ORIGINAL ARTICLE

# DISTAL REVASCULARIZATION AND INTERVAL LIGATION PROCEDURE FOR THE TREATMENT OF DIALYSIS ACCESS INDUCED STEAL SYNDROME

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**Background:** We aim to share our experience of the efficacy of Distal Revascularization and Interval Ligation (DRIL) in alleviating ischemic symptoms of dialysis access induced steal syndrome (DAISS) while preserving the original access. **Methods:** In this multicentre study, all consecutive patients with DAISS undergoing DRIL over a period of 3 years were included. **Results:** A total of 25 DRILs were included. Mean age was 37.8±SD 7.8 years and 52% (n=13) were females. Out of 25 patients; 88% (n=22) had more than one of the following ischemic symptoms: coolness (96%), pain (88%), paresthesia (80%), and discoloration (44%). Significant improvement following DRIL was noted in paraesthesia (86%, *p*-value 0.00), pain (85%, *P* value 0.00), coolness (83%, *p*-value 0.00). There was significant improvement in distal blood flow following DRIL, reflected by increase in the Aggregate Peak Systolic Velocities (PSV) in forearm vessels ($PSV_{aggregate}$ pre-op 39cm/s: $PSV_{aggregate}$ post-op 58 cm/s; *p*-value 0.01). The cumulative patency of DRIL graft was 96% at 3 months, 84% at 6 months and 76% at 1 year. **Conclusion:** Distal Revascularization and Interval Ligation significantly improves circulation to the distal limb and reduce ischemic symptoms thus making it a procedure of choice for treatment of DAISS.

**Keywords**: Hand ischemia; Arterio-venous fistula; DRIL; Steal syndrome; Dialysis access

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## INTRODUCTION

Dialysis access induced ischemic steal syndrome (DAISS) is an uncommon complication of arteriovenous fistula requiring surgical correction in 5% of cases.[1] Steal phenomenon develops due to diversion of blood flow from distal limb to low resistance vein of arteriovenous fistula (AVF).[2,3] There is also reversal of blood flow away from the higher resistance distal arterial bed into the AVF in retrograde manner.[2,3] The prevalence of such retrograde blood flow causing symptomatic steal syndrome is variable (20–90%) based on the configuration of the AVF.[4] The management of patients with mild ischemia is conservative. Definitive treatment is reserved for patients with moderate and severe ischemia clinically manifesting as rest pain, paraesthesia or tissue loss. Common options which surgically correct DAISS while maintaining the dialysis access includes banding[5], distal revascularization and interval ligation (DRIL).[5,6] and Revision Using Distal Inflow (RUDI).[7] DRIL, first described by Schanzer *et al* involves a bypass conduit from artery proximal to the arteriovenous fistula to a distal recipient artery with ligation of the artery in between the fistula and the distal anastomosis.[8] Conceptually, this combination increases peripheral perfusion to the hand while simultaneously blocking retrograde blood flow to the access.[9] The aim of this study is to evaluate the efficacy of DRIL in terms of alleviating the ischemia symptoms of steal syndrome while preserving the original haemodialysis access.

## MATERIAL AND METHODS

This study included all patients diagnosed with steal syndrome who attended Vascular Surgery Clinic between January 2015 to January 2018 in Combined Military Hospital Lahore, Combined Military Hospital Peshawar and Midcity Hospital Lahore. Patients were eligible if they had an AVF created at elbow and were suffering from clinical features of steal syndrome confirmed further by Ultrasound Doppler. Patients who denied DRIL, patients with AVF in distal forearm or wrist, patients with multiple comorbid unfit for surgery and patients who did not maintain their 6 months follow up were excluded from the study. If a patient had a repeat DRIL, such incidence was recorded as a new entity. The study was performed according to the declaration of Helsinki. The formal study approval was obtained from the Institutional Ethical Review Committee.

