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Long Term Outcomes Of "Christmas Tree" Banding for Dialysis Access Related Steal Syndrome: A Thirteen-Year Experience

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Abstract:	Background: The reduction in distal arterial flow following arteriovenous fistula (AVF) creation can cause a perfusion deficit known as Dialysis-Access related Steal Syndrome (DASS). Various techniques have been advocated to treat this difficult problem with varying success. We present the long-term outcomes following a novel banding technique. Methods: 46 patients in this cohort from 2008-2021 underwent an adjustable banding procedure using a DacronTM patch shaped with one slit-end and saw-tooth edges(resulting in a ''Christmas-tree'' pattern) to provide a ratchet mechanism to progressively constrict the fistula outflow. Real-time finger perfusion pressure monitoring allowed an accurate reduction in AVF flow whilst increasing distal arterial perfusion pressure. Baseline characteristic were recorded and Kaplan-Meier survival curves were obtained to calculate the post-intervention primary, assisted primary and secondary patency. Results: 29 patients presented with rest pain and 11 presented with tissue loss due to steal syndrome. The post-intervention primary access patency was 100%, 98%, 78% and 61% at 30 days, 60 days, 180 days and 1 year respectively. The median post-intervention primary, assisted primary and secondary patency were 1032 days, 1189 days and 2199 days respectively. Complete resolution of symptoms was achieved in 74%(n=34) of patients and a partial response needing no further intervention was achieved in 11%(n=5) of patients. A Youden index calculation suggested that opening pressures of 41mm Hg or lower were highly specific for "true" steal syndrome and pressures greater than 65mm Hg ruled out Steal syndrome.

	Conclusion: This adjustable dynamic method for treating DASS is efficacious and durable, preserving fistula patency.

Title: Long Term Outcomes Of "Christmas Tree" Banding for Haemodialysis Access Induced Distal Ischemia : A Thirteen-Year Experience

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Acquisition of data	BR,JT
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Short title: "Christmas tree" banding for AVF related distal ischemia

Abstract:

Background: The reduction in distal arterial flow following arteriovenous fistula(AVF) creation can cause a perfusion deficit known as haemodialysis access induced distal ischemia(HAIDI). Various techniques have been advocated to treat this difficult problem with varying success. We present the long-term outcomes following a novel banding technique.

Methods: 46 patients in this cohort from 2008-2021 underwent a novel banding procedure using a Dacron™ patch shaped with one slit-end and saw-tooth edges(resulting in a ''Christmas-tree'' pattern) to provide a ratchet mechanism to progressively constrict the fistula outflow. Real-time finger perfusion pressure monitoring allowed an accurate reduction in AVF flow whilst increasing distal arterial perfusion pressure. Baseline characteristic were recorded and Kaplan-Meier survival curves were obtained to calculate the post-intervention primary, assisted primary and secondary patency.

Results: 29 patients presented with rest pain and 11 presented with tissue loss due to distal ischemia. The post-intervention primary access patency was 100%, 98%, 78% and 61% at 30 days, 60 days, 180 days and 1 year respectively. Complete resolution of symptoms was achieved in 74%(n=34) of patients and a partial response needing no further intervention was achieved in 11%(n=5) of patients. A Youden index calculation suggested that digital pressures of 41mm Hg or lower in an open AVF were highly sensitive for symptomatic hand ischemia whereas pressures greater than 65mm Hg ruled out distal ischemia

Conclusion: "Christmas-tree" banding with on table finger systolic pressures is not only an efficacious and durable method for treating HAIDI but also preserves fistula patency.

