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Review Article

Revision Using Distal Inflow for the Treatment of Dialysis Access Steal Syndrome: A Systematic Review

Ali Kordzadeh, MBBS, MSc, MD, VA-BC, FEBS,[1,2] Luis Anibal Navarro Garzon, MD,[1] and Ali Davod Parsa, MD, PhD[2]

The aim of this systematic review is to establish the efficacy of revision using distal inflow (RUDI) on the primary endpoints of complete dialysis access steal syndrome (DASS) resolution and arteriovenous fistula (AVF) longevity. An electronic search of literature from 1966 to 2017 in CINAHL, Medline, Embase and the Cochrane library according to PRISMA standards was conducted. Quality evaluations and recommendations for practice were examined. Data on power, age, gender, comorbidities, arterial inflow, conduit material, fistulae type, follow-up, failure incidence, ischaemia grade, modality of diagnosis, morbidity and mortality were subjected to pooled analysis of prevalence at a 95% confidence interval (CI). Eleven studies involving 130 individuals with a median age of 57 [interquartile ranges (IQR), 54–65] and equal gender distribution were conducted. Of the patients with diabetes mellitus (67.3%), the most common type of AVF with DASS was brachiocephalic AVF (73.7%). Overall, the prevalence of success was 82.0% (95%CI, 74.4%–89.6%) over 12 months (IQR, 1–40 months). Grade 3 ischaemia was the most common type of DASS (49.2%). Grade 4 had the worst outcomes compared with grades 2 and 3. The overall morbidity was 3% with no mortality. Overall, RUDI is an effective treatment for various grades of DASS and their longevity.

[1] *Department of Vascular, Endovascular and Renal Access, Broomfield Hospital, Mid Essex Hospital Service NHS Trust, Essex, UK*
[2] *Faculty of Medical Sciences, Anglia Ruskin University, Cambridge, UK*

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Corresponding author: Ali Kordzadeh, MBBS, MSc, MD, VA-BC, FEBS. Department of Vascular, Endovascular and Renal Access, Broomfield Hospital, Mid Essex Hospital Service NHS Trust, Court Road, Essex CM17ET, UK
Tel: +44-1245-513497, Fax: +44-1245-515222
E-mail: Alikordzadeh@gmail.com

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Introduction

According to the National Kidney Foundation, Centre for Medicare and Medicaid Services (CMS) and Dialysis Patient Citizens, arteriovenous fistula (AVF) remains the access of choice (gold standard) for dialysis patients.[1,2] However, an increase in the incidence of end-stage renal disease in association with longer life expectancy has escalated the demand for more reliable, functional, cost effective and durable AVF.[3,4] This has subsequently resulted in the amplification and deployment of different endovascular and open salvage techniques for the management of AVF complications and their longevity.[5,6] Dialysis access steal syndrome (DASS) is one of those complications that not only threatens the durability of the AVF but could also result in significant morbidity and mortality.[7] Upon detection of DASS, surgical dictum mandates immediate intervention, and ligation or banding continues to be the most common modality of treatment.[8] In the last two decades, the introduction of novel and open surgical modalities have facilitated the treatment of DASS whilst preserving the longevity of the AVFs. Amongst them, revision using distal inflow (RUDI) has demonstrated some promising results; however, its efficacy has not been examined using a systematic methodology.[9] Therefore, the primary aim of this review is to evaluate the efficacy of RUDI in the treatment of DASS along with AVF preservation. The secondary objective is to evaluate the power, age, gender, comorbidities, arterial inflow, conduit material, fistulae type, follow-up, failure incidence, ischaemia grade, modality of diagnosis, morbidity and mortality.

Methods

Search strategy

A systematic and electronic search of literature from 1966 to October 2017 in Medline, Embase, CINAHL, and the Cochrane library was conducted. The following keywords

