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RESEARCH ARTICLE

HEMODIALYSIS ACCESS INDUCED DISTAL ISCHEMIA; EFFECTIVENESS OF DIFFERENT TYPES OF REVISIONAL SURGERIES.

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Abstract

Objectives: Hemodialysis access induced distal ischemia (HAIDI) is not a rare complication of hemodialysis access and may lead to limb loss at any time from creation. Distal Revascularization Interval Ligation (DRIL), Proximalization of Arterial Inflow (PAI), Surgical Banding, Revision Using Distal Inflow (RUDI), Side branch ligation (SBLs) and Distal Radial Artery Ligation (DRAL) all are surgical re-interventions aiming for improving the distal limb flow improving ischemic manifestations as well as maintaining a functioning hemodialysis access. Although DRIL and surgical Banding are well known techniques and their results are well established. RUDI,DRAL and PAI are relatively new surgical interventions for HAIDI treatment. Results of PAI, RUDI, banding, SBL and DRIL are compared in this study as regard resolutions of ischemic manifestations, patency of both the access and the vascular conduit.

Methods: All patients attending to Vascular Clinic at Mansoura University Hospital from May 2014 to May 2018 suffering from acute non-thrombotic, subacute non-thrombotic and chronic HAIDI grade 2a-4b related to the present hemodialysis access were included.

Results: 28 patients were exposed to the previously mentioned techniques. 30 procedures were performed. 12 DRIL, 4 RUDI, 2 PAI, 6 surgical Banding and 2 Side Branch Ligations. Two cases underwent DRAL for distal radial artery based AVF and two cases underwent ligation of the fistula for major tissue loss.

Mean age was 53.9 years, 57% of patients were female and 64.2% were diabetics. No differences in patient comorbidities among patients in different surgical group. The median postoperative follow up duration for the 30 procedures done was 9.5 (1-24) months with non-significant difference in mean follow up duration among the different surgical groups.

As regard the AVF patency immediate closure recorded in two cases that underwent ligation. Of the remaining 28 procedures; AVFs were kept patent all over the follow up periods (3-24 months) in 16 cases (57.1%). While in the remaining 12 cases AVF patency was 100% at 6 months follow up period and 58.3% (7 cases) at 12 months follow up.

Patency of the brachial artery bypass graft in the DRIL group was 91.7% during the whole period of follow up. Conduit patency of the RUDI group was 75% and 50% for the PAI group during the whole period of follow up.

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Overall ischemic rest pain resolution was 76.7%. Complete resolution of ischemic manifestations had occurred in 75% of the RUDI group, 50% of the PAI cases, 50% in SBLs group, 100% in DRAL group, 83.3% in the DRIL group and 66.7% in the Banding group (P-value = 0.440).

Conclusions: In this preliminary study, the RUDI demonstrated similar patency, symptom resolution, and survival compared with the DRIL for patients with severe HAIDI. All-cause mortality after any procedure for severe steal syndrome is high, and the particular intervention for management of steal must account for anatomic-, patient-, and disease-related considerations.

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Introduction:-

Steal (the reversal of flow in the distal artery) after AVF creation is common weather symptomatic or non-symptomatic as about 80% of patients show reduction in the digital pressures after access creation.1 Hemodialysis Access Induced Distal ischemia (HAIDI) has been shown to affect up to 30% of patients after brachial artery based AVF creation; however, cases requiring surgical revision are uncommon, with reported rates between 1.8% and 12%. 2

The distal revascularization interval ligation (DRIL) procedure has been first described by Schanzer et al., 3 and became the procedure of choice for the correction of distal ischemia together with access preservation.4 DRIL procedure was proved to be durable revisional surgical procedure for HAIDI with excellent long term patency rates reaching up to 80% at 5 years. 5-8

In addition to DRIL procedure, revision using distal inflow (RUDI),9 proximalization of arterial inflow (PAI),10 surgical banding of the venous outflow,11 the minimally invasive limited ligation endoluminal-assisted revision procedure,12 and transposition of the radial artery,13 have been introduced as alternative revisional procedures for the management of HAIDI. The purpose of this study was to review our local experience with different procedures and compare their outcomes in relieving HAIDI manifestations.

Patients and Methods:-

This study received ethical approval from the Faculty of Medicine Mansoura University Ethical Research Board.
All patients attending to Vascular Clinic at Mansoura University Hospital from 2014 to 2018 suffering from hand manifestations after creation of an ipsilateral hemodialysis access were examined for the presence of access related ischemia.

Demographic data and comorbidities were collected also the type of fistula was recorded. Examination for scars of previous angioaccess procedure and peripheral pulsation of both upper limbs was done. Ischemic manifestations were recorded for each patient. Ischemia severity was graded and reported according to the classification designed by Scheltinga et al. in 2009. 14

All cases underwent duplex assessment on the ipsilateral upper limb with specific comment on patency of the anastomosis, patency of the venous side of the access, patency of the ipsilateral deep venous system, patency of the arterial tree from the axillary artery down to the palmar arch, peak systolic velocity (PSV) proximal and distal to the anastomosis, flow velocity in the venous side of the access, presence or absence of flow reversal distal to the AVF. Angiographic imaging was done in selected cases according the duplex finding.

Management Protocol:-

All Patients with Brachial artery and Distal (radial or ulnar) artery based AVF and suffering from chronic HAIDI grade 2b, grade 3 and grade 4a,b were considered in this study. Patients with Acute and sub-acute non-thrombotic HAIDI were also considered in this study.