Steal syndrome was diagnosed by the presence of clinical findings of hand ischemia (coolness of the affected limb in comparison with the opposite limb, pain, paresthesia, pain on dialysis, paresis and presence of tissue loss such as ulceration and gangrene). All patients with clinical features of steal also underwent Doppler study (10 MHz linear

probe; LOGIQ Book, GE Medical Systems, Wisconsin, U.S.A). We recorded Peak Systolic Velocities (PSV) in both radial and ulnar arteries. The measurements were done at three points from elbow to wrist. Proximally within 3 centimeter of brachial artery bifurcation ($PSV_{rad\ prox}$, $PSV_{uln\ prox}$), 3 cm proximal to the palmer arch ($PSV_{rad\ distal}$, $PSV_{uln\ distal}$) and halfway between proximal and distal sites ($PSV_{rad\ mid}$, $PSV_{uln\ mid}$). Mean PSV radial ($PSV_{rad}$) was calculated as a mean of the three radial measurements. Similarly mean PSV ulnar artery ($PSV_{uln}$) was calculated as a mean of the three ulnar measurements. Mean PSV aggregate ($PSV_{agg}$) was calculated as the average PSV of all six measurements of both ulnar and radial artery. These measurements were done in all patients atleast one week before the surgery. Post operatively measurements were repeated at 3, 6 and 12 months. Mean of these 3 were calculated at all sites and used for statistical calculations.

Distal Revascularization and Interval Ligation procedure was performed using standard technique. Autologous venous graft was used in all patients as a conduit. Venous mapping Great Saphenous Vein (GSV) was done in both thighs. In patients where diameter of GSV was 3 mm or less, Basilic Vein was harvested as graft. The proximal anastomosis was done to the brachial artery in end to side fashion above the elbow. Distal anastomosis was done to the brachial artery distal to the AVF. The brachial artery was ligated in all cases just distal to the AVF. The rationale of this procedure is to provide a separate blood flow channel to forearm and hand to prevent ischemia. Also, ligation of the brachial artery just distal to AVF prevents the diastolic reflux from hand into the AVF thus improving the ischemia symptoms. The primary end point of the study was death or loss of follow up.

The data was analyzed using SPSS 17.0. The numerical variables were expressed as Means and Standard Deviations (SD) and categorical data was expressed as Frequency and Percentage. Pre and post-operative PSVs were compared using Student's t-test to determine whether there was any significant change following DRIL procedure. *p*-value was calculated using McNemar's test. A value of less than or equal to 0.05 was considered statistically significant.

## RESULTS

A total of 25 DRIL procedures who fulfilled the inclusion criteria were included in this study. They were 52% (n=13) females and 48% (n=12) males. Mean age at the time of presentation was 37.8±SD 7.8 years (Range 26–56). A total of 84% (n=21) patients had diabetes mellitus, 28% (n=7) had hypertension and 20% (n=5) had hyperlipidemia. There were 28% (n=7) patients who were smokers. The baseline demographics of all patients is provided in table-1.

All the patients included in this study had AVF made at elbow. There were 88% (n=22) brachiocephalic (BC) and 12% (n=03) brachiobasilic (BB) AVFs. Dialysis was started once the fistula was considered mature. Most of the patients (n=16, 64%) had no previously failed AV fistulas, while the remaining 36% (n=9) had atleast 1 previously failed AVF (Table-1).

Mean time from creation of fistula to development of symptoms of steal syndrome was 3.3±SD 1.1 months (Range 1–5). The distribution in terms of time elapsed from fistula creation to development of ischemic symptoms of steal syndrome is shown in figure-1. Mean time interval between access creation and DRIL was 3.8±SD 1.1 months (Range 2.5–7). Autologous venous graft was used in all patients as a conduit; GSV was harvested from thigh in 80% (n=20) patients while ipsilateral Basilic Vein was used as a graft in 20% (n=5) cases. Mean flow rates in AVF before and after the DRIL procedure were 855 and 832 ml/min respectively. There was no statistical change in AVF flow rates related to DRIL procedure (*p*-value 0.18).

