From the Society for Clinical Vascular Surgery

Prediction of graft patency and mortality after distal revascularization and interval ligation for hemodialysis access-related hand ischemia

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Objective: **The treatment goals of access-related hand ischemia (ARHI) are to reverse symptoms and salvage the access. Many procedures have been described, but the optimal treatment strategy remains unresolved. In an effort to guide clinical decision making, this study was undertaken to document our outcomes for distal revascularization and interval ligation (DRIL) and to identify predictors of bypass patency and patient mortality.**

Methods: **A retrospective review was performed of all patients who underwent DRIL at the University of Florida from 2002 to 2011. Diagnosis of ARHI was based primarily upon clinical symptoms with noninvasive studies used to corroborate in equivocal cases. Patient demographics, procedure-outcome variables, and reinterventions were recorded. Bypass patency and mortality were estimated using cumulative incidence and Kaplan-Meier methodology, respectively. Cumulative incidence and Cox regression analysis were performed to determine predictors of bypass patency and mortality, respectively.**

Results: **A total of 134 DRILs were performed in 126 patients (mean [standard deviation] age, 57 [12] years) following brachial artery-based access. The postoperative complication rate was 27% (19% wound), and 30-day mortality was 2%. The wrist-brachial index and digital brachial index increased 0.31 (0.25) and 0.25 (0.29), respectively. Symptoms resolved in 82% of patients, and 85% continued to use their access. Cumulative incidences (± standard error of the mean) of loss of primary and primary-assisted patency rates were 5% ± 2% and 4% ± 2% at 1 year and 22% ± 5% and 18% ± 5% at 5 years, respectively, with mean follow-up of 14.8 months. Univariate predictors of primary patency failure were DRIL complications (odds ratio [OR], 3.3; 95% confidence interval [CI], 1.2-8.9; $P = .02$), configuration other than brachiobasilic/brachiocephalic autogenous access (OR, 3.4; 95% CI, 1.4-8.3; $P = .009$), and two or more prior access attempts (OR, 4.1; 95% CI, 1.6-10.4; $P = .004$). Brachiocephalic access configuration (OR, 0.2; 95% CI, 0.04-0.8; $P = .02$) and autogenous vein conduit (OR, 0.2; 95% CI, 0.06-0.58; $P = .004$) were predictors of improved bypass patency. All-cause mortality was 28% and 79% at 1 and 5 years, respectively. Multivariable predictors of mortality were age >40 (hazard ratio [HR], 8.3; 95% CI, 2.5-33.3; $P = .0004$), grade 3 ischemia (HR, 2.6; 95% CI, 1.5-4.6; $P = .0008$), complication from DRIL (HR, 2.4; 95% CI, 1.3-4.5; $P = .004$), and smoking history (HR, 2.2; 95% CI, 1.3-4; $P = .007$). Patients with no prior access attempts had lower predicted mortality (HR, 0.5; 95% CI, 0.3-0.9; $P = .02$).**

Conclusions: **The DRIL procedure effectively improves distal perfusion and reverses the symptoms of ARHI while salvaging the access, but the long-term survival of these patients is poor. Given the poor survival, preoperative risk stratification is critical. Patients at high risk for DRIL failure and mortality may be best served with alternate remedial procedures. (J Vasc Surg 2013;57:451-8.)**

Access-related hand ischemia (ARHI), commonly known as "steal syndrome," is one of the most challenging complications to manage after hemodialysis access construction. The creation of an arteriovenous fistula results in a predictable decrease in arterial perfusion pressure distal to the fistula that can lead to ischemia if the compensatory mechanisms are inadequate. The diagnosis of ARHI is largely clinical and can be aided in equivocal cases with noninvasive vascular laboratory studies.[1-3] Access-related hand ischemia occurs in approximately 5% to 20% of brachial artery-based access procedures, with roughly half classified as severe and meriting some type of remedial treatment.[3-10] Treatment goals are to reverse the hand ischemia and preserve the access while preventing any long-term hand disability.

