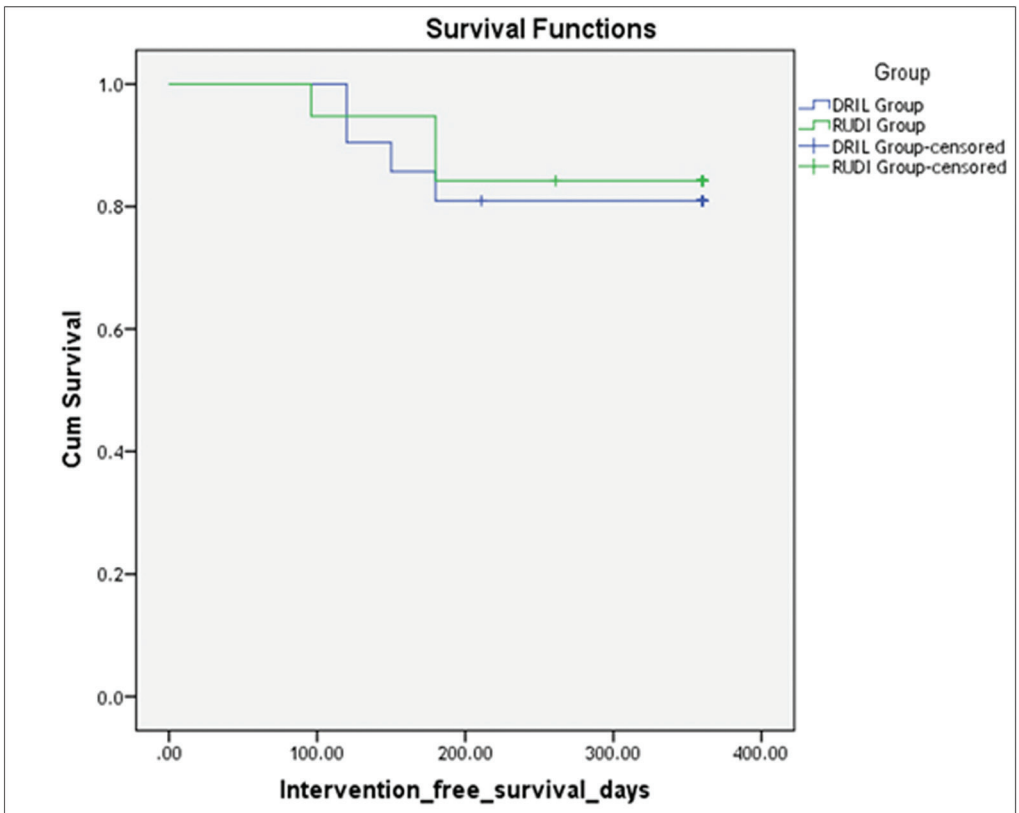
Although most reports of RUDI support the native veins as a conduit for reconstruction [10,11,23,24], a high proportion of ePTFE grafts were used in the RUDI group (75%) in the study by Misskey *et al.* [25]. Although this technique involved extension to the distal radial artery, it demonstrated acceptable secondary patency (77%) at 16-month follow-up. In addition, wound complication rates were lower in the RUDI group when compared with the DRIL group (15 vs. 17%; *P*=not significant) [25].

Ring-reinforced ePTFE was used pre-dominantly in an effort to prevent kinking of the conduit across the elbow joint. This configuration has been previously described by Chemla *et al.* [22] for 17 patients with upper arm fistulas or grafts with high-output heart failure. So, the use of ePTFE as the primary conduit did not appear to negatively affect patency rates. Further studying and comparison with autogenous conduit are needed to determine whether these theoretical advantages are clinically significant.

In our study, mean access flow data demonstrate a significant drop between preoperative and postoperative values. Mean postoperative access flow rates are lower in the RUDI group than in the DRIL group, with no statistically significant difference between both groups.

In a study by Misskey *et al.* [25], patients with RUDI demonstrated significantly greater reductions in access

Figure 4



Group	Mean			
	Estimate	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
DRIL Group	318.571	18.787	281.748	355.395
RUDI Group	327.158	17.771	292.327	361.988
Overall	322.650	13.000	297.170	348.130

Kaplan–Meier for intervention-free survival.

flow rates than with DRIL, thus recommending RUDI for patients with very high access flow (>2000 ml/min) or signs of high-output cardiac failure. In contrast, patients with low flow rates (<800 ml/min) or severely diseased proximal radial and ulnar arteries that would significantly compromise arterial inflow are better treated with DRIL.