Keywords: Steal Syndrome, ischemia, dialysis access

Introduction

Arteriovenous fistulae(AVF) are the preferred route of vascular access for patients undergoing haemodialysis(HD)(1). The number of patients using an AVF for HD has steadily increased from 40% in 2010(2) to 72% (3)over the last 10 years, causing an increase in the number of complications including distal ischemia)(4). Several terms have been proposed to describe distal ischemia caused by placement of arteriovenous access, but the most common terms are dialysis access associated steal syndrome(DASS), haemodialysis access induced distal ischemia(HAIDI) and arteriovenous access induced steal(AVAIS). But given that the presence of steal or reversal of flow is not mandatory for vascular access induced distal ischemia(5), this phenomenon is best described as HAIDI(6), The incidence of HAIDI has been reported to vary from 2% to 8% of the HD population, although asymptomatic steal is noted in more than 90% of patients with AVFs(7).

HAIDI is characterized by rest pain, motor or sensory loss, and/or tissue loss which could potentially be limb threatening. It can be caused by the presence of distal arterial occlusive disease, excess blood flow through the AVF, a lack of arterial collateralization or a combination of these factors(8,9). The more proximal the AVF, the greater the incidence of HAIDI. For example an AVF at the antecubital fossa is associated with a 10 times higher incidence than one at the wrist(7). Although the diagnosis of severe HAIDI is straight-forward, it presents a unique diagnostic challenge in patients with less-severe symptoms. Neurological problems are common in patients undergoing haemodialysis with over 60% of patients suffering from polyneuropathy due to diabetes or uraemia. Nerve compression syndromes such as carpal tunnel and ulnar compression syndromes are also common in patients on dialysis, and some of these are related to or exacerbated by the access(10). The significant overlap of clinical features between these conditions makes the diagnosis of less severe HAIDI more difficult.

Although most patients remain asymptomatic by adjusting via collateralization and compensatory flow mechanisms, a subset of patients who are unable to adequately compensate, develop manifestations of ischemia, necessitating surgical intervention. These interventions include fistula banding, plication(11,12) revascularization using distal inflow(RUDI)(13), distal revascularization with interval ligation(DRIL) (14),the Minimally Invasive Limited Ligation Endoluminal-assisted Revision(MILLER) procedure(15),proximalization of arterial inflow(PAI)(16,17) or ligation of larger side branches to reduce the extent of distal ischemia(18).

While these procedures can potentially reverse ischemia associated with steal allowing preservation of access for HD, patients with insufficient relief of symptoms after access revision may need ligation or sacrifice of access. Sacrifice of access is best avoided due to the increased morbidity associated with dialysis catheters and serial procedures to create further AVF.

Although banding was the first described technique to address HAIDI and one of the least invasive revision procedures, it has been associated with a significant incidence of failure possibly because of unreliable methods of quantifying flow limitation(19,20). The aim of this paper was to assess the long-term outcomes following "Christmas Tree" Banding for the treatment of HAIDI with respect to patency and relief of symptoms.

Materials and Methods:

This retrospective review of a prospectively maintained database was conducted at a tertiary care referral vascular centre. The clinical, intra-operative and follow-up information were gathered and analysed.

Patient selection:

Patients with features suggestive of HAIDI such as cramping pain, paraesthesia, cold hand, weakness, pallor or tissue loss underwent measurement of finger systolic pressures in the affected hand with the AVF fully patent and then repeated with the AVF manually occluded during their index clinical visit along with an arterial duplex scan of the upper limbs. The finger pressures were then compared with the opposite side while making a note of the systemic blood pressure to look for surrogate markers of digital occlusive disease. A transient improvement of symptoms because of momentary distal reperfusion following AVF occlusion and/or an increase in finger pressures of greater than 20mm Hg were taken as indications of likely improvement following banding. The general aim was to offer banding if patients had a baseline pressure consistent with ischemia which improved to a pressure inconsistent with ischemia following clamping or occlusion. Patients who did not exhibit an improvement in symptoms or an increase in finger pressures were not offered banding and were assessed for potentially treatable stenotic arterial disease or other causes such as peripheral neuropathy or Carpal Tunnel Syndrome. The patients were classified based on severity as per the Tordoir classification (21).