HAIDI was considered acute when presented in the first 24 hours and subacute when presented in the first month. The clinical classification of chronic HAIDI cases in this study follows that proposed by Scheltinga et. al. in 2009 illustrated in table (1).

Patients were selected randomly to the surgical procedure; RUDI group (I), DRIL group (II), PAI group (III) Banding group (IV). Patients with distal artery based AVF induced HAIDI were exposed to DRAL procedure. Patients with multiple or single side branch were exposed to side branch ligation (SBLs) either alone or with other revisional procedure. Fistula ligation was performed in patients with HAIDI grade 4b, poor life expectancy, postoperative nonfunctioning fistula, failed multiple salvage trials.

HAIDI GRADE	Clinical presentation	Management
HAIDI Grade I	no clear symptoms Slight cyanosis of nail beds, mild coldness of skin of hand, reduced arterial pulsations at wrist, reduced systolic finger pressures.	Conservative.
HAIDI Grade IIa	Complain during dialysis orintense use of hand. Tolerable pain, cramps, parasthesias, numbness or disturbing coldness in fingers or hand.	Conservative.
HAIDI grade IIb	Complaint during dialysisor use of hand. Intolerable pain, cramps, parasthesias, numbness or disturbing coldness in fingers or hand.	Combined treatment including conservative and invasive treatment (endovascular or surgical).
HAIDI Grade III	Rest pain Motor dysfunction of fingers or hand.	Urgent invasive treatment supported by conservative measures.
HAIDI Grade Iva	Minor tissue loss (ulceration or necrosis). Hand function is probably maintained if ischemia is reversed.	Urgent invasive treatment supported by conservative measures.
HAIDI Grade IVb	Irreversible tissue loss Impossibility to preserve hand function.	Ligation. Amputation is required.

Table 1:-Clinical classification of HAIDI.14

Surgical Technique:-

SBLs.

If the diagnostic work up or intraoperative findings reveals SBs, these structures require dissection and ligation as a first step before proceeding to a more difficult revisional procedure as this technique may be less effective if hemodynamically important SBs are left untreated. If pulse recurs after SBLs, nothing else will be done.

DRIL.

DRIL procedure is done in a similar manner to the previously published data. 4 Proximal anastomosis was taken from the brachial artery at least 7 cmproximal to the site of the AVF to prevent arterial bypass thrombosissecondary to locoregional hypotension produced by the AVF. 5

The distal bypass was being performed to either the brachial artery, radial artery or ulnar artery and was performed in an end-to-side manner. The preferred conduit for bypass was autologous saphenous vein at least 3 mm in diameter, with ipsilateral upper limb vein or PTFE graft used only in the absence of saphenous vein.

PAI.

PAI procedure technique is based on its first description by Zanow J. et al., in 2006. 10

After exposure of the pre-existing AVA through a curvilinear skin incision at the cubital fossa; the venous side of the fistula is ligated insitu or divided and ligated and the proximal cuff is used as patch for repair of the brachial artery. Another skin incision in the axilla (3 cm) is used to expose and mobilize a segment from the proximal brachial artery or the axillary artery (the proximal arterial target). Using an autogenous vein graft (great saphenous

vein is preferred) or a 6 cm prosthetic PTFE graft (converting the autogenous access to a composite one); an end to end or end to side anastomosis was created between the graft and the venous side of the previous access using continuous 6/0 Prolene suture. The conduit is then tunneled subcutaneously to be anastomosed with the proximal arterial target in the axilla using also continuous 6/0 Prolene suture.

RUDI.

The RUDI technique was based on the originaltechnique described by Minion et al in 2005. 5 After duplex assessment of the distal arterial tree and clinical evaluation by Allen's test the nondominant artery was used as the new arterial inflow leaving the dominant artery intact to perfuse the hand. The present AVA, brachial artery, cephalic vein (or basilic) were dissected, mobilized and controlled through extension of the previous skin incision.The distal arterial target was exposed through the same incision or through another incision in the proximal forearm. Then the distal arterial target was dissected and mobilized about 5 cm from the brachial artery bifurcation. The original venous outflow was ligated insitu or ligated and divided; when division ligation was done the residual cuff was used as patch for closure of the brachial artery. A 6-mm externally supported polytetrafluoroethylene graft (PTFE) was used as the preferred conduit as it crosses the elbow joint. Anastomosis is done with continuous 6-0 Prolene suture to the proximal part of the distal arterial target (radial or ulnar artery), and the graft was tunneled subcutaneously to reach the venous side of the pre-existing access 4-5 cm proximal to the previous anastomosis and an end to end or end to side anastomosis is performed.

Banding Procedure:

Under local anesthesia and complete aseptic conditions through transverse skin incision a 3 cm segment of the matured vein (2 cm from the AVA) was exposed and skeletonized circumferentially. A 2 cm PTFE segment was prepared and cut longitudinally to be wrapped around the matured vein narrowing it to a degree that restore the distal circulation and preserve the fistula patent and functioning guided by pulse examination and intraoperative duplex when available.

DRAL:

Under local anesthesia and complete aseptic conditions the radial artery was exposed distal to the site of anastomosis and ligated insitu by silk suture.

