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Venous Side Branch Ligation as a First Step Treatment for Haemodialysis Access Induced Hand Ischaemia: Effects on Access Flow Volume and Digital Perfusion

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WHAT THIS PAPER ADDS
Non-functional venous side branches may contribute to hand ischemia in the presence of a haemodialysis access fistula. This study indicates that a "side branch ligation first approach" is safe and durable without compromising AVF function in selected patients.

Objective: Haemodialysis access induced distal ischemia (HAIDI) induced by an autogenous arteriovenous fistula (AVF) is caused by loss of blood pressure somewhere along the arterial blood supply of the arm. In some patients, side branches of the access' venous outflow tract may contribute to this blood pressure loss. Beneficial effects of side branch ligation (SBL) as a first step approach to ischemic symptoms have been reported. However, effects on access flow and AVF function after prolonged follow up are unknown.
Materials and methods: Prior to SBL, HAIDI patients with a brachial artery based AVF were studied using a questionnaire quantifying hand ischemia, digital brachial index (DBI, finger plethysmography), and Duplex analysis. Access flow volume, patency rates, hand perfusion, and complications were determined during a 12 month observation period following SBL.
Results: In 9 years, SBLs were performed in 20 haemodialysis patients, either as a single operative procedure ($n = 10$) or supplemented ($n = 10$) with additional surgical techniques during the same procedure (banding, $n = 5$; basilic vein transposition, $n = 4$; DRIL, $n = 1$). Follow up data after 12 months were available in 18 patients. One patient with progressive hand ischemia required access ligation 3 months after SBL. Hand ischemia was attenuated or abolished in the remaining 17 patients (94% clinical success rate). DBI improved from 0.51 ± 0.05 (pre-operative) to 0.68 ± 0.04 (immediate post-operative) and 0.83 ± 0.07 (at 1 year follow up). One year primary, assisted primary, and secondary patency rates were 67% (12/18), 83% (15/18), and 94% (17/18), respectively, while mean access flows remained acceptable at 710 ± 70 mL/min.
Conclusions: Ligation of non-functional venous side branches of an autogenous brachial artery AVF causing hand ischemia leads to prolonged attenuation of hand ischemia whereas access flow volumes are maintained after 1 year of follow up. Side branch ligation must be considered prior to embarking on more invasive surgery for HAIDI.

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INTRODUCTION

A brachial artery based arteriovenous fistula (AVF) for haemodialysis (HD) is occasionally associated with long-term sequelae such as aneurysm formation, high access flow, or haemodialysis access induced distal ischemia (HAIDI).[1–3] Hand hypo-perfusion may initially be experienced only during a dialysis session, but some individuals develop progressive ischemia leading to limited hand function and reduced quality of life.[4] Up to 9% of HD populations require an evaluation for HAIDI in due course.[4,5]

The pathophysiological mechanism underlying lower limb ischemia and HAIDI may be comparable. Loss of perfusion pressure anywhere between the heart and distal portion of an extremity characterize both HAIDI and lower limb ischemia.[6] If hand ischemia in a HD patient is progressive, diagnostic efforts are directed towards visualizing the

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source of blood pressure loss (as in lower limb ischemia). If lowered hand digital pressures are not the result of a drop in systemic blood pressure (cardiac origin) or a stenosed axillary or brachial inflow artery feeding the access, blood pressure loss may be associated with the fistula's low pressure venous outflow system ("pressure sink").[7] Surgical AVF revision such as venous outflow banding is based on attenuation of blood pressure loss at the arteriovenous junction.[8] Conversely, incremental banding resulted in corresponding increases in finger pressures and attenuation of ischemic symptoms in one population with HAIDI.[9]

A recent study demonstrated that ligating the AVF's venous side branches (side branch ligation, SBL) immediately resulted in increased finger pressures and attenuation of symptomatic hand ischemia.[10] It was concluded that SBL effectively reduces the pressure loss around the anastomosis. Moreover, the effectiveness of an additional flow reducing technique such as banding or DRIL is improved as excess shunting of blood is reduced. However, the long-term effects of a "SBL first" approach on hand perfusion, access flows, and AVF patency are unknown. The present research was undertaken to study these parameters in HD patients who previously underwent SBL for haemodialysis access induced distal ischemia. It was hypothesized that a "SBL first" approach effectively treats hand ischemia without compromising AVF function.