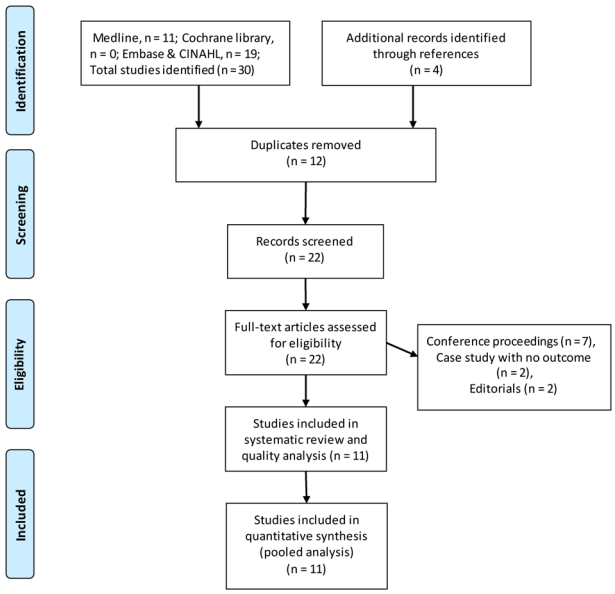

Fig. 1 The PRISMA flow chart.

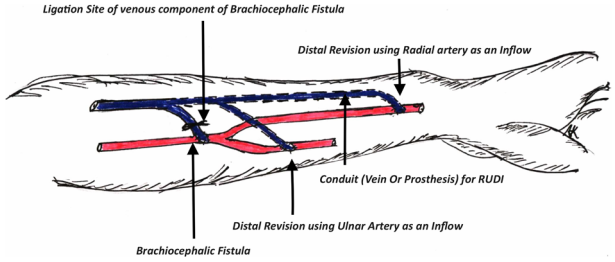

Fig. 2 Illustration of revision using distal inflow (RUDI) of the left-sided brachiocephalic fistula, demonstrating the site of ligation immediately at the old arteriovenous fistula (AVF), conduit positioning (5–10 cm), and use of radial or ulnar artery as an inflow.

and/or medical subject headings (MeSH) were used: 'Revision using distal inflow' and 'arteriovenous fistula,' 'Revision using distal inflow' and 'Fistula', and 'Revision using distal inflow' and 'AVF,' as well as 'RUDI' and 'arteriovenous fistula,' 'RUDI' and 'fistula', and 'RUDI' and 'AVF.' This search was conducted in accordance with PRISMA guidelines.[10] References for the retracted articles were manually evaluated for additional articles not identified in the primary search. Abstracts and data extraction were conducted by two independent investigators (AK and AA). The search was conducted in the English language, and articles with a paediatric population, animal inclusion, narrative reviews, conference proceedings, commentaries, editorials and opinions were excluded (**Fig. 1**).

Revision using distal inflow

RUDI was defined as an open salvage procedure that involved the ligation of the fistula at its origin, followed by establishment of the fistula via a vein and/or prosthesis conduit from a distal artery to the original AVF (**Fig. 2**).[9]

Table 1 Grades of ischaemia according to the classification by Tordoir et al.

Grade	Presentation
I	Pale/blue and/or cold hand without pain
II	Pain during activity/exercise and/or haemodialysis
III	Rest pain
IV	Ulceration/necrosis/gangrene

Definition and endpoint

a. DASS was defined as limb ischaemia secondary to the arteriovenous fistula with symptoms of pallor, pain, paraesthesia and poikilothermia, tissue loss and gangrene according to the grade of ischaemia classification developed by Tordoir et al. (**Table 1**).[11]

b. The endpoint was set as complete treatment of DASS, with a patent fistula for dialysis immediately after the RUDI without any adjuvant intervention for AVF preservation or that of DASS, including amputation.

Quality assessment and analysis

In order to reach an informed conclusion based on evidence-based practice, all included studies were examined for their bias, validity, inference and applicability using the critical appraisal tool provided by the Oxford Critical Appraisal Skills programme (CASP).[12] The grade and level of the evidence and their recommendations were evaluated according to the National Institute for Health and Care Excellence (NICE) Checklist.[13] Recommendations for future research were formulated based on the current systematic review outcomes. Data extraction included the power of each study, age, gender, comorbidities, distal inflow artery for RUDI (radial, ulnar and brachial artery), conduit material (great saphenous vein, cephalic vein, basilic vein and prosthetic material [PTFE]), fistula type (brachiocephalic AVF [BCAVF], brachio–basilic AVF), grade of ischaemia (grade 1–4), modality of diagnosis, follow-up period (months), failure incidence, morbidity and mortality.

