J Clin Invest Surg. 2018; 3(1): 14-19
doi: 10.25083/2559.5555/31.1419

Research Article

Stenotic ligature: a simple technique for managing distal hypoperfusion ischemic syndrome following arteriovenous fistulas

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Abstract

Introduction. Distal Hypoperfusion Ischemic Syndrome (DHIS) is a multifactorial debilitating condition causing peripheral ischemia and potentially tissue necrosis. In an effort to further refine its surgical treatment we aim to describe a modified, simple and reliable technique for managing DHIS in patients with arteriovenous fistulas.

Materials and Methods. Twenty-nine consecutive patients with DHIS operated by a single surgical team over a period of 7 years were included in the study. All patients underwent the same surgical technique: stenotic ligature. Outcomes were analyzed clinically and the effectiveness of the procedure was proven using McNemar test. Clinical variables were statistically analyzed in SPSS 17.0 for Windows.

Results. The technique we used consists in performing a stenosing ligature on the vein, using a 0-silk suture, and adjusting the suture in order to achieve either a radial pulse or capillary pulse, while maintaining a good thrill at palpation of the vein. The procedure was successful in 83% of patients proved by immediate symptomatic relief. Paired data analysis showed significant decrease of all symptoms: cold extremity ($p=0,021$), paraesthesia ($p<0,001$), pain ($p<0,001$). History of coronary artery disease, arteriopathy or the absence of radial pulse is statistically correlated with an increased risk of developing DHIS.

Conclusions. Stenotic ligature is a simple, cheap and reliable technique for managing DHIS with lower septic risks which can be easily performed under local anesthesia.

Keywords : arteriovenous fistulas, stenotic ligature, distal hypoperfusion ischemic syndrome

Highlights

- ✓ Stenotic ligature for managing distal hypoperfusion ischemic syndrome following arteriovenous fistulas is an easy to learn technique, with low costs, that can be done in an outpatient setting under local anesthesia.
- ✓ When compared with other procedures, our technique has a comparable success rate and all the benefits described.

To cite this article: Roata EC, Morosanu C, Makkai-Popa ST, Morarasu S, Lunca S, Dimofte G. Stenotic ligature: a simple technique for managing distal hypoperfusion ischemic syndrome following arteriovenous fistulas. *J Clin Invest Surg*. 2018; 3(1): 14-19. DOI: 10.25083/2559.5555/31.1419

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Introduction

In hemodialyzed patients with arteriovenous fistulas (AVF) the presence of pain, numbness and/or cold extremity in the limb that bears the fistula is referred to as digital hypo-perfusion ischemic syndrome (DHIS) (1). Previously DHIS was known as arterial theft syndrome however now it is clear that more factors stand at the basis of DHIS development. Besides true retrograde flow, peripheral arteriopathy and arterial stenosis proximal to the AVF are cumulative risk factors (2, 3). Although the latter two cannot be surgically controlled, arterial theft can be diminished by different surgical approaches thus relieving distal ischemia. In the setting of arterial theft, there are two widely known compensatory mechanisms: distal vascular relaxation, which leads to increased blood flow in the fistula and peripheral arteries, and secondary development of collateral circulation. When these mechanisms are exceeded by increased retrograde flow and/or arterial obstruction, DHIS becomes clinically manifest (4).

The current management of DHIS is split into percutaneous and surgical approaches. Two main percutaneous procedures are known, each one addressing one specific cause for developing peripheral ischemia. In selected cases with arteriographic proven arterial stenosis as the main cause, percutaneous angioplasty can be used with successful results. Otherwise, distal flow can be increased by reducing arterial theft (5). A percutaneous procedure addressing this cause with good results is the minimally invasive limited ligation endoluminal assisted revision (Miller) (6). The technique is based on the application of a Nylon ligature around an inflated endoluminal balloon.

Regardless of procedure details, all surgical interventions are aimed at reducing retrograde flow through the AVF, relieving distal blood flow, without compromising the functionality of the fistula. The surgical techniques described to date are distal revascularization and interval ligation (DRIL) (7, 8), proximalization of the arterial inflow (9), the revision using distal inflow technique (RUDI) (10), banding (11) and plication (12) techniques. Banding is a simple technique to reduce fistula flow however it is associated with thrombosis of the AVF (2). More reliable procedures such as DRIL, RUDI or proximalization of arterial inflow have good outcomes in augmentation of distal blood flow, but all are invasive procedures with associated intraoperative complications, increased costs and prolonged hospitalization (5).