MATERIALS AND METHODS

General information

Presently, some 110 patients undergo chronic HD in Máxima Medical Center in Veldhoven and Eindhoven, the Netherlands. The preferred brachial artery based AVF is the 'Gracz fistula'. In this type of AVF, the median antecubital vein or its deep perforating vein is mobilized and anastomosed to the brachial artery. AVF outflow in most instances occurs via both the cephalic and basilic veins. Patients suffering from possible HAIDI are discussed at a weekly multidisciplinary meeting. If hand ischemia is deemed likely, patients are invited for further analyses at the vascular outpatient clinic. The patient is then interviewed and the dialysis hand is inspected. By manually blocking the AVF's venous outflow tract including its side branches (SB), the ischemia is considered reversible if a warmer hand is experienced and radial artery pulsations return ("compression test").

If HAIDI is likely, the patient is invited to complete a questionnaire quantifying hand ischemia (HIQ).[2,11] Although a HIQ score may not always accurately reflect the severity of HAIDI, previous studies have demonstrated that HIQ scores (0, no ischemia, 500, maximal ischemia) reliably predict the presence of HAIDI.[2,8,9] A finger pressure (P_{dig}) with and without compression is obtained at the vascular laboratory (VasoGuard Nicolet, 8 Mhz, Scimed Ltd, Bristol, UK).[8] Patients with a minimum type 2b HAIDI undergo imaging of the access' arterial inflow and venous outflow using a Duplex or angiography.[4,11,12] If venous side branches (SBs) are present in a 3—5 cm area proximal to the anastomosis, a SBL procedure is offered as a first step surgical approach with additional flow reducing surgery at the same time when deemed necessary. All patients with a brachial artery based AVF with symptoms of at least type 2b HAIDI and with venous SBs in a 3—5 cm area in proximity to the anastomosis were included in this study.

The first patient undergoing a SBL approach was operated on in 2005.[9] During a SBL procedure, visible venous outflow SBs are ligated using a standard open approach. The effect is monitored with the use of digital pressures (VasoGuard Nicolet, 8 Mhz, Scimed Ltd, Bristol, UK) and access flow measurements using an ultrasonic transit time technique (Optimax flow probes, HT 313, Transonic Systems Inc, New York, USA). If digital pressures did not increase or hand perfusion did not improve as subjectively judged on the basis of radial pulsations or digital skin colour, additional surgery such as banding (if flow is >1 L/min) or distal revascularization interval ligation (DRIL, <1 L/min) was performed during the same operative procedure, as previously published.[2,13]

Characteristics of present follow up study

The immediate effects of SBL have been reported previously.[10] All patients from this previous study were also included in rates calculated after a 1 year follow up period. Clinical data were collected from standard nephrological and surgical electronic patient files. Access flows of operated patients were prospectively monitored and recorded every 2 months using a standard two needle dilution technique (HD01, Transonic Systems Inc, New York, USA) as suggested by DOQI.[14] Symptoms possibly associated with recurrent or residual HAIDI were quantified using the HIQ. Digital pressure measurements at 1 year were obtained in a portion of the patients. All patients gave oral informed consent for their treatment and follow up. As all of these evaluations are considered standard of care by the hospital dialysis specialists, approval of the local medical ethics committee was not requested.

Statistical analysis

SPSS software version 17.0 was used for data collection and statistical analysis (SPSS Inc, Chicago, IL). Distribution of data was studied for normality and the Wilcoxon-signed rank test compared differences between variables. A repeated measures ANOVA was performed to analyse access flow over time. A two-way ANOVA determined group differences in access flow over time. Follow up period was expressed in months as mean ($\pm$SEM). Results were expressed as mean ($\pm$SEM). Patency rates were expressed as recommended by the Society for Vascular Surgery and the American Association for Vascular Surgery.[15] A p value $<.05$ was considered to be significant.