Statistical Analysis:-

Data were analyzed with SPSS version 21. The normality of data was first tested with one-sample Kolmogorov-Smirnov test. Qualitative data were described using number and percent. Association between categorical variables was tested using Chi-square test While Fischer exact and test was used when expected cell count less than 5. Continuous variables were presented as mean ± SD (standard deviation) for parametric data and median for non-parametric data. ANOVA test was used to compare more than 2 means While kruskil Wallis test was used to compare more than 2 medians. For all above mentioned statistical tests done, the threshold of significance is fixed at 5% level (p-value). The results was considered non-significant when the probability of error is more than 5% ($p > 0.05$), significant when the probability of error is less than 5% ($p \leq 0.05$), highly significant when the probability of error is less than 0.1% ($p \leq 0.001$). The smaller the p-value obtained, the more significant are the results.

Results:-

From 2014 to 2018, 28 cases of upper limb HAIDI were admitted to the Vascular surgery Department at Mansoura University Hospital. 17 patients of them had autogenous brachiocephalic AVF, 7 patients had brachiobasalic AVF, 2 patients had synthetic brachioaxillary AVF and 2 patients had distal radiocephalic AVF. Type of access and onset of symptoms after creation are illustrated in table (2).

Table (2): Type of Access and Onset of HAIDI after AVF creation.

Variables	Study group (n=28)		Onset of HAIDI by (Months)
	No	%	
Type of present AVF			
Distal Radiocephalic	2	7.1%	
Brachiocephalic	17	60.7%	Median = 6.5 (1-24)
Brachiobasalic (two stage)	7	25%	
Synthetic Brachioaxillary	2	7.1%	

53.6% of patients were HAIDI grade IVa, 39% wereHAIDI grade 3 HAIDI and 7% presented in the subacute stage. Risk factors among the different groups were similar with DM and HTN were the most common. Demographic criteria and comorbidities are summarized in table (3).

Table (3): Demographic and medical history of the studied group.

Demographic data		Study group (n=28)	
		No	%
Sex	Male Female	12 16	43% 57%
Age / y	Mean ± SD (Min-Max)	53.9±10 (35-69)	
DM		18	64.2
HTN		19	67.8
IHD		8	28.5
SLE		2	7.1
Dyslipidemia		7	25
Stroke		3	10.7
LL_PVD		3	10.7
Previous amputations		1	3.5
Smoking		7	25

No significant difference in the demographic data and patient comorbidities was noticed between the different surgical groups.

30 surgical interventions were performed during this study with 2 cases each of them underwent 2 different procedures; 12 DRIL (40%), 6 Surgical Banding (20%), 4 RUDI (13.3%), 2 (6.7%) PAI and 2 (6.7%) SBLs were performed for proximal brachial artery based AVF. Of the remaining 4 cases 2 underwent DRAL for distal radial artery based AVF and 2 brachiocephalic AVFs underwent ligation due to poor life expectancy.

As regard the indication of surgery for the 30 procedures, ischemic rest pain was present in all patients however it was a primary indication for surgery in only 12 (40%) patients. 18 (60%) patients had ischemic tissue loss (digital ulceration, digital necrosis, forearm ulcer or gangrene) as primary indication for intervention. Associated neurological pain was present in 8 patients (26.7%). 19 (63.3%) patients had motor hand weakness compared to the other hand. Table (4) illustrates the clinical presentation for the 30 surgical procedures.

No significant difference has been noticed among the different operative techniques as regard the clinical presentation, 100% of the DRAL group, 100% of the PAI group and 58% of the DRIL group were HAIDI grade 4a at presentation, 50% of the Banding group and 50% of the SBLs group were also HAIDI grade 4a. Only one patient in the RUDI group was HAIDI grade 4a. Eleven patients presented with grade 3 HAIDI, 5 (41.3%) in the DRIL group, 3 (75%) in the RUDI group, 2 (33.3%) in the Banding group and one (50%) in the SBLs group. Only one case was subacute presentation and the fistula was ligated. Table (5) summarizes the clinical grade of HAIDI for patients in each group at time of presentation. Two (100%) cases of the DRAL and two (100%) of the PAI groups had ischemic tissue loss at presentation. 7 cases (58.3%) of the DRIL group had ischemic tissue loss, 3 cases (50%) in the banding group and only one patient in the RUDI (25%) and SBLs (50%) groups with no significant difference among the different groups (P value> 0.05).

Table (4): Clinical presentation of patients prior to surgical intervention.

Variables	Study group (n=30)	
	No	%
Rest Pain	30	100
Neurological Pain	8	26.7
Motor Affection Not affected Mild weakness Moderate weakness Sever affection	 11 8 9 2	 36.7 26.6 30.0 6.7

Digital Ulceration	12	40.0
Digital Necrosis	7	23.3
Gangrene No Single finger Multiple fingers	 24 3 3	 78.6 10.7 10.7
Onset of symptoms after AVF Creation by months Median (Min-Max)	6.50 (1-24)	
Stage Chronic III Chronic IVa Subacute	 11 17 2	 36.7 56.6 6.7

Table 5:-Relation between Operative Technique and HAIDI Grade.