To further refine surgical management of DHIS we present a modified technique for reducing arterial theft and improving distal flow which can be done in an outpatient basis under local anesthesia. Moreover, we aim to analyze clinical variables and their influence on developing DHIS.

Materials and Methods

We retrospectively studied a group of 29 consecutive patients operated by a single surgical team over a period of 7 years at „Sf. Ioan" Emergency Hospital, Surgical Department, Iasi. The study was approved by the Ethics Committee of the "Grigore T. Popa" University of Medicine and Pharmacy and by the Ethics Committee of the "Sf. Ioan" Emergency Hospital. Patients presenting with symptomatic digital hypo-perfusion ischemic syndrome after an arteriovenous fistula were included in the study.

Exclusion criteria were:

- diabetic patients previously diagnosed with neuropathy, presenting for paraesthesia after AVF
- patients complaining of ischemic phenomena after being subjected to cold conditions
- patients in which ischemic symptoms improved after vasodilators and antiplatelet medication

On presentation the symptoms were evaluated and the timeframe until each of the clinical signs appeared was noted. The analyzed symptoms were:

- paraesthesia
- cold extremity
- pain
- trophic lesions

All patients were averted not to alter their anti-hypertensive medication within the week prior to surgery so the procedure would be performed in the setting of everyday blood pressure parameters. All patients were informed regarding the procedure and signed an informed consent. All patients underwent the same procedure: stenotic ligature. After two months patients were called in for follow-up and the aforementioned symptoms were reassessed and compared.

The statistical analysis was done in SPSS 17.0 for Windows. We first performed a descriptive analysis of the study group and then a McNemar test was used to assess the effectiveness of our method by comparing the presence and absence of symptoms before the procedure and after 2 months. At the same time the chi-square and t-tests were used to evaluate the correlation between different comorbidities and the hypo-perfusion symptoms.

Results

Surgical procedure

The patient is placed in supine position, with the arm bearing the fistula in abduction at a 90 degrees angle, the palm placed in supination and the other arm tucked in along the side of the patient.

The incision is made along the vein starting at 2 cm proximal to arteriovenous anastomosis. Venous collaterals and perforator vessels are ligated. The presence of radial or capillary pulse is then assessed, depending on which of the two was present before performing the arteriovenous fistula. We continued by performing a stenosing ligature on the AVF.

The stenosing ligature consists in encircling the vein twice at a small distance from the site of the fistula, using a 0 silk suture. A single knot is tied in the ligature, in order to allow for further adjustment of the degree of stenosis induced. In patients presenting a radial pulse before performing arteriovenous anastomosis, the knot is adjusted to a degree which allows us to feel a radial pulse, while making sure there is still a good thrill palpable on the vein. In patients who did not present a palpable radial pulse before the fistula formation, the stenosis is induced gradually until capillary pulse is observed distal to the fistula and the patient feels the arm warming up, while again making sure there is still a good thrill on palpation of the vein. Once the degree of stenosis is satisfactory, second and third knots are performed and the subcutaneous layer and skin are closed in the usual fashion (Figure 1).

Figure 1. Aspect of the stenotic ligature applied on the AVF

Statistical analysis

A total of 29 patients were included in the study. The procedure was successful in 24 cases (82.7%). In 5 patients (17.2%) re-intervention was necessary as the ligature failed to maintain proper flow to the peripheral arteries. Demographic data showed a mean age of 56 years old (47-68) with a slight male predominance, 55.17% compared to 44.83%. With regards to smoking status, the majority of patients were non-smokers (62%) (Figure 2).