Statistical analysis

The lack of comparative data (group vs. controlled) in the recruited articles meant meta-analysis was not plausible. Therefore, pooled prevalence of analysis at a 95% confidence interval (CI) was conducted. Variables were reported in median values along with interquartile ranges (IQR) and percentages. In studies where primary numerical data was not available, data was extracted from the provided percentage obtained from the total patient pool. Inter-observer agreeability for study selection, review and data extraction was examined by two independent review-

Table 2 Quality assessment of (n=11) studies by Oxford Critical Appraisal Skills programme (CASP) for cohort studies and level of evidence (NICE)

Investigator/ year	Study type	Cases	Clear aim	Recruitment bias	Exposure bias	Outcome measure-ment	Confounding factors	Follow up	Results	Applicability	Total score	Level of evidence
Minion et al. 2004 (15)	Cohort	n=4	Yes	No	No	Yes	Maybe	Yes	Yes	Yes	7/8	3
Chemla et al. 2007 (16)	Cohort	n=17	Yes	Maybe	No	Yes	Maybe	Yes	Yes	Yes	6/8	3
Callaghan et al. 2011 (23)	Cohort	n=7	Yes	No	No	Yes	Considered	Yes	Yes	Yes	8/8	3
Gupta et al. 2011 (24)	Cohort	n=4	Yes	No	No	Yes	Considered	Yes	Yes	Yes	8/8	3
Corfield et al. 2012 (25)	Cohort	n=3	Yes	No	No	Yes	Considered	Yes	Yes	Yes	8/8	3
Huynh et al. 2014 (26)	Cohort	n=15	Yes	No	No	Yes	Maybe	Yes	Yes	Yes	7/8	3
Vaes et al. 2015 (27)	Cohort	n=19	Yes	No	No	Yes	Considered	Yes	Yes	Yes	8/8	3
Leake et al. 2015 (28)	Cohort	n=21	Yes	Maybe	Yes	Yes	Maybe	Yes	Yes	Yes	5/8	3
Loh et al. 2016 (29)	Cohort	n=19	Yes	No	No	Yes	Maybe	Yes	Yes	Yes	7/8	3
Misskey at al. 2016 (30)	Cohort	n=20	Yes	No	No	Yes	Maybe	Yes	Yes	Yes	7/8	3
Huber et al. 2016 (31)	Cohort	n=1	Yes	No	No	Yes	Maybe	Yes	Yes	Yes	7/8	3

ers (AK and AA) using the Kappa coefficient. The statistical analysis was conducted using MedCalc Statistical software version 17.9 (MedCalc Software, Ostend, Belgium).

Results

The search produced a total of n=30 studies (**Fig. 2**). A further manual search of references revealed four more articles. All 34 articles were retrieved and studied by two separate investigators. Of these, 12 articles were duplicates and were thus excluded, seven were conference proceedings and two were case studies with no outcome. Therefore, 13 articles were further evaluated. After application of the exclusion criteria, a total of 11 articles were deemed suitable for this systematic review and pooled analysis. Of the eleven articles, four studies scored the maximum number of points (8/8), five scored 7/8, one 6/8 and one 5/8 according to the CASP tool. According to NICE guidelines, the level of evidence was III, with a grade C recommendation for clinical practice. The inter-observer agreeability (Kappa coefficient) was 0.8 (**Table 2**).

Outcome

The median age of the cohort was 57 (IQR, 54–65). There was an equal distribution amongst gender (male [50%, IQR, 38.1%–57.9%] vs. female [50%, IQR, 41.1%–61.95%]). Diabetes mellitus was noted in 67.3% (IQR, 59.3%–88.8%) of the population. In addition to clinical diagnosis (100%), duplex sonography was deployed in six studies (46.1%), digital photoplethysmography in five (38.4%) and digital arterial pressure in three (23%). The most common type of AVF with DASS was BCAVF (73.7%), followed by brachio–basilic AVF (25%), and the remaining AVF cases (1.3%) were prosthetic BCAVF. The presentation of ischaemic grade in order of prevalence was grade 3 (n=64/130, 49.2%), followed by grade 2 (n=53/130, 40.8%) and grade 4 (n=13/130, 10%). The conduit of choice for RUDI was the great saphenous vein (GSV) (55%), followed by the cephalic vein (21.8%), basilic vein and prosthetic material. The most common distal inflow artery used in RUDI was radial (61.5%), followed by the ulnar artery (38.5%). A total of 130 patients underwent RUDI; of these, 82% (n=106/130) (95%CI, 74.4%–89.6%) had a successful outcome over a median patency (follow-up) of 12 months (IQR, 1–40 months). A total of 10.7% (n=14/130) AVF cases following RUDI had ligation because of ongoing DASS, and 7.6% (n=10/130) had thrombosed AVF following RUDI creation. Two patients had single-digit amputation 1.5%, (n=2/130), one individual had permanent ischaemic neuropathy 0.76% (n=1/130) and one exhibited a noticeable evacuation of haematoma due to AVF rupture (0.76%).