HAIDI Grade	DRAL (n=2)	DRIL (n=12)	RUDI (n=4)	PAI (n=2)	Banding (n=6)	SBLs (n=2)	Ligation (n=2)	p-value
Chronic 3	-	5 (41.7)	3 (75)	-	2 (33.3)	1 (50)	-	0.293
Chronic 4a	2(100)	7 (58.3)	1 (25)	2 (100)	3 (50)	1 (50)	1 (50)	
Subacute	-	-	-	-	1 (16.7)	-	1 (50)	

Preoperative duplex assessment was available in only 21 patients. Steal (flow reversal) was found in 13 patients (61.9%). Non-significant proximal atherosclerotic changes were found in 13 (61.9%) patients, the remaining 8 patients had normal duplex finding as regard the proximal arterial tree. Distally to brachial bifurcation the finding were different as only 7 (33.3 %) patients had a normal radial and ulnar arteries, 4 (19.1 %) patients had severe attenuated distal vessels, two (9.5 %) patients had moderate atherosclerotic changes of the distal vessels and 8 (38.2 %) patients had non-significant disease. The median proximal peak systolic velocity (PSV) was 245 cm/sec while the median distal PSV was 30 cm/sec. The preoperative venous flow velocity (VFV) was 2061.95 ± 622.42 ml/min. There was no significant difference between the different types of interventions as regard the preoperative duplex findings. Flow reversal was found in 57.1% cases of DRIL, 100%cases underwent DRAL, 100% cases of PAI, 25% case of RUDI, 33.3 of Banding and 100% one case of SBLs (P value = 0.291).

Proximal PVD was found in 71.4% cases of DRIL, 50% of RUDI, 100% of PAI, 33.3% of Banding and 50% of DRAL (P value = 0.832) while distal PVD was found in 71.4% of DRIL, 75% of RUDI, 100% of PAI, 33.3% of Banding and 50% of DRAL (P value = 0.861). The median distal PSV for DRIL cases was 32 cm/sec, for RUDI cases was 32.5 cm/sec, for PAI cases was 22.5 cm/sec and for Banding cases was 27 cm/sec (P value = 0.180). Also there was no significant difference in the preoperative venous flow velocity measurements. Mean VFV for DRIL cases was 2308.16±1059 ml/min, 1986.75±271.5 ml/min for RUDI, 1981±165.5 ml/min for PAI cases, 1993±288.04 ml/min for Banding cases (P value = 951). For the 30 operative procedures diagnostic CT Angiogram was done in only 5cases as preoperative diagnostic tool. 4 cases (13.3 %) shows markedly attenuated distal (radial and ulnar) arteries one of them had intact palmar arch. Only one case (3.3%) had healthy proximal arterial tree and completely non-visualized distal vessels proved by duplex to be healthy but it was absent due to flow reversal.

The mean time interval from original fistula creation to revision was 17.9±13.3 months (median = 18, range 1-48). The median time interval by months was 32, 24, 18, 11.5, 11.25 and 11 months for PAI, DRAL, DRIL, Banding, SBLs and RUDI respectively. Follow up from the intervention to study completion was completed in 25 of the 28 patients (89%), three patients died through the study period (11%). The median postoperative follow up duration for the 30 procedures done was 9.5 (1-24) months and there was no significant difference in the mean follow up duration among the different surgical groups, 13.5 months for DRAL, 12.5 months for RUDI, 12 months for PAI, 10.5 months for DRIL, 9 months for SBLs and 6.5 months for Banding (P value = 0.628).

The arterial target and the type of conduit was different from procedure to another, the 12 DRIL procedures were performed with upper ipsilateral limb vein in 5 cases (41.7%), great saphenous vein in 4 cases (33.3%) and synthetic PTFE 6 mm in 3 cases (25%). The proximal arterial target was the brachial artery in all cases of DRIL, while the distal arterial target was the main brachial artery in 5 cases (41.7%), the radial artery in another 5 cases (41.7%) and the brachial bifurcation at the ulnar side in 2 cases (16%). For RUDI cases the distal arterial target was the proximal

radial artery in all cases and the used conduit was the GSV in two cases (50%), upper limb vein in one case (25%) and the remaining case underwent mobilization of the vein and re-implantation in the radial artery. All cases of PAI were done by PTFE 6 mm graft with the axillary artery the new proximal inflow artery. As regard the AVF patency immediate closure recorded in two cases that underwent ligation. Of the remaining 28 cases; AVFs were kept patent all over the follow up periods (3-24 months) in 16 cases (57.1%). While in the remaining 12 cases AVF patency was 100% at 6 months follow up period and 58.3% (7 cases) at 12 months follow up. The overall AVF patency for DRIL was 50%, 50% for PAI, 25% for RUDI, 66.7% for Banding and 100% for both DRAL and SBLs.The overall AVF patency for the studied group (n=30) was 53.3% over median follow up of 9.5 (1-24) months. Patency of the brachial artery bypass graft in the DRIL group was 91.7 % during the whole period of follow up. Only one case (8.3%) that underwent DRIL using upper limb vein was complicated by partial thrombosis of the bypass graft which was treated conservatively and follow up duplex proves the complete recanalization occurred within 3 months. Conduit patency of the RUDI group was 75% and 50% for the PAI group during the whole period of follow up. Conduit thrombosis occurred only in one case of RUDI (25%) in which the graft was upper limb vein.

The overall ischemic rest pain resolution was 76.7%. Complete resolution of ischemic manifestations had occurred in 75% of the RUDI group, 50% of the PAI cases, 50% in SBLs group, 100% in DRAL group, 83.3% in the DRIL group and 66.7% in the Banding group (P value = 0.440). Three cases shows only partial improvement as regard ischemic rest pain; one after RUDI, one after PAI and one after SBLs. Persistent ischemic rest pain was recorded postoperatively after two DRIL procedures and two Banding procedures. One of the banding procedures was preceded by DRIL and in both there was no change as regard the pain and the patient underwent radial and ulnar pallon angioplasty followed by ligation of the fistula. Failure of the other case of Banding was attributed to graft infection and removal. Table (6) and table (7) summarize resolution of ischemic rest pain all over the study and for each specific operation.