RESULTS

Between January 2005 and December 2013, 46 HD patients from a single institution were diagnosed with HAIDI. These 46 patients represent 5% of the total population receiving

Table 1. Demographic data of patients undergoing side branch ligation for HAIDI.

N	20
Age, mean ± SEM	69 ± 3
Sex, male/female	10/10
Diabetes mellitus, yes/no	5/15
Peripheral arterial disease, yes/no	4/16
Hypertension, yes/no	11/9
HAIDI type, 2b/3/4	8/11/1

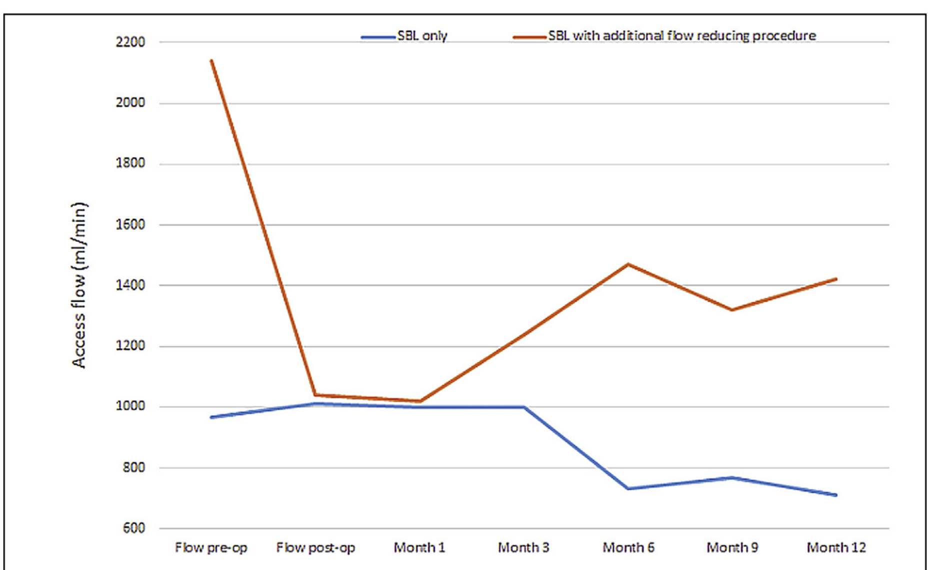
chronic HD at any time during this 9 year observation period. As six HAIDI patients successfully underwent endovascular treatment of an arterial inflow stenosis and two patients with HAIDI type 2A received conservative treatment, a total of 38 patients were operated on. In this surgical HAIDI population, seven patients received banding, six AVFs were ligated. Another two patients underwent basilic vein transposition, whereas two received a DRIL. Clinically significant SBs following physical examination or Duplex were not identified in any of these 17 patients.

Of the 38 patients requiring surgery, SBL was possible in the remaining 21 patients (55%). All 21 underwent a SBL first approach, although one patient was excluded as she had a radiocephalic AVF. All 20 brachial artery based AVFs were Gracz type. Demographics of this study population are shown in Table 1. Ten individuals underwent SBL as a single operative procedure. However, in the remaining 10 patients, a SBL was supplemented with banding ($n = 5$), basilic vein transposition ($n = 4$), or DRIL (n = 1) in the same session.[10]

During the 12 month follow up period following SBL, two of these 20 patients died (requested discontinuation of dialysis, $n = 1$; heart failure, $n = 1$). Eighteen patients reached the 12 month endpoint (SBL only $n = 8$; SBL with additional flow reduction technique, $n = 10$). During this 1 year observation period, one patient demonstrated progressively lower access flows and recurrent signs of hand ischemia caused by diffuse atherosclerosis necessitating ligation and construction of a PTFE thorax loop arteriovenous graft (AVG) 3 months after SBL. The AVFs of two additional patients occluded, one because of aneurysm formation resolved by successful revision 10 months after SBL whereas a second AVF was successfully revised after 1 month using a PTFE upper arm loop AVG.