The most frequently reported symptom of steal syndrome amongst the patients was coolness of the affected limb relative to the patient's opposite limb, occurring in 96% of all patients (n=24). Paresthesia, pain and discoloration were next common symptoms seen in 80% (n=20), 88% (n=22), 44% (n=11) patients respectively (Table-2). All patients had more than one symptom and 88% (n=22) had three or more of the above four commonest symptoms. A total of 56% (n=14) patients had complete resolution of DAISS symptoms. In order of frequency, the symptoms relieved post-operatively were; paresthesia (n=19, 86.3%) followed by pain (n=17, 85%), coolness (n=20, 83.3%), discoloration (n=9, 81.8%), paresis (n=4, 80%), pain at dialysis (n=5, 71.4%) and ulceration (n=4, 66.7%). There was no further progression of digital gangrene in patients (n=4, 100%) after DRIL who initially had gangrene of finger tips before DRIL. Few patients developed symptoms after DRIL. The new onset of ischemic symptoms following the DRIL procedure were pain (n=3, 12%), discoloration (n=2, 8%), pain at dialysis (n=1, 4%), coolness (n=1, 4%), paresthesia (n=1, 4%) and paresis (n=1, 4%). None of the patients presented with new onset tissue loss, i.e., ulceration or gangrene after DRIL, during the follow up period.

Peak Systolic Velocities in the ulnar and radial artery were compared using the Paired t-test

(Table-3). A significant difference (*p*-value 0.01) was noted in mean PSV in the ulnar artery after DRIL. There was an increase in PSV from 41 cm/s to 65 cm/s (*p*-value 0.01) in the proximal segment, 40 cm/s to 71 cm/s (*p*-value 0.01) halfway and 41 cm/s to 66cm/s (*p*=0.01) in the distal segment respectively. Similarly, increase in PSV in radial artery was also noted after DRIL. However, the changes were statistically insignificant (*p*-value 0.07). The mean PSV increased from 38 cm/s to 46 cm/s (*p*-value 0.06) in the proximal segment, 39 cm/s to 52 cm/s (*p*-value 0.08) halfway and 39 cm/s to 52 cm/s (*p*-value 0.07) in the distal segment. There was significant increase in the Aggregate Peak Systolic Velocities (PSV) in forearm vessels (PSV $_{aggregate}$ pre-op 39cm/s: PSV $_{aggregate}$ post-op 58cm/s; *p* value 0.01)

Primary end points of study was death (0%) in first year, failure of DRIL graft due to thrombosis (12%, n=3) or stenosis (8%, n=2) and other failures (20%, n=5). Both patients with graft stenosis underwent successful angioplasty of the graft thus alleviating their residual DAISS symptoms. Two out of 3 patient with thrombosis underwent successful thrombectomy. No mortality was reported in first 12 months. However, we lost 24% (n=6) patients in second year due to multiple comorbidities thus bringing down the survival rate to 76% at the end of 2 years.

Out of the 25 procedures, 96% (n=24) were patent at 3 months, 84% (n=21) at 6 months. The primary patency of DRIL at 1 year was 60% (n=15). However, after successful interventions in 4 patients, the cumulative patency rate at 1 year rose to 76% (n=19) (Figure-2). Mean Follow up after DRIL was 2 years ± SD 0.4 (Range 1.5–3.5).

**Table-1**: **Baseline demographics of patients and their AVFs**

| **No. of patients (n)** | **25** |
|---|---|
| **Gender [n (%)]:** | |
| Male | 12 (48) |
| Female | 13 (52) |
| **Age in Years [Mean ± SD]** | 37.8±SD 7.8 |
| **Comorbid factors [n (%)]:** | |
| Diabetes Mellitus | 21 (84) |
| Hypertension | 7 (28) |
| Hyperlipidaemia | 5 (20) |
| Smoking | 7 (28) |
| Peripheral vascular disease | 15 (60) |
| Coronary artery disease | 17 (68) |
| **Site of AVF [n (%)]:** | |
| Brachiocephalic (BC) | 22 (88) |
| Brachiobasilic (BB) | 3 (12) |
| **Previous failed AVFs [n (%)]:** | |
| 0 | 16 (64) |
| 1 | 4 (16) |
| 2 | 4 (16) |
| 3 or more | 1 (4) |