Table 6:-Ischemic rest pain resolution.

	Study group	
	No	%
Ischemic pain no change partial resolution complete resolution	 4 3 23	 13.3 10.0 76.7
Onset of resolution of ischemic pain after surgery / days	2(1-17)	

Table 7:-Specific rest pain resolution.

Ischemic pain	DRAL (n=2)	DRIL (n=12)	RUDI (n=4)	PAI (n=2)	Banding (n=6)	SBLs (n=2)	p-value
No change	-	2 (16.7)	-	-	2(33.3)	-	0.440
Partial resolution	-	-	1 (25)	1 (50)	-	1 (50)	
Complete resolution	2 (100)	10(83.3)	3 (75)	1 (50)	4(66.7)	1(50)	
onset of resolution of ischemic pain /day	2(1-3)	1(1-17)	3.50 (1-12)	3.50 (3-4)	1.5 (1-3)	1(1-1)	0.716

All patients with ischemic tissue loss have taken conservative medications postoperatively. Complete healing of ischemic ulcers and amputation stumps had occurred after12 procedures (66.7%). 4 patients (22.2%) shows only marked regression as regard the size of ulcer and extent of the gangrene (two after ligation, one after PAI and one after SBLs). Progressive ischemic tissue loss has occurred after two procedures (11.1%) one DRIL and one Banding. Newly developed ischemic tissue loss had occurred only after one DRIL procedure and one SBLs procedure. No significant difference among different techniques was noticed as regard complete healing. Complete healing was recorded in 6 cases out of 7 who had ischemic tissue loss in the DRIL group (85.7%), 2 of 2 in the DRAL group (100%), one of one in the RUDI group, two of three in the Banding group (66.7%), one of two in the PAI group (50%) (P value = 0.746). Regression of the size of ischemic ulcer and extent of gangrene has occurred after the two (100%) ligation procedures, 50% of PAI and 50% of SBLs at the follow up period. Progressive ischemic tissue loss has occurred after two procedures one DRIL (14.3%) and one Banding (33.3%) in the same patient despite functioning bypass graft. This patient underwent pallon angioplasty later followed by below elbow amputation.

Table (8) summarizes healing of ischemic tissue loss all over the study and for each specific procedure. Two patients required partial digital amputation after DRIL procedure despite functioning bypass graft and one patient required below elbow amputation after DRIL, Banding and pallon angioplasty procedures.

Table 8:-Ischemic tissue loss healing after Revisional surgeries.

Ulcer and Digital Amputation stump healing	Study group	
	No	%
Newly developed tissue loss	2	
progression	2	11.1
regression	4	22.2
complete healing	12	66.7
Onset of complete ulcer healing after surgery / days	21.45±9.34	

Ulcer healing and Digital Amputation stump healing	DRAL	DRIL	RUDI	PAI	Banding	SBLs	P value
Progression	-	1(15.3)	-	-	1 (33.3)	-	0.746
Regression	-	-	-	1(50)	0 (0)	1 (100)	
Complete healing	2(100)	6 (85.7)	1(100)	1(50)	2 (66.7)	-	
onset of complete ulcer healing after surgery / days	8.50±2.12	22±7.81	23±0.0	29±11.31	28±0.0	-	0.217

Irreversible ischemic tissue loss that requires at least hand amputation had occurred in two cases (7.1%). One after ligation; the second had occurred in one case after two different procedures DRIL then Banding. Minor tissue loss requiring digital amputation had occurred in four patients (13.3%); after three DRIL procedures and after one ligation procedure. One of the DRIL group developed ischemic tissue loss at the distal two phalanges of the middle finger after the procedure and the other two were presented preoperatively by gangrenous distal two phalanges of the middle finger and distal phalnyx little finger. Both underwent partial digital amputation with complete healing of the amputation stump. Symptom recurrence had occurred after three different procedures (10%), after DRIL, RUDI and SBLs, (3.3% for each).

Graft thrombosis had occurred after three procedures (10%); DRIL, RUDI and PAI (3.3% for each). The DRIL and the RUDI procedures were performed with ipsilateral upper limb vein while the PAI procedure was performed by PTFE synthetic graft. DRIL graft shows partially thrombosed graft by duplex and treated conservatively while both RUDI and PAI cases underwent thrombectomy. Secondary intervention was performed after five (16.7%) different procedures; two thrombectomy one after PAI and one after RUDI for thrombosed venous outflow access (6.7%). Three reinterventions were performed to increase the distal arterial flow (10%); RUDI after Banding, Banding after DRIL and Angioplasty after DRIL. Other surgical complications were not rare. Table (9) summarizes surgical complications in the study and after each surgical procedure.

Table 9:-Postoperative surgical complications.

Complications	Study group (n=30)	
	No	%
Bleeding	2	6.7
Wound Infection	3	10.0
Wound gapping	4	13.3
Seroma	5	16.7
Hematoma	2	6.7
Graft infection	3	10.0
Graft Thrombosis	3	10.0
Acute Limb ischemia	0	0.0
Venous HTN	0	0.0
Re-intervention	5	16.7

Thrombectomy	2	6.7
Mortality	4	13.3
Cause of death		
RF	2	6.6
septicemia	1	3.3
Hemorrhagic stroke	1	3.3
Postoperative edema	4	13.3
Mild	3	10
Sever	1	3.3

There was no significant difference among the different surgical procedures as regard the intraoperative and postoperative complications.