Three non-ischemic complications were observed during follow up. One patient developed symptoms of venous congestion only 6 months after SBL in the presence of an access flow >1600 mL/min requiring flow reducing surgery by revision using distal inflow (RUDI). Moreover, two patients underwent endovascular angioplasty of a significant stenosis of the brachial artery because of diminishing access flows, both 9 months after SBL (SBL only, $n = 1$; SBL with additional BT, $n = 1$). Primary, assisted primary, and secondary access patency rates following SBL were 67% (12/18), 83% (15/18), and 89% (16/18), respectively.

Access flows are shown in Fig. 1. In patients undergoing SBL only ($n = 10$), access flow did not change immediately after the operation (1100 ± 320 vs. 1010 ± 100 mL/min). Moreover, flow remained well above the critical thrombosis threshold (400 mL/min) during the 12 month post-operative observation period (710 ± 70 mL/min, $n = 10$). Over time, access flow did not significantly decrease, although a trend was observed ($p = .07$) using a repeated measures ANOVA. In contrast, post-operative access flow in patients undergoing SBL and a supplemental procedure ($n = 10$) increased to 1420 ± 200 mL/min at 12 month follow up, ($p = 0.24$, using repeated measures ANOVA). The two-way ANOVA showed a statistically significant interaction between study



SBL only (N)	11	9	9	6	6	7	7
SBL + FRP (N)	10	9	9	6	6	7	8

Figure 1. Mean access flow (mL/min) before and after side branch ligation (SBL) in patients with HAIDI.

groups and time on access flow ($p = .01$). This effect is mainly because of access flow differences in the study groups ($p = .01$) and not because of time ($p = .96$).

Table 2 demonstrates effects of SBL on subjectively and objectively obtained parameters of hand ischemia. Immediately following SBL, scores reflecting ischemia dropped threefold. Moreover, hand ischemic scores at 12 month follow up were still less than half pre-operative scores. DBI remained well above 0.6, a generally accepted cut off point for ischemia, both immediately post-operatively as well as at the 1 year follow up (0.68 ± 0.04 and 0.83 ± 0.07, respectively). Except for the one patient requiring access ligation because of progressive occlusive disease, no other patient underwent a novel evaluation or surgical procedure for recurrent hand ischemia during this time period. Therefore, a 94% (17/18) SBL success rate was obtained.

DISCUSSION

Haemodialysis access induced distal ischemia may be found in up to 9% of unselected dialysis populations.[4,5] If conservative measures (treating anaemia, gloves, optimization of medication) or a minimally invasive procedure (inflow angioplasty) fail, most surgeons would argue that a first line of invasive treatment is dictated by access flow volume. If flows exceed 1.5–2.0 L/min, reducing access flow using banding or RUDI is likely to lead to increased hand perfusion and attenuation of hand ischemia.[2] If access flow is <1 L/min, inflow proximalization or DRIL may be preferred.[16]

However, it must be realized that an inappropriate loss of perfusion pressure along the heart hand axis intensifies symptoms of HAIDI. Therefore, treatment should also be aimed towards attenuating these causes for loss of blood pressure. The AVF's non-functional venous SBs were recently found to potentially contribute to limb blood pressure loss. One study demonstrated that SBL indeed optimized hand perfusion, whereas immediate post ligation access flows were essentially unaltered.[10] The results of the present 1 year follow up study demonstrate that access flow was maintained following SBL whereas hand perfusion remained sufficient in the vast majority of patients.