A variety of remedial treatment strategies have been reported for ARHI, including access ligation, banding (ie, flow-limiting strategies), bypass, and proximalization of the arteriovenous anastomosis. The choice is contingent upon multiple factors, including the severity of symptoms, patient comorbidities, and the potential utility of the access itself. The distal revascularization and interval ligation procedure (DRIL) is our preferred treatment because it

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reverses the ischemic symptoms and salvages the access in approximately 90% of the cases.[11] However, several reports have raised concerns regarding the need for ligation of the brachial artery, thus leaving distal forearm and hand perfusion reliant upon a functioning brachial–brachial bypass.[12-14] Furthermore, the postoperative complication rates after the DRIL can range from 5% to 15%,[11,12,15] and primary patency at 2 years is estimated to be 70% to 80%.[8,11,12,16] Given these potential issues, the decision regarding choice of remedial procedure must also consider the patient's life expectancy. The 1-year survival rate in our previous DRIL series was 70%, suggesting that the annual mortality rate for patients with ARHI may exceed the 20% to 23% annual rate reported in the United States for all patients on hemodialysis.[11,17]

These observations and reported concerns about the DRIL procedure prompted this analysis in an effort to guide clinical decision making. This study was undertaken to evaluate our outcomes for the DRIL procedure and to identify predictors of bypass patency and patient mortality.

METHODS

Experimental design. All patients undergoing creation of an upper extremity hemodialysis access between 2002 and 2011 at the University of Florida were identified. A prospectively maintained database was queried, and those patients who had undergone remedial procedures for ARHI were further studied (126 patients including the 61 patients previously described by Huber et al[11]). Approval for this study was obtained from the Institutional Review Board.

Clinical practice. A defined and validated algorithm to optimize the use of autogenous conduit access was followed by all surgeons.[18] All patients underwent noninvasive arterial and venous imaging preoperatively, and confirmatory invasive arterial and/or venous angiography was used in selected cases. Hierarchy for the access configurations followed the recommendations of the Kidney Disease Outcomes Quality Initiative (KDOQI)/Society for Vascular Surgery (SVS) guidelines and our previously published algorithm.[19,20]

The diagnosis of ARHI was primarily a clinical assessment of the operating surgeon. Selected patients had undergone noninvasive arterial testing, which included brachial, radial, ulnar, and digital pressures and velocity waveform analysis. These data were used to confirm ARHI diagnosis in equivocal cases. The management of patients with mild (grade 1) ARHI was expectant, whereas definitive remediation was reserved for patients with moderate (grade 2) or severe (grade 3) ischemia (see Definitions). Upper extremity digital subtraction arteriography was used in the majority of cases to determine if there was a correctable arterial inflow stenosis. Decision to proceed with DRIL followed a published algorithm for management of ARHI.[21]

The DRIL procedure was performed as previously described.[22] The proximal anastomosis of the brachial–brachial bypass was created ≥7 cm proximal to the arteriovenous anastomosis of the access. The distal anastomosis was constructed immediately distal to the access anastomosis, and the brachial artery was ligated or transected immediately proximal to the distal bypass anastomosis. The preferred conduit was greater saphenous vein (≥3 mm) with alternative conduit choices based on conduit availability (arm vein > femoral vein > cadaveric vein > prosthetic graft). All attempts were made to preserve upper extremity veins for potential future access creation. Doppler insonation and palpation of the radial/ulnar pulse were used to determine technical adequacy of the bypass. Completion arteriography or intraoperative duplex scanning was used at case completion in selected cases at the operating surgeon's discretion. Postoperatively, patients were given aspirin (81 mg) (unless contraindicated) and evaluated with a standardized surveillance protocol. This involved upper extremity pressure/waveform analysis and duplex scanning of the brachial–brachial bypass as previously described for our lower extremity bypasses.[11,23] Postoperative duplex surveillance of the DRIL occurred at 1, 3, 6, 9, and 12 months and every 6 months thereafter. Reintervention was based on the presence of recurrent hand symptoms, significant decrease in arterial pressures (≥15 mm Hg drop in arterial wrist pressure), and/or abnormal graft scan (mean graft velocity <50 cm/s, maximum velocity ratio >3.5).[24]

Definitions and data analysis. Comorbidities were defined and retrospectively recorded as follows: coronary artery disease (any history of myocardial infarction, angina, prior coronary intervention, or electrocardiographic changes consistent with prior myocardial infarction); cerebrovascular occlusive disease (history of transient ischemic attack, stroke, and/or prior carotid endarterectomy/stent/angioplasty); congestive heart failure (chart history, New York Heart Association class II or greater, diagnosis on preoperative evaluation); chronic obstructive pulmonary disease (chart history or preoperative pulmonary function testing consistent with the diagnosis, medication); diabetes mellitus (chart history, insulin, oral hypoglycemics); peripheral artery disease (ankle-brachial index <0.9, chart history, prior peripheral endovascular intervention or open infrainguinal reconstruction); hypertension (chart history, antihypertensive medications, or preoperative blood pressure ≥140/90 mm Hg); dyslipidemia (chart history, taking cholesterol-lowering medications); and smoking history (any prior or current smoking). Data collection also included preoperative antiplatelet (aspirin, aspirin + dipyridamole, or clopidogrel), anticoagulant (warfarin), and statin medication use.