There was no report of mortality from RUDI (**Table 3**).

Discussion

The outcome of this review indicates that RUDI is a feasible and safe procedure in resolving 82% of DASS whilst preserving the primary AVF over a median of 12 months. This is an acceptable outcome in contrast to the ligation technique, which results in complete loss of AVF with the requirement for bridging catheters that are not free from complications and cost implications. In addition, creation of a new AVF may not be free of anatomical and functional maturation pitfalls.[14] The outcome of this study suggests that patients with brachial artery-originated AVF—brachiocephalic (74%) and brachio-basilic AVF with a history of diabetes mellitus (67%)—are more prone to DASS as opposed to other variations of AVF. In our review, we encountered equal gender distribution (1:1), which appears to be in conflict with earlier reports (female predominance). This is attributable to the lack of any collated evidence in the literature and reliance on single cohort studies.[15]

Table 3 Results of pooled prevalence of analysis

Variables	Outcome
Demographics	
Age	57 (IQR, 54–65)
Male	50% (IQR, 38.1%–57.9%)
Female	50% (IQR, 41.1%–61.95%)
Diabetes mellitus (DM)	67.3% (IQR, 59.3%–88.8%)
Investigations	
Clinical examination	100%
Duplex sonography	46.1%
Digital photoplethysmography	38.4%
Digital arterial pressure	23%
Grade of ischaemia	
Grade 2	40.7% (n=53/130)
Grade 3	49.2% (n=64/130)
Grade 4	10% (n=13/130)
Arteriovenous fistula	
BCAVF	73.7% (66.7%–89.5%)
BBAVF	25% (6.8%–33.3%)
Conduit type	
Great saphenous vein (GSV)	55% (22.5%–73.3%) N=48/130
Cephalic vein	21.8% (0%–45%) N=14/130
Prosthetic (PTFE)	0% (0%–18.8%) N=7/130
Basilic vein	0% (0%–13.2%) N=7/130
Distal artery	
Radial artery	61.5% (50%–88.8%)
Ulnar artery	38.5% (11.3%–50%)
Brachial artery	0% (0%–5.3%)
Outcome	
Patency	12 (IQR, 1–40) months
Morbidity	3% (n=4/130)
Mortality	0%

BCAVF: brachiocephalic arteriovenous fistula; BBAVF: brachi-basilic arterivenous fistula

Development of chronic or acute ischaemia in AVF requires prompt recognition to avoid irreversible neurological damage and tissue loss. This is clinically suspected and was confirmed by haemodynamic studies ranging from digital pulse plethysmography to Doppler flow and fistulograms.[16] This review demonstrated that clinical diagnosis of DASS was 100% accurate and was supplemented with the aforementioned adjuvant modalities of investigations depending on each centre's expertise before and after RUDI. Overall, it appears that manual compression of the AVF and increase in the distal pressure and/or reversal of the flow confirms ischaemic changes in these settings.[17] In such circumstances, the treatment is focussed on the resolution of the ischaemic changes by improving the distal flow and perfusion whilst preserving the AVF.[11] The 'Hagen–Poiseuille's Law' states that the flow of a fluid with constant viscosity across a gradient is proportional to the fourth power of radius of the lumen and inversely proportional to the length.[18] Therefore, in order to achieve flow reduction (stealing AVF) and direct higher flow to the distal arteries, reduction of inflow radius and/or lengthening of the conduit (outflow) according to this law remains the most viable and logical approach.[18] In such circumstances, RUDI takes advantage of both principles—use of the radial and ulnar artery instead of the brachial artery and lengthening of the conduit—whilst preserving the fistula. Some clinicians may contend that banding (Dacron wrap, T-banding, MILLER)[8,19] may be equally effective; however, banding of the fistulae primarily addresses one principle (reduction of inflow) and is associated with a higher incidence of thrombosis, as flow reduction has to be meticulously calculated (intraoperatively). Furthermore, it does not account for daily variations in the blood pressure. Secondly, revision of the banding because of its primary failure or of the prosthetic graft could prove technically challenging. Finally, the question of precise optimal surface reduction or percentage in banding for different vessel calibres (diameter) remains unanswered despite some encouraging outcomes.[20]