Several findings contribute to the diagnosis of HAIDI. The patient's history (pain, cold hand, diminished strength, cramps, reduced sensation) may seem subjective but these symptoms and signs can be objectively scored using a published hand ischemia questionnaire.[2,10,17] Mean scores in dialysis populations not suffering from HAIDI were found to range from 35 to 60 on a 0–500 point scale. In contrast, a 153 ± 33 score was demonstrated in type 2b-4 HAIDI requiring flow reduction. Successful surgery reduced postoperative scores to normal values (42 ± 15).[2,10,17] In the present study, SBL immediately reduced the ischemic score from 184 ± 20 to 60 ± 15. SBL is durable, and an effective treatment for HAIDI in the long term, as scores were maintained at a 79 ± 35 level after 1 year.

If symptoms of hand ischemia are insufficiently attenuated following conservative measures, arterial stenotic lesions (if present) require angioplasty. In the present study population, an arterial inflow lesion was endovascularly corrected leading to improved hand perfusion in 13% (6/46). If this first step of a minimally invasive approach for HAIDI is unsuccessful, the next step is non-invasive evaluation of the hemodynamic consequences of open SBs on the access' venous outflow, if present. During an initial outpatient department evaluation, manually compressing the AVF and/or its SBs may subjectively lead to a warmer hand, and distal radial pulsations may become more prominent. Digital pressures may indeed increase following these compression tests. In addition, Duplex analysis allows for assessing flow volume along these open SBs. Combining all of these findings may allow for the planning of operative intervention and may predict whether "a SBL only" approach is successful, or whether an additional surgical technique is probably necessary. However, intra-operative findings such as increased plethysmographic finger pressures, more prominent distal pulsations, improved hand skin colour, maintained access flow volume and access thrills also dictate whether SBL will suffice.

Any HAIDI treatment is aimed at reducing symptoms of hand ischemia while maintaining access flow volume, allowing for effective ongoing haemodialysis. The ideal surgical technique is minimally invasive, effective, and durable. In the present cohort of 46 patients, 38 patients required some sort of surgical procedure. Of these, 53% (20/38) underwent ligation of side branches around a brachial artery based AVF as a first minimally invasive approach, either exclusively (26%, 10/38) or as an adjunct preceding a flow reducing technique such as banding (26%, 10/38). Interestingly, SBL alone was successful in abolishing hand ischemia in 22% (10/46) of the population with HAIDI undergoing surgery. Therefore, it is concluded that SBL is a simple and safe first step in the surgical approach for HAIDI patients.

The present study suffers from shortcomings including incomplete data sets of flows and finger pressures at various time points during the 1 year study period. Some patients may have rejected invasive surgery but were not registered as such, potentially introducing a selection bias. The choice to combine various types of surgical techniques is solely dependent on the senior author's preference and subjective judgement during the surgical procedure.

In conclusion, a "venous side branch ligation first approach" for the treatment of hand ischemia in the

Table 2. Ischemic scores and digital pressures following side branch ligation (SBL) in patients with HAIDI.

	Before SBL	Immediately after SBL	12 ± 0 months after SBL
Hand ischemic score[a]	184 ± 21 ($n = 18$)	60 ± 15[b] ($n = 18$)	79 ± 35[b] ($n = 8$)
Digital brachial index (Pdig/Psyst)	0.51 ± 0.05 ($n = 20$)	0.68 ± 0.04 ($n = 20$)	0.83 ± 0.07[c] ($n = 8$)

[a] 0 points, no signs ischemia – 500 points, maximal severe ischemia.
[b] $p < .05$ compared with before SBL.
[c] $p < .05$ compared with before and immediately after SBL.

presence of an autogenous brachial artery based fistula is an effective modality for hand ischemia in over half of the patients with HAIDI. Access flow volumes were maintained after 1 year of follow up, allowing ongoing proper haemodialysis. If venous side branches are deemed to contribute to loss of perfusion pressure, ligation is mandatory prior to executing more invasive types of surgery.

CONFLICT OF INTEREST

None.

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APPENDIX A. SUPPLEMENTARY DATA

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.ejvs.2015.07.037.