The DRIL bypass patency was objectively assessed with duplex ultrasound scanning and/or selective arteriography. Patient mortality was verified by query of the Social Security Administration's Death Master File. Preoperative and postoperative wrist-brachial index (WBI) and digital brachial index (DBI) were compared with paired *t*-test, and $P \leq .05$ was accepted as significant.

The ARHI was categorized using the SVS reporting standards as mild (grade 1), moderate (grade 2), or severe (grade 3).[25] Patients categorized as having grade 2 or 3 ischemia presented with a spectrum of symptoms and physical examination findings. The predominant (most severe)

symptom was recorded as the indication for DRIL (tissue loss > motor dysfunction > rest pain > intermittent, hemodialysis-dependent rest pain > paresthesia > coolness). Grade 2 ischemia was defined by the presence of hand coolness, numbness/paresthesia, or intermittent hand pain while on hemodialysis. Grade 3 ischemia was defined as rest pain (including while off a hemodialysis circuit), neuromotor hand dysfunction, or presence of ulceration/gangrene.

Risk model design. The outcomes of interest were time to loss of primary or primary-assisted patency, time to secondary intervention, and time to death. The distribution of mortality was estimated using the Kaplan-Meier method. The distributions of the loss of patency outcomes were summarized using cumulative incidence functions due to the presence of mortality as a competing risk with occurrence of DRIL failure.[26,27] Cumulative incidence regression, rather than Cox proportional hazards regression, was used to study predictors of primary DRIL patency because mortality and graft failure were considered to be competing risks.[28] In the presence of competing risks, Kaplan-Meier estimates are inaccurate because this methodology assumes all events are independent (ie, that patients who die after DRIL are still at risk for graft failure, which is clearly false).

For mortality, all possible models with up to five risk factors were considered, and the model with the best measure of the relative goodness of fit (defined as lowest AIC or "an information criterion" taking into account the number of risk factors and the fit of a model) was selected. The maximum number of risk factors considered in the multivariable model was limited to five because the number of mortality events was only 60. No multivariable models for primary patency were considered given that there were only 14 events. Statistical analysis was performed using SAS 9.2 (SAS Institute, Cary, NC) and R 2.15.0 (http://www.r-project.org/).

RESULTS

From 2002 to 2011, 2753 access-related procedures were performed (excluding dialysis catheters), of which 1882 were new access creations. Of these new access procedures, the overall incidence of grade 2 or 3 ARHI requiring remediation was 7.8%. The distribution of permanent access creations are noted in Fig 1, with the majority based off the brachial artery. Four patients underwent proximalization, 17 had access ligation, and 126 underwent a DRIL procedure. Of the patients with an autogenous brachial–cephalic or brachial–basilic upper arm access, 8% underwent DRIL compared with 11% of those with brachial–axillary indirect autogenous or cadaveric femoral vein translocation. In contrast, only 1% with a prosthetic brachial–axillary access configuration underwent DRIL, and no patients with autogenous radial–cephalic direct wrist access required remediation for ARHI.

A total of 134 DRIL operations were performed on 126 patients (mean [standard deviation] age, 57 [12] years). The mean total time on hemodialysis before presenting with ARHI requiring remediation was 26 (41) months. The majority of patients were female (59%) and had a preoperative diagnosis of diabetes (69%). Other demographic and access-related surgical history date are given in Table I. Thirteen percent of the patients undergoing DRIL had two or more prior access attempts (defined as any prior access creation operations), and 15% had a prior clinical diagnosis of ARHI (with or without remediation). Table II lists the distribution of preoperative access configurations and preoperative medication use. Sixteen percent of the DRIL patients had an autogenous brachial–axillary indirect femoral vein translocation,[19] and only 2% had a prosthetic brachial–axillary access. Before the DRIL procedure, only 10% of patients were not on any anticoagulation or antiplatelet regimen. More than half of the patients (53%) were taking a statin medication at the time of their procedure.