Table 10:-Relation between operative technique and surgical complications

	DRAL (n=2)	DRIL (n=12)	RUDI (n=4)	PAI (n=2)	Banding (n=6)	SBLs (n=2)	p-value
Bleeding	-	2 (16.7)	-	-	-	-	0.720
Wound infection	-	1(8.3)	-	1(50)	1(16.7)	-	0.483
Wound gapping	-	-	1(25)	1(50)	2(33.3)	-	0.228
Seroma	-	2(16.7)	1(25)	-	2(33.3)	-	0.786
Hematoma	-	2(16.7)	-	-	-	-	0.720
Graft infection	-	1(8.3)	1(25)	-	1(16.7)	-	0.867
Symptom recurrence	-	1(8.3)	-	-	1(16.7)	1(50)	0.483
Graft thrombosis	-	1(8.3)	1(25)	1(50)	-	-	0.444
Acute Limb ischemia	-	-	-	-	-	-	-
VenousHTN	-	-	-	-	-	-	-
Arterial Reinterventions	-	1(8.3)	-	-	1(16.7)	-	0.899
Venous Thrombectomy	-	-	1(25)	1(50)	-	-	0.103
Mortality	-	1(8.3)	-	-	1(16.7)	-	0.899
Postoperative edema	-	2 (16.7)	2 (50)	-	-	-	0.285

Patient survival was equal with no significant difference between different procedures all over the follow up period; only four patients died (13.3%), two after ligation (6.6%), one after DRIL (3.3%) and one after Banding (3.3%). The cause of death was end stage renal disease in two cases (6.6%), septicemia in one case and hemorrhagic shock in one case.

Discussion:-

Findings of this study prove that DRIL, RUDI, PAI, DRAL, SBLs and Banding procedures provide accepted similar patency rates and ischemic symptom resolution for selected patients with HAIDI grade 3 and grade 4a. Distal perfusion was improved similarly after each procedure, proved clinically by either immediate pulse recurrence or relive of rest pain, associated wound complications or re-interventions were uncommon among the procedures.

Mechanisms by which HAIDI symptoms and hand perfusion improved are different. RUDI involves extension of arterial inflow of the existing fistula to forearm artery distal to brachial bifurcation allowing distal perfusion from the other artery. Distalization of the arterial inflow together with longer access length and narrowing of the access inflow (as the conduit is smaller in diameter than the native outflow vein) results in increased the fistula resistance improving the distal perfusion causing resolution of HAIDI symptom. The more complex mechanism of DRIL involves improvement of the distal perfusion by arterial bypass from brachial artery proximal to the AVA to a distal target after the AVA. Also, the relative resistance between the fistula and the distal arterial system is altered and the flow reversal is prevented by ligation of the brachial interval.

DRIL procedure has historically excellent outcomes as regard patency, symptom resolution together with preserving a functioning access. Several large studies, has demonstrated secondary patency of the venous access after a DRIL procedure of 76% to 82% at 5 years. 8,15,16 Despite concerns regarding the ligation ofthe main brachial artery and dependence of the forearm perfusion on the bypass graft, multiple large studies proves that graft thrombosis is a very rare event, with primary patency of 86% to 100% at 1 year and 78% to 96.9% at 5 years. 5, 8, 15, 16, 17

A large study of 134 DRIL procedures shows that only 8 brachial artery bypass grafts were thrombosed during follow up and three of those eight were asymptomatic, and the remainders underwent repeat DRIL, without significant tissue loss or functional deficit. 5

Findings of our study were consistent with previously published reports, with patency of the brachial artery bypass conduit of the DRIL of 91.7 % at the follow up and only one case was found to have asymptomatic brachial artery bypass graft partial thrombosis.

Few published studies on patency and clinical results of RUDI procedure were present, the clinical improvement reaches 100% in six studies. 9, 18, 19, 20, 21 this success was attributed to the low number of cases in those studies. However one larger study on 30 patients all underwent RUDI performed by Loh M. et al. in 2016 shows 100% clinical improvement and 87% patency rate at one year. 22 Also Leak et al. 2015 shows high patency rates up to 94% and clinical improvements up to 95% on 19 patients.17

However being limited in number and limited number of patients in each, results of RUDI studies for HAIDI has shown acceptable patency rates and symptom resolution and corroborate well with the findings of this series as regard ischemic pain improvement (100% with one case showing partial improvement) but the patency rate was similar (75%) to previously published data by Misskey et al. 2016. 1 and Chemla et al. 2007. 18 but lower than those published by Leak et al. 2015. 17 This difference was attributed to the relatively lower number of cases in our study. The results of RUDI procedure are affected by the type of the primary fistula (autogenous or synthetic), type of conduit and the operative technique.

Several technical considerations with the RUDI procedure are worthy of discussion. The original RUDI described by Minion et al, 9 involves distalization of the arterial inflow to the proximal radial or ulnar artery 2 to 3 cm distal to the brachial bifurcation. Extension to the distal radial artery has been reported but is usually reserved only for fistulas with very high flows, access related heart failure (ARHF) or both. 18

In our series, the distal arterial target (radial artery or ulnar artery) for RUDI was chosen according to the Allen's test, where the nondominant artery was used as the new inflow artery to the fistula and the dominant artery was left to supply the hand.

Duplex assessment of both arteries is mandatory before the procedure as the presence of arterial occlusive disease will cause persistent HAIDI manifestations.

Reduction of the mean dialysis access flows was significant after the RUDI procedure rather than after the DRIL, this was explained by the more distal smaller inflow artery and the increased resistance of the outflow access (longer access and narrower conduit).