Other studies reported that RUDI, like DRIL and proximalization of the arterial inflow, is theoretically applicable to patients with normal and high-flow DASS [19]. However, the use of a smaller distal vessel as inflow in RUDI has raised concerns regarding higher rates of fistula dysfunction, incomplete dialysis, and thrombosis [12]. The burden of distal artery disease and the technical feasibility of distalizing the anastomosis should be considered when deciding whether to proceed with RUDI [25].

In our study, primary, assisted primary and secondary patency rates between the RUDI and DRIL at 12 months were comparable, with no statistically significant difference between both groups.

DRIL procedure has historically demonstrated excellent outcomes with respect to patency, symptom resolution, and fistula functionality. An increasing base of evidence, including multiple large studies, has shown secondary patency rates after DRIL of 76–82% at 5 years [3,23,26,27]. Despite concerns regarding the need for ligation of an axial artery and dependence of a limb on an arterial bypass, numerous large studies have shown that graft thrombosis is a very rare event, with primary patency of 86–100% at 1 year and 78–96.9% at 5 years [9,12,23,24,26].

There have been few published studies on patency and clinical outcomes for RUDI procedure, showing significant heterogenicity in the index access (fistula or graft), RUDI conduit, operative technique, operative indications, and outcome measures [3,9,23,26,28].

Multiple studies have demonstrated good preliminary results with RUDI for the management of high-output heart failure alone or combined with DASS [22,24,25]. Despite these limitations, reported RUDI outcomes for DASS show acceptable patency and symptom

resolution and corroborate well with the findings of these series [25].

Conclusion

RUDI shows comparable symptom resolution, patency rates, and complication rates to DRIL for patients with severe DASS. So, RUDI is a good alternative option that preserves native antegrade arterial continuity and avoids complexity of the DRIL procedure.

Limitation

This study is limited by the small sample size of both the RUDI and DRIL groups. This is due to limited number of cases presented with stage III and stage IV DASS in native AVF, being a single-center study. In addition, the duration of patient recruitment in the study was long, which makes long-term follow-up difficult.

Recommendation

Further multiple-center studies with long-term follow-up are needed.

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Conflicts of interest

No conflict of interest.

References

1 Tawfik AM, Zidan MH, Salem A, Salem A. A randomized controlled study of early versus standard cannulation of arteriovenous grafts in hemodialysis patients. J Vasc Surg 2022; 75:1047–1053.

2 Kordzadeh A, Garzon LAN, Parsa AD. Revision using distal inflow for the treatment of dialysis access steal syndrome: a systematic review. Ann Vass Dis 2018; 11:473–478.

3 Schanzer H, Skladany M, Haimov M. Treatment of angio-access-induced ischemia by revascularisation. J Vasc Surg 1992; 16 861–866.

4 El-laboudy ME, Sorour WA, Tawfik AM. Is polytetrafluoroethylene circular banding an effective technique for treatment of high-flow vascular access-induced steal syndrome?. Egypt J Surg 2020; 39:387–392.

5 Tordois JH, Dammers R, van der Sande FM. Upper extremity ischemia and hemodialysis vascular access. Eur J Vasc Endovasc Surg 2004; 27:1–5.

6 Scali ST, Huber TS. Treatment strategies for access-related hand ischemia. Semin Vasc Surg 2011; 24:128–136.

7 Padberg FT Jr, Calligaro KD, Sidawy AN. Complications of arterio:venous hemodialysis access: recognition and management. J Vasc Surg 2008; 48(5 Suppl):555–80S.

8 Inston N, Schanzer H, Widmer M, Deane C, Wilkins J, Davidson I, *et al*. Arteriovenous access ischemic steal (AVAIS) in haemodialysis: a consensus from the Charing Cross Vascular Access Masterclass 2016. J Vasc Access 2017; 18:3–12.

9 Scali ST, Chang CK, Raghinaru D, Daniels MJ, Beck AW, Feezor RJ, *et al*. Prediction of graft patency and mortality after distal revascularization and interval ligation for hemodialysis access-related hand ischemia. J Vasc Surg 2013; 57:451–458.