Many patients presented with multiple symptoms and physical examination findings consistent with ARHI. The most severe or predominant indications for DRIL are given in Fig 2. Sixty-nine percent of patients had grade 3 ischemia. The average time from index access creation to DRIL was 82 ± 153 days (Fig 3). A planned, preemptive DRIL (performed at time of index access procedure) was performed in eight patients (6%) because of a prior history of ARHI (n = 6) or known severe, distal forearm occlusive disease (n = 2). Conduit use for the DRIL brachial–brachial artery bypass was greater saphenous vein in 75%, arm vein 18%, composite autogenous vein 3%, cadaveric vein or artery 3%, and prosthetic graft 1%.

During the DRIL procedure, 5.5% (n = 7) had adjunctive procedures performed (subclavian angioplasty and/or stent, n = 5; central vein venoplasty, n = 2). Average postoperative length of stay was 4.2 ± 4.8 days. The overall composite postoperative procedure complication rate was 27%, with the majority attributable to wound infection (Table III). Thirty-day mortality was 2%, and mean follow-up is 14.8 (17.6) months (median, 7 months; range, 0-81 months). Significant increases in mean WBI and DBI were detected between the preoperative and postoperative measurements (WBI: 0.31 [0.25]; $P = .02$; DBI: 0.25 [0.29]; $P = .03$; Fig 4). Symptoms fully resolved in 82% of patients (Fig 5), and 85% continued to use the index hemodialysis access for which the DRIL was performed at time of last follow-up.

Patency results and prediction. Cumulative incidences of loss of primary and primary-assisted patencies of the DRIL bypass (± standard error of the mean) were 5% ± 2% and 4% ± 2% at 1 year, and 22% ± 5% and 18% ± 5% at 5 years (Fig 6). Univariate predictors of primary patency failure are given in Table IV. No multivariable analysis for DRIL patency was attempted due to the low number of patency failure events.

DRIL reintervention and outcome. Median time to any reintervention (including repeat DRIL procedures) was 9.4 months (range, 0.2-16.4 months), and cumulative incidence of reintervention was 15% ± 6% at 1 year and 21% ± 7% at 5 years. Three patients had primary-assisted

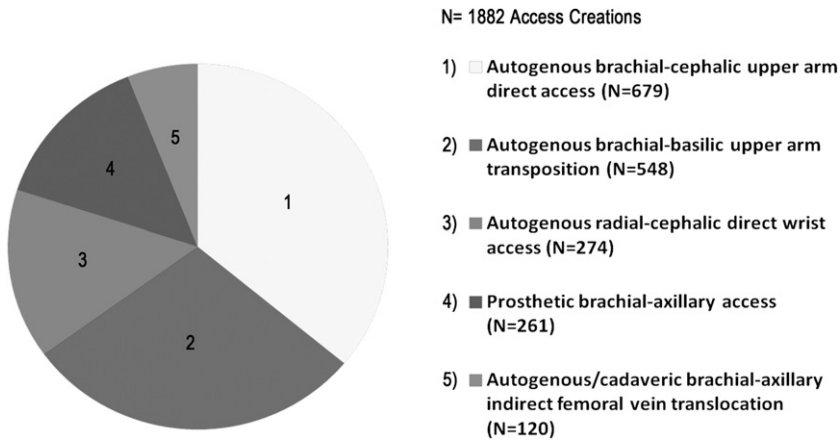

Fig 1. Absolute numbers and proportions of new access configurations performed between 2002 to 2011.

Table I. Patient demographic information, comorbid conditions, and prior access history (including access-related hand ischemia)

Demographics	n = 126
Age, mean (SD), years	57 (12)
Gender (% female)	59%
Comorbidities	
Hypertension	95%
Diabetes	69%
Dyslipidemia	55%
Coronary artery disease	49%
Smoking	46%
Congestive heart failure	21%
Prior hand ischemia	15%
Prior access attempts (≥2)	13%

SD, Standard deviation.