REFERENCES

1 Pasklinsky G, Meisner RJ, Labropoulos N, Leon L, Gasparis AP, Landau D, et al. Management of true aneurysms of hemodialysis access fistulas. *J Vasc Surg* 2011;**53**(5):1291—7.
2 van Hoek F, Scheltinga M, Luirink M, Pasmans H, Beerenhout C. Banding of hemodialysis access to treat hand ischemia or cardiac overload. *Semin Dial* 2009;**22**(2):204—8.
3 Yeager RA, Moneta GL, Edwards JM, Landry GJ, Taylor Jr LM, McConnell DB, et al. Relationship of hemodialysis access to finger gangrene in patients with end-stage renal disease. *J Vasc Surg* 2002;**36**(2):245—9 [discussion 9].
4 Scheltinga MR, van Hoek F, Bruijninckx CM. Time of onset in haemodialysis access-induced distal ischaemia (HAIDI) is related to the access type. *Nephrol Dial Transplant* 2009;**24**(10):3198—204.
5 Padberg Jr FT, Calligaro KD, Sidawy AN. Complications of arteriovenous hemodialysis access: recognition and management. *J Vasc Surg* 2008;**48**(5 Suppl):55S—80S.
6 Scheltinga MR, Bruijninckx CM. Haemodialysis access-induced distal ischaemia (HAIDI) is caused by loco-regional hypotension but not by steal. *Eur J Vasc Endovasc Surg* 2012;**43**(2):218—23.
7 Wixon CL, Hughes JD, Mills JL. Understanding strategies for the treatment of ischemic steal syndrome after hemodialysis access. *J Am Coll Surg* 2000;**191**(3):301—10.
8 Scheltinga MR, Van Hoek F, Bruyninckx CM. Surgical banding for refractory hemodialysis access-induced distal ischemia (HAIDI). *J Vasc Access* 2009;**10**(1):43—9.
9 van Hoek F, Scheltinga MR, Luirink M, Raaymakers LC, van Pul C, Beerenhout CH. Access flow, venous saturation, and digital pressures in hemodialysis. *J Vasc Surg* 2007;**45**(5):968—73.
10 Vaes RH, Scheltinga MR. Side Branch ligation for haemodialysis-access-induced distal ischaemia. *Eur J Vasc Endovasc Surg* 2012;**44**(4):452—6.
11 Vaes RH, Tordoir JH, Scheltinga MR. Blood flow dynamics in patients with hemodialysis access-induced hand ischemia. *J Vasc Surg* 2013;**58**(2):446—51.
12 Tordoir JH, Dammers R, van der Sande FM. Upper extremity ischemia and hemodialysis vascular access. *Eur J Vasc Endovasc Surg* 2004;**27**(1):1—5.
13 Berman SS, Gentile AT, Glickman MH, Mills JL, Hurwitz RL, Westerband A, et al. Distal revascularization-interval ligation for limb salvage and maintenance of dialysis access in ischemic steal syndrome. *J Vasc Surg* 1997;**26**(3):393—402 [discussion 402—4].
14 K/DOQI clinical practice guidelines for cardiovascular disease in dialysis patients. *Am J Kidney Dis* 2005;**45**(4 Suppl 3):S1—153.
15 Sidawy AN, Gray R, Besarab A, Henry M, Ascher E, Silva Jr M, et al. Recommended standards for reports dealing with arteriovenous hemodialysis accesses. *J Vasc Surg* 2002;**35**(3):603—10.
16 Schanzer H, Schwartz M, Harrington E, Haimov M. Treatment of ischemia due to “steal” by arteriovenous fistula with distal artery ligation and revascularization. *J Vasc Surg* 1988;**7**(6):770—3.
17 van Hoek F, Scheltinga MR, Kouwenberg I, Moret KE, Beerenhout CH, Tordoir JH. Steal in hemodialysis patients depends on type of vascular access. *Eur J Vasc Endovasc Surg* 2006;**32**(6):710—7.