10 Callaghan CJ, Mallik M, Siyaprakasam R, Lype S, Pettigrew GJ. Treatment of dialysis access-associated steal syndrome with the 'revision using distal inflow' technique. J Vasc Access 2011; 12:52–56.

11 Minion DJ, Moore E, Endean E. Revision using distal inflow: a novel approach to dialysis-associated steal syndrome. Ann Vasc Surg 2005; 19:625–628.

12 Gupta N, Yuo TH, Konig G4th, Rilayoy E, Leers SA, Chaer RA, *et al*. Treatment strategies of arterial steal after arteriovenous access. J Vasc Surg 2011; 54:162–167.

13 Storey BG, George CR, Stewart, JH, Tiller DJ, May J, Sheil AG. Embolic and ischemic complications after anastomosis of radial artery to cephalic vein. Surgery 1969; 66: 325–327.

14 Malgor RD, Yoshida R, Sobreira M, Giannini M, Yoshida W, Almeida H. Distal revascularization and interval ligation for the treatment of steal syndrome secondary to hemodialysis arteriovenous fistula in the lower limb. J Vasc Bras 2007; 6:288–292.

15 Wang S, Almehmi A, Packer J. Dilator-assisted banding for managing complications associated with excessive hemodialysis access flow. Semin Dial 2013; 26:100–105.

16 Schanzer H, Schwartz M, Harrington E, Haimov M. Treatment of ischemia due to 'steal' by arteriovenous fistula with distal artery ligation and revascularization. J Vasc Surg 1988; 7:770–773.

17 Smith GE, Barnes R, Green L, Kuhan G, Chetter IC. A 'christmas tree' band for the treatment of arteriovenous dialysis accessrelated steal syndrome. Ann Vasc Surg 2013; 27:239.e9–239.e12.

18 Illig KA, Surowiec S, Shortell CK, Davies MG, Rhodes JM, Green RM. Hemodynamics of distal revascularization-interval ligation. Ann Vasc Surg 2005; 19:199–207.

19 Bruns SD, Jennings WC. Proximal radial artery as inflow site for native arteriovenous fistula. J Am Coll Surg 2003; 197:58–63.

20 Wixon CL, Hughes JD, Mills JL. Understanding strategies for the treatment of ischemic steal syndrome after hemodialysis access. J Am Coll Surg 2000; 191:301–310.

21 Mickley V. Steal syndrome estrategies to preserve vascular access and extremity. Nephrol Dial Transplant 2008; 23:19–24.

22 Chemla ES, Morsy M, Anderson L, Whitemore A. Inflow reduction by distalization of anastomosis treats efficiently high-inflow high-cardiac output vascular access for hemodialysis. Semin Dial 2007; 20:68–72.

23 Leake AE, Winger DG, Leers SA, Gupta N, Dillavou D. Management and outcomes of dialysis access-associated steal syndrome. J Vasc Surg 2015; 61:754–760.

24 Vaes RH, van Loon M, Vaes SM, Cuypers P, Tordoir JH, Scheltinga MR. One-year efficacy of the RUDI technique for flow reduction in high-flow autologous brachial artery-based hemodialysis vascular access. J Vasc Access 2015; 16(Suppl 9):S96–S101.

25 Misskey J, Yang C, MacDonald S, Baxter K, Hsiang Y. A comparison of revision using distal inflow and distal revascularization-interval ligation for the management of severe access-related hand ischemia. J Vasc Surg 2016; 63:1574–1581.

26 Berman S, Gentile AT, Glickman MH, Mills JL, Westerhand A, Marek JM. Distal revascularization-interval ligation for limb salvage and maintenance of dialysis access in ischemic steal syndrome. J Vasc Surg 1997; 26:393–404.

27 Zamani P, Kaufman J, Kinlay S. Ischemic steal syndrome following arm arteriovenous fistula for hemodialysis. Vasc Med 2009; 14:371–376.

28 Knox RC, Berman SS, Hughes JD, Gentile AT, Mills JL. Distal revascularization-interval ligation: a durable and effective treatment for ischemic steal syndrome after hemodialysis access. J Vasc Surg 2002; 36:250–255.