Table II. Distribution of access configurations and preoperative antiplatelet, anticoagulation, and statin use among patients who underwent distal revascularization and interval ligation (DRIL)

Access configurations	n = 126
Autogenous brachial–cephalic upper arm direct access	46%
Autogenous brachial–basilic upper arm transposition	36%
Autogenous/cadaveric brachial–axillary indirect femoral vein	16%
Prosthetic brachial–axillary access	2%
Preoperative medication use	
Aspirin	84%
Statin	53%
No anticoagulation/antiplatelet	10%
Clopidogrel	20%
Warfarin	14%

patency events occurring at 1 (subclavian stent), 61 (angioplasty of proximal anastomosis), and 367 (angioplasty of distal anastomosis) days after the initial DRIL operation. Of the 11 patients who had documented brachial–brachial bypass occlusion, three were asymptomatic,

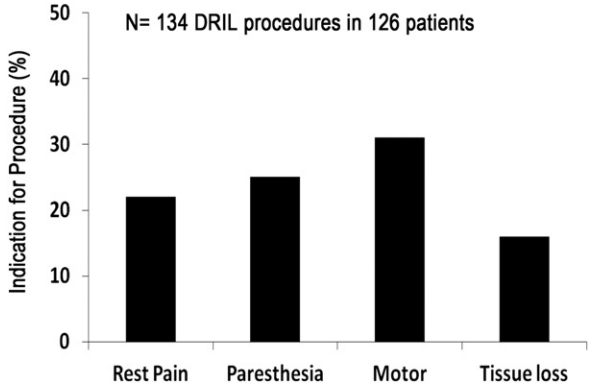

Fig 2. Predominant indication for distal revascularization and interval ligation (*DRIL*) procedure. A few patients underwent DRIL at the time of index access creation due to prior access-related hand ischemia and are not represented in this graph.

and eight patients underwent a second DRIL procedure at a median interval of 10.2 months (range, 0.2-16.4 months). No patient with a brachial–brachial bypass underwent graft thrombectomy or thrombolysis with revision (ie, no secondary patency events). Of the eight patients who underwent a second DRIL procedure, six (75%) were patent at the time of this analysis. Two patients with a patent second DRIL had mild, residual paresthesia, and one patient with two failed DRIL operations had permanent neurologic hand dysfunction secondary to ischemic monomelic neuropathy that was retrospectively determined to be present before the initial DRIL occlusion. No minor or major amputations resulted from DRIL thrombosis.

Mortality prediction. All-cause mortality was 28% ± 5% at 1 year and 79% ± 6% at 5 years (Fig 7). Multivariable predictors of mortality are listed in Table V. Predictors of mortality after DRIL were age >40 years, grade 3 ischemia, any complication after DRIL, and any smoking history. If patients had no prior hemodialysis access

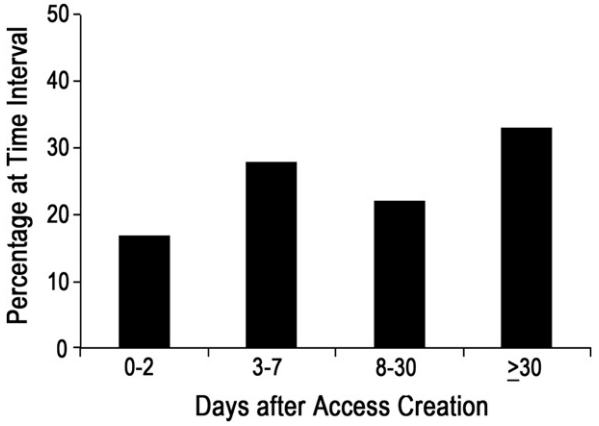

Fig 3. Performance of distral revascularization and interval ligation (DRIL) procedure in days after the index access creation.

Table III. Thirty-day morbidity and mortality after distal revascularization and interval ligation (DRIL)

Morbidity	27%
Wound	19%
Peripheral nerve	3%
Cardiac	2%
Gastrointestinal	2%
Cerebrovascular	1%
Thirty-day mortality	2%

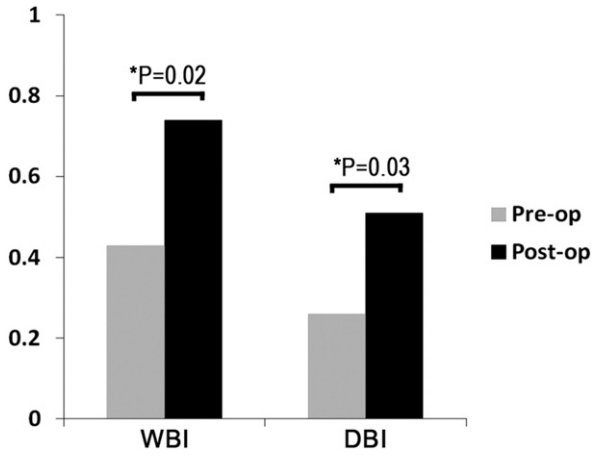

Fig 4. Mean preoperative (*Pre-op*) and postoperative (*Post-op*) wrist-brachial index (*WBI*) and digital brachial index (*DBI*). Significant increases were noted for both indices following distal revascularization and interval ligation (DRIL) (*$P < .05$). Preoperative hemodynamic data were available for 75% (n = 95) of cases, whereas 68% (n = 86) had at least one postoperative duplex scan of the graft with WBI/DBI measurements.