On the other hand, use of smaller distal artery as new inflow in the RUDI procedure has raised the concerns of higher rates of fistula dysfunction, incomplete dialysis, and thrombosis. 5 Also, in the presence of sever peripheral occlusive disease in the forearm arteries in association with HAIDI this may cause inadequate access flow, fistula dysfunction and thrombosis. So, the decision to perform RUDI should depend mainly on the patency of the distal arterial tree.

Although most reports of the RUDI advocate for the use of autologous tissue for construction, 9, 17, 20, 23 However, high proportion of PTFE was used in a single study on the RUDI procedure with accepted patency rates reaching 77% at 16 months. 1 In this study all conduits of the RUDI procedure were autogenous and carry the same patency rates (75%) at the period of follow up.

The mechanism by which Banding procedure improves the distal perfusion is dependent only increasing the outflow resistance by narrowing the native vein and lowering the pressure gradient across the fistula thus increasing the distal arterial flow. This could be beneficial only in the presence of healthy distal arterial system as the presence of arterial occlusive disease in the forearm arteries impairs lowering the pressure gradient.

The surgical Banding procedure is known to have high patency and ischemic symptom resolution rates by markedly reducing the flow rates through the venous access (up to 2000 ml/min reduction) but this was observed to be over a short follow up period less than 12 months. 24

Another study was made to evaluate the long term efficacy of the Banding procedure over a follow up period more than 12 months found that more than 50% of cases have recurrent high flow access (more than 2000 ml/min) with or without symptom recurrence. The main risk factors of recurrence were young age and immediate postoperative access flow more than 100ml/min. 24

Banding in our study have shown relatively accepted results as regard the access patency rate which was 100% but ischemic rest pain resolution was occurred only in 66.3% of cases which is a lower rate than the previously published data. This difference in results was attributed to the fact that one of the two patients that did not respond well to the banding procedure had sever distal arterial occlusive disease and the other was exposed to graft removal due to infected graft.

On the other hand, the mean follow up period for Banding cases was 6.5 months which is very short period that is not enough to evaluate the long term effectiveness of this procedure.

The PAI procedure depends on trans-positioning the arterial inflow to a more proximal arterial source of higher flow that allow both supplying the fistula and keeping the distal perfusion. Also, the elongation of the venous access together with the use of non-expandable PTFE graft will increase the fistula resistance and lower the pressure gradient across the fistula.

Zanow et al, 2006 first published study on PAI show excellent patency and symptom resolution rates up to 84%. This study show also that PAI is more preferred in treating HAIDI patients with low flow fistulae but it is likely ineffective in patients with severe tissue loss. 10

Results of the PAI procedure in this study were not coping with the previously published data as patency rate was 50% and symptom resolution was 50% (incomplete ischemic ulcer healing) but the lower number of cases underwent PAI in this study makes it difficult to be compared with the previously published data or even with other procedures.

The DRAL procedure is the simplest procedure as regard its technical feasibility. Also, its mechanism is well understood which depends only on preventing the retrograde flow from the palmar arch through the fistula by ligating the radial artery distal to the anastomosis and the hand perfusion is maintained by the patent ulnar artery.

Immediate resolution of ischemic rest pain associated with rapid ischemic digital ulcer healing was reported in the previously published data with 100% patency rates data over 2 years follow up. Also, the flow reversal from the palmar arch was proved to be interrupted by postoperative duplex ischemic manifestations disappear immediately after the operation and the venous flow of the fistula was increased from 350 mL/min to 500mL/min after 16 months. 25

In this study the DRAL procedure shows 100% postoperative access patency rate and 100% ischemic rest resolution with 100% ulcer healing; this higher rates are due the limited cases of grade 3 or grade 4a HAIDI after distal radial artery based AVF even in center with high rates of fistula creation.

The overall results of this study shows that there was non-significant difference in the postoperative findings as regard symptom resolution, patency rates and incidence of complications after each procedure. The incidence of wound infection after RUDI, DRIL, PAI and Banding was similar weather the used conduit was autogenous or PTFE. This may be attributed to the small number of cases in each group. However, further studies are required to compare and prove the advantage of autogenous conduit over a PTFE not only to avoid infection but also as regard the long term conduit patency.

The RUDI procedure have demonstrated significant greater reductions in venous flow velocity than other procedures thus the RUDI procedure is more preferred in patients with high flow rates (more than 2000 mL/min) and ARHF. In

contrast, cases with low flow rates (less than 800 mL/min) or severe peripheral occlusive distal to the bifurcation the DRIL procedure is preferred.

Mortality rates of HAIDI patients undergoing revisional surgeries shows limited survival. The DRIL procedure for sever HAIDI have shown marked reduction in survival during follow-up with mortality rates reaching up 28% at 1 year, 55% at 4 years, and 79% at 5 years. 5, 8, 15, 16, 17

Mortality rates for RUDI are also high reaching 49.2% but still lower than those for DRIL; however, this difference is due to lower reported rates of sever HAIDI. This high mortality rates prevent the accurate conclusions about the long-term patency rates and this may contribute to an overestimation of patency rates. 1

Given the nonrandomized nature of the study, there is an inherent selection bias in patients undergoing each procedure. Patients with tissue loss in the RUDI group were lower in number compared to those in the DRIL group (25% vs 58.3%; P value = 0.293 not significant). This may potentially bias results, specially the lower rates of ischemic tissue loss healing and ischemic pain resolution seen with DRIL compared to the RUDI.