**Table-2: Symptoms and symptoms relief before and after the DRIL procedure**

| **Symptoms** | **Before DRIL [n (%)]** | **Symptoms relieved after DRIL [n (%)]** | ***p*-value** | **Patients developing symptoms after DRIL [n (%)]** |
|---|---|---|---|---|
| Pain | 20 (80) | 17 (85) | 0.00 | 3 (12) |
| Pain at dialysis | 7 (28) | 05 (71) | 0.06 | 1 (4) |
| Coolness | 24 (96) | 20 (83) | 0.00 | 1 (4) |
| Discoloration | 11 (44) | 09 (82) | 0.04 | 2 (8) |
| Paresthesia | 22 (88) | 19 (86) | 0.00 | 1 (4) |
| Paresis | 5 (20) | 4 (80) | 0.12 | 1 (4) |
| Ulceration | 6 (24) | 4 (67) | 0.12 | 0 (0) |

**Table-3**: **Peak Systolic Velocities in radial and ulnar arteries**

| **Peak Systolic Velocity (PSV)** | **Ulnar artery** | | | **Radial Artery** | | |
|---|---|---|---|---|---|---|
| | **Pre-op (Mean) (cm/s)** | **Post-op (Mean) (cm/s)** | ***p*-value** | **Pre-op (Mean) (cm/s)** | **Post-op (Mean) (cm/s)** | ***p*-value** |
| PSV proximal | 41 | 65 | 0.01 | 38 | 46 | 0.06 |
| PSV halfway | 40 | 71 | 0.01 | 39 | 52 | 0.08 |
| PSV distal | 41 | 66 | 0.01 | 37 | 50 | 0.07 |
| PSV Mean | 41 | 66 | 0.01 | 38 | 50 | 0.07 |

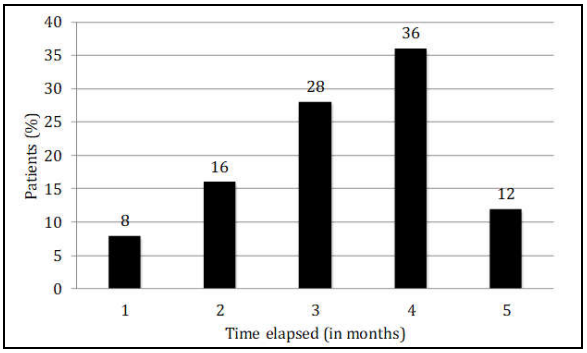


**Figure-1: Time elapsed from Steal to DRIL**

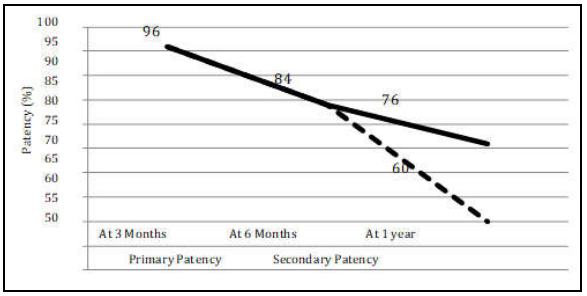


**Figure-2: Patency rates of bypass graft after DRIL procedure**

## DISCUSSION

Dialysis access induced ischemic steal syndrome is uncommon complication occurring in 5–20% patients and half of these require operative intervention.[1,5,10] The goal of treatment is to reverse the ischemia symptoms in hand while preserving the primary

access. Various treatment options are available including banding, bypass and proximalization.[5,7] DRIL is considered an effective option since it results in reversal of ischemic symptoms in more than 90% of patients.[11] The exact mechanism in which DRIL relieves DAISS is complex. Provision of extra conduit for forearm and hand separate from the primary AVF, along with blockade of retrograde flow from high resistance forearm towards low resistance AVF (diastolic reflux) by ligation of the main artery distal to AVF are the main contributing factors for relief of ischemic symptoms.[2–4]

Patients developing ischemia are mostly females and diabetics .[6,7,12–14] In our study also there were 52% females. Interestingly 85% (11/13) of these females were diabetics too. Hence, we propose that female gender and diabetes are positive risk factors for development of DAISS.