attempts before the index access creation (for which the DRIL operation was performed), improved survival was predicted.

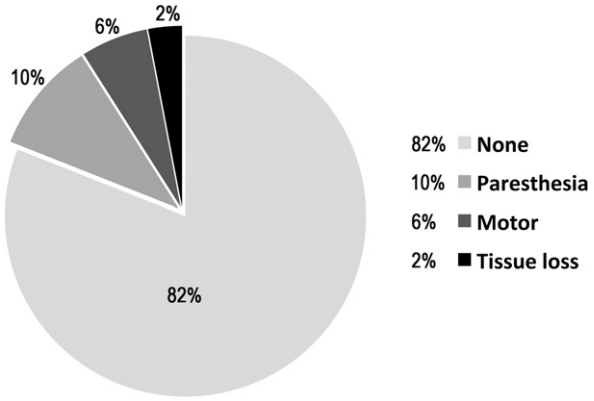

Fig 5. Proportion of patients with complete symptom resolution following distal revascularization and interval ligation (DRIL) and of patients with residual paresthesia, motor dysfunction, or tissue loss following DRIL.

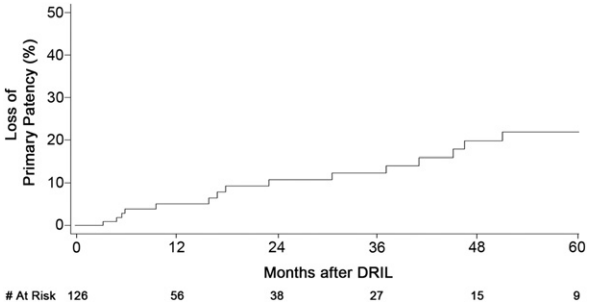

Fig 6. Cumulative incidences of the loss of primary patency of the distal revascularization and interval ligation (*DRIL*) bypass. The standard errors were <10% throughout the time interval represented. Numbers of patients at risk are given beneath the curve.

DISCUSSION

The results of this study highlight the safety and efficacy of the DRIL procedure for management of ARHI and elucidate risk factors that have an impact on bypass patency and predict patient mortality. The benefits of DRIL in relieving the symptoms of ARHI while simultaneously preserving the access for hemodialysis are substantial, as >80% of patients had complete symptom relief and were still utilizing their access at time of last follow-up. These findings are corroborated by the demonstrated hemodynamic benefits, with significant improvements in both WBI and DBI after DRIL.

The hemodynamic basis for the DRIL procedure is the low-resistance arterial bypass that overcomes the high-resistance collateral circulation and the ligation that prevents retrograde flow from the distal vessels through the fistula. Interestingly, the components that afford the hemodynamic advantage (ie, arterial bypass, ligation) have also been cited as limitations of this procedure. Concerns have been raised of the possibility of catastrophic outcomes with DRIL thrombosis due to the bypass-dependent hand perfusion. The patency rates demonstrated

Table IV. Univariate predictors of loss of distal revascularization and interval ligation (*DRIL*) primary patency

Predictor[a]	*HR*	*CI*	P *value*
≥2 prior access creations	4.1	1.6-10.4	.004
Nonautogenous brachial–cephalic/brachial–basilic access[b]	3.4	1.4-8.3	.009
Complication from DRIL	3.3	1.2-8.9	.02
Autogenous vein conduit	0.2	0.06-0.58	.004
Autogenous brachial–cephalic upper arm direct access	0.2	0.04-0.8	.02

CI, Confidence interval; *HR*, hazard ratio.

[a]Cumulative incidence regression was used to determine univariate associations between patient covariates and DRIL bypass primary patency. Cumulative incidence regression was used due to the competing risk of patient mortality.