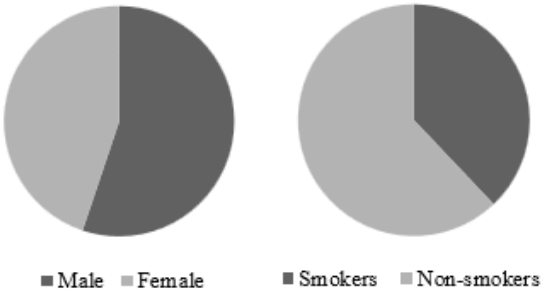

Figure 2. Demographic data regarding gender and smoking status

Most common type of fistula done was on the basilic vein (72.4%) with the rest being on the cephalic vein (27.59%) (Fig. 3). In 44.82% of patients radial pulse was present before the AVF was performed, while in the rest was absent.

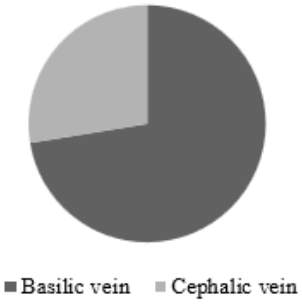

Figure 3. Location of AVF. 21 were on the basilic vein and 8 on the cephalic vein

Literature-linked comorbidities prior to AVF formation were found in our group of patients as follows: diabetes 100% (51.7% were insulin dependent), coronary artery disease 17.24%, arteriopathy 20.68%, history of ischemic stroke 0% (Table 1).

Comorbidities prior to AVF formation	Rate (no. of patients with disease/percentage)
Diabetes	29 / 100%
Coronary artery disease	5 / 17.24%
Arteriopathy	6 / 20.68%
Ischemic Stroke	0

Table 1. Comorbidities found in patients prior to AVF formation

A t-test showed no correlation between the type of fistula and the appearance of trophic lesions, which is a sign of severe hypo-perfusion ($p>0.05$).

In order to analyze how comorbidities correlate with the appearance of DHIS, we did a paired analysis in SPSS and grouped four associated diseases (diabetes, coronary artery disease, arteriopathy and ischemic stroke) and the presence or absence of radial pulse with

symptomatic hypoperfusion. Statistically significant correlations were found between coronary artery disease (p<0,001), arteriopathy (p=0,002) and absence of radial pulse (p<0,001) with appearance of DHIS. These results were matched, thus stratifying patients in two risk groups: high-risk patients who have one or more of the mentioned risk factors and low-risk patients who don`t present any of the factors studied (Table 2). A multivariate analysis was not possible due to the small size of the cohort. No correlation was found between the presence of insulin-dependent diabetes mellitus and the severity of ischemic symptoms. History of ischemic stroke could not be analyzed because in was not present in any of our studied patients.

High-risk patients for developing DHIS
History of coronary artery disease
Arteriopathy
Absence of radial pulse prior to AVF formation

Table 2. High risk patients for developing symptomatic hypoperfusion

In almost all patients the effect of the stenotic ligature was immediately observed by us and felt by the patients. Patients noticed the arm warming up right on the operating table, while the paraesthesia and motor function impairment went away immediately after the procedure. In order to understand whether our procedure is an effective way to deal with the hypo-perfusion symptoms, we applied a McNemar test which was statistically significant for all of the studied symptoms: cold extremity (p=0,021), paraesthesia (p<0,001), pain (p<0,001) (Table 3).

Symptoms	**p value**
Cold extremity	p=0.021
Paraesthesia	p<0.001
Pain	p<0.001

Table 3. Statistical association between symptoms before and after stenotic ligature

Eight patients (27.59 %) had the AVF formed between the humeral artery and cephalic vein and it was successful in all cases. The rest of the 21 patients (72.41 %) had an anastomosis between the humeral artery and basilic vein. In these 21 cases the stenotic ligature was successful in 16 patients, while the other 5 patients required a second intervention which was proximalization of the arterial inflow. A chi-square test showed that the absence of radial pulse before the arteriovenous anastomosis is statistically correlated with failure of the stenotic ligature and the need for reintervention (p=0.027).

Discussion

Surgical interventions aimed at reducing arterial theft through the AVF are various with variable results. Minimally invasive techniques are the first option considering that most patients with AVF are high risk surgical patients. They require a minimal setting but are prone to eventual failure. Moreover, vein plication and banding have one important disadvantage – the calibration cannot be properly adjusted and once the procedure is finished, it is irreversible and thus impossible to calibrate (13).