The clinical worth of DRIL is based on how effective it is in relieving the ischemic symptoms while preserving the original access. The resolution of ischemic symptoms in excess of 80% has been reported in various studies.[13-15] We have also seen improvement in various ischemic symptoms. DRIL has been markedly effective in relieving ischemic rest pain and coolness and tissue loss in excess of 80% similar to previously reported studies. Interestingly, there were 3 patients who had paresthesia as chief complaint and after DRIL their paresthesia instead of getting any relief, reportedly got worse. This phenomenon has been explained as ischemic monomelic neuropathy which is resistant to get a cure with DRIL.[14–16] We presume these 3 patients in our series also had monomelic neuropathy as they did not find any relief to their neuropathic symptoms after DRIL although other ischemic symptoms such as coolness and ulceration showed improvement.

Although most of the studies have clinically assessed the efficacy of DRIL in terms of improvement in the ischemic symptoms.[13,14] Others in addition to clinical symptoms, have quantitatively measured the blood flow rates in forearm and hand by using various indices such as systolic index finger pressure.[17] wrist/brachial and digital/brachial indices[15,8] and pulsed volume recordings.[18] etc. Waltz *et al* concluded a significant increase in pulse volume recordings after DRIL ($P$ value < 0.05).[18] Similarly, Scali *et al* has demonstrated a significant increase in wrist/brachial and digital/brachial indices ($p$-value <0.05).[15] We measured PSV and there was marked increase in aggregated mean PSV following the DRIL procedure ($p$-value <0.05). These findings are consistent with previous studies; hence further augmenting the fact quantitatively, that DRIL is a very effective and reliable option for relief of DAISS. Vaes *et al* while investigating the blood flow hemodynamics in DAISS, demonstrated that such patients had marked reduction in blood flow in terms of PSV and systolic index finger pressure when compared to a control group.[17] Although, we had no control group in our study but our PSVs before and after the DRIL procedure clearly showed a significant improvement in terms of blood flow to the ischemic hand. We understand that there should be multiple quantitative measurements performed to assess the improvement in blood flow more effectively and we consider this as a limitation to our study.

We have used autologous vein as a conduit in all our patients. 80% had autologous GSV harvested from thigh. Due to the fear of small diameter of vein below the knee or those who had a diameter of less than 3mm above the knee, we used basilic vein as bypass graft. We believe the use of autologous graft is a positive factor for higher graft patency. This is consistent with reports of its impact on patency of lower extremity arterial bypass graft.[19] Similar to our study; Scali *et al*[15] used GSV in 75% and arm vein in 18% cases while Aimaq *et al*[14] used GSV in 91% of their DRILs.

The long-term survival of patients undergoing DRIL is low due to the fact that such patients have multiple comorbidities along with end stage renal disease (ESRD). We are reporting mortality rate of 24% in this study by the end of 2 years. Berman *et al* reported a high mortality rate of 29% within first year of DRIL and this was due to multiple cardiovascular complication in ESRD patients.[20] Other studies have also shown a high mortality rate due to similar comorbidities; ranging from 10–40% at year 1–44% by the end of 2 years .[3,6,8,15,20]

There is certain limitation in our study. The small sample size predisposes the study to type 2 error. However, the total number of patients in various studies is also small. Misskey *et al* had done a total of 22 cases and Loh *et al* has performed 28 DRIL procedures.[12,13] Leake *et al* had 59 DRIL but over a span of a decade.[5] Furthermore, even in institutions where the workload of primary AVF creation is high, there are few patients who develop DAISS needing surgical intervention. Considering that it is a non-randomized study there is always a risk of selection bias, however it is worth noting that due to small number of patients and multiple comorbidities in such cohort, we believe that such a randomized trial in this subset of patients is very unlikely. Finally, high mortality rate in patients after DRIL, raises a question mark on midterm and long-term patency rates of DRIL grafts hence contributing to overestimation of their patency rates.

## CONCLUSION

DRIL is an effective procedure in alleviating the dialysis access induced ischemic symptoms while preserving the primary access. Although the short-term patency of the graft is very good, the long-term patency needs further evaluation since such patients have limited life expectancy due to multiple comorbidities. Multicentre studies on large scale with large cohort of patients may be helpful in assessing the long-term patency of graft and efficacy of DRIL.

## AUTHORS' CONTRIBUTION

RU, MJ: Study conception. AK, AT: Data collection, investigation. RU, AK, AT: Analysis. RU, MJ, AK, AT: Writing, critical review, revision, final approval, accountability for all aspects of the work.

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