[b]Nonautogenous brachial–cephalic/brachial–basilic access includes configurations of autogenous indirect femoral vein translocation brachial–axillary access, cadaveric femoral artery/vein brachial–axillary access, and prosthetic brachial–axillary access.

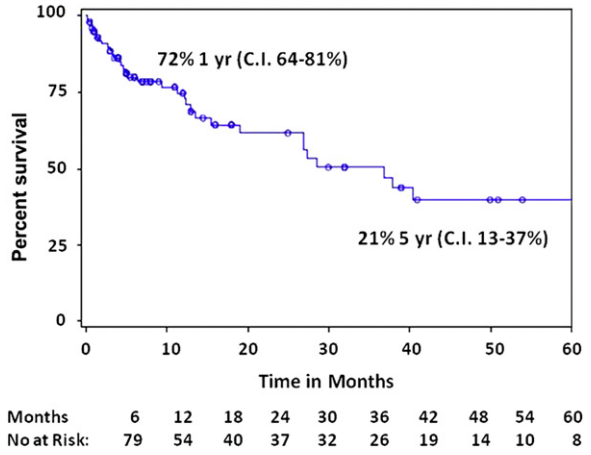

Fig 7. Kaplan-Meier curve for patient survival. The standard errors were <10% throughout the time interval represented. Numbers of patients at risk are given beneath the curve. *C.I.*, Confidence interval.

Table V. Independent predictors of all-cause patient mortality after distal revascularization and interval ligation (*DRIL*) determined using multivariable Cox proportional hazard regression analysis

Predictor[a]	*HR*	*CI*	P *value*
Age >40 years	8.3	2.5-33.3	.0004
Grade 3 ischemia	2.6	1.5-4.6	.0008
Complication from DRIL	2.4	1.3-4.5	.004
Smoking history (past/current)	2.2	1.3-4	.007
No prior access procedures	0.5	0.3-0.9	.02

CI, Confidence interval; *HR*, hazard ratio.

[a]Cox proportional hazard regression analysis.

in our series are quite good, with a 5-year primary-assisted patency rate >80%. Furthermore, of the 11 patients in our series who had DRIL thrombosis, none underwent amputation and only one had permanent hand dysfunction that predated the index DRIL procedure. Thus, the concerns for catastrophic complication with DRIL thrombosis may be unfounded. Unfortunately, the observed hemodynamic benefits of the DRIL procedure failed to relieve all of the precipitating neurologic complaints, as a small subset of patients had persistent paresthesias. We hypothesize that these patients likely had a severe, irreversible ischemic nerve injury before DRIL.[29] It has been our anecdotal impression that this irreversible nerve injury can occur fairly quickly in terms of the time elapsed from access creation and suggests the importance in the timing of DRIL.

Several univariate associations with primary patency failure were found in this analysis. As noted earlier, it was impossible to evaluate the independent influence of each factor on DRIL patency due to the small number of events. However, these associations still merit discussion. The observations that two or more prior access creations and access configurations other than autogenous brachial–cephalic or brachial–basilic upper arm access were predictive of decreased DRIL patency may be due to several factors. The majority of these patients had a brachial–axillary indirect access configuration with either translocated (autogenous or cadaveric) femoral vein or, rarely, polytetrafluroethylene. This likely selected for a subgroup of patients who were dependent on hemodialysis for a longer duration and/or one with multiple prior failures, potentially due to the presence of more severe forearm arterial occlusive disease or poor vein graft remodeling.

The use of autogenous conduit was found to be protective of primary graft patency. The protective association of this factor is consistent with reports of its impact on lower extremity bypass patency.[30] We noted this association some time ago, and. since 2009, we have largely abandoned the use of cadaveric conduit. Similar to lower extremity bypasses, the greater saphenous vein from the thigh is our preferred conduit, with ≥3 mm our diameter criterion for a suitable vein.[18] We are reluctant to harvest the saphenous vein below the knee in patients with significant peripheral vascular disease due to concerns with wound healing. In patients who do not have suitable saphenous vein, we have used the cephalic or basilic vein in select cases, attempting to balance the benefit of preserving the current access against the loss of a future access option.