The success of the procedure in relation to the ischaemia grade did not exhibit any statistical difference on both endpoints (preservation of AVF and no adjuvant surgery) despite higher a number of individuals in grade 3 ischaemia (49.2%) (grade 2, 40.7%; grade 4, 10%). However, if morbidity is considered an independent endpoint

(irrespective of AVF preservation), RUDI for grade 4 had the worst outcome as opposed to grades 2 and 3 with 3% morbidity (n = 4), thus requiring adjuvant intervention or investigations (digital amputation, ischaemic neuropathy and AVF rupture). Finally, the clinical question could be raised as to why such an advanced grade of ischaemia (grade 4) was not noted or treated at a much earlier phase.

The outcome of this review demonstrates that once RUDI has been planned, the use of an autogenous conduit in the form of the great saphenous vein (55%) and cephalic vein (21.5%) remains the preferred choice over prosthetic material. This is because autogenous conduits have demonstrated better long-term patency along with easier cannulation (needling). Moreover, they are less liable to infection and proven to be more cost effective.[21] The most common distal inflow in RUDI was radial (61.5%), followed by ulnar artery (38.5%). This is primarily because the radial artery possesses a greater blood flow as opposed to the ulnar artery and remains the dominant vessel at the wrist level.[22]

Finally, the question remains as to why the remaining patients (18%) with DASS did not benefit from RUDI. Amongst them, 7.6% (n = 10/130) of the individuals had a thrombosed AVF following surgery. If technical setbacks are regarded as a minor contributing factor, an objective inference can be drawn that inflow disease (brachial, radial or ulnar) rather than high flow or steal could contribute to this adversity (thrombosis). Therefore, a precise preoperative haemodynamic evaluation of inflow artery irrespective of ischaemic grade remains vital as this could serve as a filtering tool and help avoid the unnecessary multiple exposures of patients to interventions.

Strengths and Limitations

This is the first systematic review that investigated the efficacy of RUDI for the treatment of DASS and could serve as a platform for future research and practice. This review inherits a reproducible and robust methodology along with grading and critical analysis. A meta-analysis instead of pooled analysis would have been optimal; however, this depends on the availability of data and not on the discretion of the investigators.

This study is relatively low in power for an objective inference and a larger cohort would have been preferred. Some studies did not report the included patient details meticulously. However, a good percentage of reporting was achieved in the pooled analysis. The outcome of this review only applies to those patients that had RUDI for DASS. In addition, the outcome does not suggest in any way that this procedure should be used as a replacement for other techniques, such as distal revascularisation and interval ligation (DRIL) or proximalisation of arterial inflow (PAI or PAVA), as no active comparison could be conducted.

Overall, there is no clear consensus on the best modality for the treatment of DASS in terms of procedure (DRIL vs. RUDI vs. PAVA). It is believed that the radial artery-based access procedures (e.g., RUDI) usually result in poor outcomes for elderly and diabetic patients. However, it is worth mentioning that RUDI, as a modality, threatens the AVF and not the inflow (artery). Moreover, the ideal length and diameter of conduit for RUDI has not been established, but an increase in the arterial resistance proximal to the AVF remains a positive outcome of this RUDI. Randomised controlled trials comparing such modalities with their indication may be very useful in defining an algorithmic approach to DASS treatment.

Conclusion

The success of RUDI (82%) is incorporated in its ability to tackle two primary principles: smaller distal inflow and lengthening of the outflow conduit. RUDI is a feasible and effective treatment for different ischaemia grades; however, the best outcome (AVF preservation and no adjuvant therapy) was achieved in grades 1–3 with overall 12 months' patency (Level III evidence and grade C recommendation).

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Author Contributions

Study concept: AK
Data collection: all authors
Writing: AK
Critical review and revision: all authors
Final approval of the article: all authors
Illustration: AK

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