Finally, although patency, fistula flow and clinical results were available, dialysis variables such as rates of fistula dysfunction, and functional patency rates, were not collected. They may provide further insight into the feasibility of each procedure and its implications on the hemodialysis process.

Conclusion:-

In this preliminary study, the RUDI, PAI, DRIL, Banding and SBLs procedures for the management of brachial artery based HAIDI demonstrated similar patency, symptom resolution, and survival rates. Also, DRAL shows accepted excellent patency, symptom resolution, and survival rates for the management of distal radial artery based HAIDI.

The ultimate decision in choosing re-intervention for HAIDI treatment involves surgeon experience with the respective procedure and this must be dependent on understanding the hemodynamics of the present fistula, anatomic considerations and patient comorbidities.

References:-

1. Misskey J., Yang C., MacDonald S., et al., (2016): A comparison of revision using distal inflow and distal revascularization-interval ligation for the management of severe access-related hand ischemia. J Vasc Surg; 63(6):1574-81.
2. Gupta N., Yuo T., Konig G., et al., (2011): Treatment strategies of arterial steal after arteriovenous access. J Vasc Surg; 54: 162-167.
3. 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;7:770-3.
4. Scali S. and Huber T. (2011): Treatment Strategies for Access-Related Hand Ischemia. Seminars Vasc Surg; 24 (2): 128-136.
5. Scali T., Chang K., Daniels J., et al., (2013): Prediction of graft patency and mortality after distal revascularization and interval ligation for hemodialysis access-related hand ischemia. J Vasc Surg; 57:451-8.
6. Huber T., Brown M., Seeger J., (2008): Midterm outcome after the distal revascularization and interval ligation (DRIL) procedure. J Vasc Surg;48:926-32.
7. Aimaq R. and Katz S. (2013):Using distal revascularization with interval ligation as the primary treatment of hand ischemia after dialysis access creation. J Vasc Surg;57:1073-8.
8. Knox RC, Berman SS, Hughes JD, Gentile AT, Mills JL. Distalrevascularization-interval ligation: a durable and effective treatment for ischemic steal syndrome after hemodialysis access. J Vasc Surg 2002;36: 250-5.
9. Minion D., Moore E. and Endean E. (2005): Revision using distal inflow: a novel approach to dialysis-associated steal syndrome. Ann Vasc Surg; 19(5):625-8.
10. Zanow J., Kruger U. and Scholz H. (2006): Proximalization of the arterial inflow: a new technique to treat access-related ischemia. J Vasc Surg; 43:1216-1221.
11. Kirkman R. (1991):Technique for flow reduction in dialysis access fistulas.

Surg GynecolObstet;172:231-3.

12. Miller G., Goel N., Friedman A., et al., (2010):The MILLER banding procedure is an effective method for treating dialysis-associated steal syndrome. Kidney Int;77: 359-66.
13. Bourquelot P., Gaudric J., Turmel-Rodrigues L., (2009): Transposition of radial artery for reduction of excessive high-flow in autogenous arm accesses for hemodialysis. J Vasc Surg;49: 424-8.
14. Scheltinga M., van Hoek F. and Bruijninckx C. (2009): Time of onset in hemodialysis access-induced distal ischemia (HAIDI) is related to the access type. Nephrol Dial Transplant; 24: 3198-3204.
15. Schanzer H., Skladany M. and Haimov M. (1992): Treatment of angio-accessinduced ischemia by revascularization. J Vasc Surg;16: 861-4.
16. Berman S., Gentile A., Glickman M., et al., (1997): Distal revascularization-interval ligation for limb salvage and maintenance of dialysis access in ischemic steal syndrome. J Vasc Surg;26:393-404.
17. Leake A., Winger D., Leers S., et al., (2015): Management and outcomesof dialysis access-associated steal syndrome. J Vasc Surg; 61(3):754-60.
18. Chemla E., Morsy M., Anderson L., et al., (2007): Inflow reduction by distalization of anastomosis treats efficiently high-inflow high-cardiac output vascular access for hemodialysis. Semin Dial; 20:68-72.
19. Gupta N., Yuo T., Konig G., et al., (2011): Treatment strategies of arterial steal after arteriovenous access. J Vasc Surg; 54: 162-167.
20. Callaghan C., Mallik M., Sivaprakasam R., et al (2011): Treatment of dialysis access-associated steal syndrome with the "revisionusing distal inflow" technique. J Vasc Access;12:52-6.
21. Corfield L., Muller J., Ryan J., et al., (2012): Distalization of the anastomosis:an effective treatment for dialysis accessassociated steal syndrome. Ann Vasc Surg;26:572.e11-3.
22. Loh M., Bennett E. and Peden K. (2015): Revision using distal inflow is a safe and effective treatment for ischemic steal syndrome and pathologic high flow after access creation. J Vasc Surg; 63(2):441-4.
23. Asif A., Leon C., Merrill D., et al., (2006): Arterial steal syndrome: a modest proposal for an old paradigm. Am J Kidney Dis;48:88-97.
24. Roel H., Wouda R., van Loon M., et al., (2015): Effectiveness of surgical banding for high flow in brachial artery-based hemodialysis vascular access. J Vasc Surg; 61:762-6.
25. Cordova E., Pettorini L., Scrivano J., et al., (2015): Preoperative duplex examination in patients with dialysis access-related hand ischemia: indication for distal radial artery ligation. J Vasc Access; 16(3): 255-7.