The DRIL procedure has been our preferred choice for ARHI given our favorable results. However, several other alternatives may play a role in specific scenarios. For patients who lack suitable autogenous conduit, proximalization of

the arterial inflow with polytetrafluroethylene may be a reasonable alternative to ligation.[31,32] Others have described a variant of the "proximalization" approach by complete mobilization of the venous outflow track (ie, the entire cephalic vein from the antecubital fossa to the shoulder) and translocating this in a looped configuration with the anastomosis based on the proximal brachial artery to obviate the use of a prosthetic conduit.[10,31] Our own experience with the proximalization of the arterial inflow procedure has been limited, and we echo conclusions by Zanow et al[31] that it likely is ineffective in patients with severe tissue loss. We have not performed any revision using distal inflow procedures but have been struck by the lower incidence of ARHI in access procedures performed using the proximal radial artery as opposed to the brachial artery at the antecubital fossa.[33] Our enthusiasm for the flow-limiting approaches is tempered by the inconsistent reports in the literature and the requisite, tenuous balance between adequate distal perfusion and sufficient access flow to sustain effective dialysis. However, the various flow-limiting strategies may be effective for patients who have very high flow rates, particularly those with cardiac dysfunction.[34]

The management of ARHI really begins during the initial evaluation before the index access procedure. All available strategies should be used to reduce this adverse outcome, including originating the arteriovenous anastomosis as distal on the arterial tree as possible and confirming the absence of an arterial inflow stenosis. We follow the KDOQI/SVS guidelines[35] and our own well-defined algorithm to optimize the use of autogenous conduit for access creation[18] that prioritize radial artery over brachial artery inflow. Patients are evaluated with both arterial and venous noninvasive duplex imaging in contrast with many practices that just focus on the quality of the vein. In addition, for patients estimated to be at particularly high risk for ARHI (eg, those with a previous history of hand ischemia or documented evidence of severe forearm occlusive disease and cases using large-diameter, compliant conduit such as translocated autogenous femoral vein), we have performed simultaneous access creation and DRIL procedures. In other high-risk patients, we have performed a preoperative saphenous vein survey to identify a suitable conduit for DRIL before the index access creation.

Dialysis patients are known to have poor long-term survival in comparison with the general population, as documented by the United States Renal Data System. In fact, in 2010 the United States Renal Data System reported a strikingly high 20% annual mortality for all hemodialysis patients.[36] Our data suggest that patients with ARHI may represent a population at even higher risk, with a 1-year mortality of nearly 30% after the DRIL procedure. We do not believe the DRIL procedure contributes to this higher mortality but rather that patients with ARHI have an increased number and severity of comorbid conditions, including longer dependence on hemodialysis, that likely lead to poorer survival. Our analysis demonstrated that age >40, any smoking history, and grade 3 ischemia all were independently predictive of increased mortality. Unfortunately, none of these identified predictors can be modified to reduce risk in the preoperative setting. This novel survival finding may be better applied in the selection of patients for DRIL or patient counseling of risks and benefits.

The study has several limitations that merit further discussion. The retrospective nature of our data collection likely leads to an underestimation of the incidence of hand ischemia and precludes an accurate assessment of the disease severity of both the hand ischemia and the underlying patient comorbidities. It is conceivable that several of our access patients developed ARHI and had their remedial procedures performed at outside institutions, although this is unlikely given our access referral practice. In addition, there was an inherent selection bias that had an impact on which access and which remedial procedure were performed. This is evident in the lack of a comparative alternative remedial strategy to DRIL in our series. Complication from DRIL was identified as a risk factor for primary patency failure and mortality but, unfortunately, cannot be determined preoperatively to guide decision making. The development of a prediction model for complication after DRIL may be important in defining a subset of patients with higher concurrent risk of perioperative complication, DRIL failure, and all-cause mortality. This is the subject of a future analysis and may further identify patients who would be best served with alternative remedial operations for management of ARHI.

CONCLUSIONS

The DRIL procedure effectively improves distal perfusion and reverses the symptoms of ARHI while salvaging the access. Avoidance of nonautogenous conduit use is important to achieve good outcomes. All-cause mortality after DRIL is high, and, given the high mortality of this patient population, preoperative risk stratification is critical for optimal utilization of this remedial strategy. Patients at high risk for DRIL failure and mortality may be best served with alternate remedial procedures.

AUTHOR CONTRIBUTIONS

Conception and design: SS, CC, TH
Analysis and interpretation: SS, CC, TH
Data collection: SS
Writing the article: SS, CC, TH
Critical revision of the article: SS, CC, DR, MD, AB, RF, SB, TH
Final approval of the article: SS, CC, DR, MD, AB, RF, SB, TH
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