Resolving the arterial theft by a bypass procedure (synthetic or venous graft) and distal ligation of the artery bearing the fistula is the most efficient choice, with success rate reaching 100% (7). However they require general anesthesia, a second surgical wound, increased costs and postoperative inpatient care (5, 14). Thus, we believe the perioperative risks to be too high considering the general status of patients with AVF.

We tried to come up with a simpler, easier to calibrate technique, that can be performed under local anaesthesia, with a reduced septic risk. The major advantage of our technique is the fact that we can test the calibration in vivo while the patient is still on the operating table. The patient leaves the operating room only when we achieved a proper balance between distal perfusion and thrill on the vein. This balance is a major asset for our technique. A comparison with the Miller technique (6), which uses a fix stenosing ligature calibrated on a 4-5mm intra-luminal balloon, reveals the major advantage of flexibility in calibration for our technique. All patients included in our study who underwent the procedure as described above had a functional fistula at 2 months and the McNemar test showed the procedure was effective for symptomatic and clinical relief. Our results are comparable to the known standardized techniques (Table 4).

Although efficient, our technique is blended from the minimal invasive approaches so failure in some cases is expected. In our study five patients (17%) required re-intervention, due to the persistence of hypo-perfusion symptoms. These patients underwent inflow proximalization, with excellent results. The need for a re-intervention can be predicted by the absence of radial pulse before the anastomosis, as shown in the paired analysis (p=0.027).

Study	Procedure used	Success rate	Number of patients
Our Study	Stenotic Ligature	83%	29
Berman et al.[15]	DRIL	100%	21
Huber et al.[16]	DRIL	78%	64
Zanow et al.[17]	Proximalization	84%	30
Minion et al.[10]	RUDI	100%	4
Gupta et al.[13]	RUDI	100%	3
Yaghoubian et al.[12]	Vein plication	85.7%	7
Papalois et al.[11]	Banding	82%	226
Scheltinga et al.[18]	Banding	38%	21
Goel et al.[6]	Miller	94%	16

Table 4. Literature comparison regarding success rate after various surgical procedures for DHIS correction

After an arteriovenous anastomosis some degree of hypoperfusion clearly develops as flow is shunted in a low resistance area created by the fistula. Lazarides et al.(19) retrospectively studied 69 patients with AVF and proved that in 94% of cases a degree of hypoperfusion syndrome exists distal to the fistula as differences in blood pressure were found between the arm bearing the fistula and the controlateral one. However, clinically manifest DHIS will develop only in 8% of patients as compensatory mechanisms (arterial collaterals and distal vasodilatation) improve tissue perfusion (3). Other studies have shown that a surgical procedure is necessary in 1,7% - 9% of patients (20-22). If these compensatory mechanisms are altered by the presence of arterial atherosclerosis, arterial stenosis, vascular calcification secondary to Chronic Kidney Disease or peripheral neuropathy, then ischemia occurs and clinical signs appear (23).

The pathophysiology behind DHIS is based on three different mechanisms: true arterial theft, distal arteriopathy and arterial stenosis proximal to the AVF. Comorbidities such as diabetes (especially insulin-dependent), coronary artery disease and peripheral arteriopathy are all linked to accelerated atherosclerosis and subsequently are prone to developing ischemia symptoms when blood flow is altered as it is the case of an arteriovenous anastomosis (3, 5, 21). Our study confirmed coronary artery disease and arteriopathy as risk factors for developing DHIS. However diabetes, even insulin-dependent type, was not found to be associated with increased risk for DHIS appearance.

Conclusions

We describe a simple, effective and cheap approach for treating Distal Hypoperfusion Ischemic Syndrome (DHIS). It is an easy to learn technique, with low costs, that can be done in an outpatient setting under local anesthesia. When compared with other procedures, our technique has a comparable success rate and all the benefits described earlier.

In our study the absence of radial pulse was statistically correlated with the need of a re-intervention, while the type of diabetes did not influence the risk of developing hypoperfusion symptoms. We consider that inflow proximalization and DRIL are good salvage techniques when stenosing ligation fails to improve tissue perfusion.

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