Given that a significant number of patients with HAIDI present with atypical symptoms, the decision to offer treatment was mainly based on the changes in finger systolic pressure measurements during the index clinical

visit. All patients with suspected distal ischemia were discussed in a multidisciplinary team meeting with a detailed duplex scan, targeted cross-sectional imaging or an angiogram if needed. These patients and were offered banding only if the MDT agreed that the symptoms were secondary to access placement and if there were no proximal targets for intervention. Patients with resting finger pressures below 40mm Hg and normal systemic blood pressure were offered "Christmas-Tree" banding as the first line of treatment on an urgent basis after the MDT discussion. Patients with higher resting finger pressures(>40mm Hg) or systolic pressures less than 70mm Hg on manual compression of the AVF were further investigated with neurological investigations and were only offered banding if there was no treatable distal arterial disease or entrapment syndrome, and based on a multidisciplinary team discussion. Patients who presented with mild paraesthesia, numbness or pain during dialysis were initially managed with reduction of flow-rate during dialysis and titration of blood pressure medication, if hypotensive on dialysis prior to offering intervention for steal syndrome(9,21,22).

Photoplethysmography(PPG) technique

The resting perfusion pressures were measured at the fingers on both sides using digital Photoplethysmography(PPG-Dopplex Assist Range; PPG Assist,Huntleigh Healthcare Ltd,Luton,UK). This was performed by placing a small blood pressure cuff at the base of the digit and a PPG probe on the pulp of the finger. The probe uses an electro-optical signal to measure pulsations associated in changes of blood volume, and the presence of these can be monitored in relation to the cuff pressure to establish digital perfusion pressure(Figure 1).

We did not routinely measure the digit-brachial index(DBI) in this cohort, as previous evidence has suggested that pre-operative DBI can be relatively inconsistent. It has also been shown that DBI has a lower sensitivity to detect ischemia as many patients with low DBIs are asymptomatic.(23,24)Although high flow rate AVFs are a risk factor for steal syndrome, it has also been suggested that flow-rates don't necessarily correlate with steal.(25) Given that high flow rates and DBI have a lower sensitivity to recognize steal, we used PPG measurements which are a reliable physiological measurement of distal perfusion. Moreover, indices such as the DBI give us information relating to the relative burden of atherosclerotic disease between vascular territories, while absolute values of finger pressures are a better surrogate for tissue perfusion in a target area. (26)

The banding technique(Figures:2&3) is performed under local anaesthesia with intravenous antibiotic prophylaxis. The upper limb is painted and draped with the PPG probe in place and ensuring the exclusion of the PPG equipment from the surgical field. A suitable portion of the outflow vein is dissected and slings positioned to allow proximal and distal control. A Dacron™ patch with a width of 10mm is then cut to shape with ''rachets'' cut to each side approximately 5 mm apart from each other. Once prepared in this manner, the patch resembles a ''Christmas tree'' and is ready for implantation. The band is suitably sized as per the size of the draining vein at the identified site of banding.

The band is wrapped around the draining vein and the ''ratchets'' progressively tightened until they begin to restrict the vein. Digital perfusion pressure is measured before the procedure and as each ratchet is passed through the slit in the patch until a digital perfusion pressure >60mmHg is achieved. Once this target pressure is reached, the thrill in the AVF is clinically assessed, and if required the band can be easily released and readjusted. Once a finger perfusion near to target pressure is reached and a thrill in the AVF is still palpable, interrupted polypropylene sutures are placed fixing the ratchets in place on both sides and securing it in this final position. Finger perfusion is continuously measured for at least five minutes after securing the band in its final position to ensure that the target systolic pressure is maintained prior to closure. Any excess band length is then trimmed and the wound closed with absorbable sutures. The patient is discharged after a period of 2 to 3 hours if distal finger perfusion is adequate and AVF observations by the operating surgeon report an ongoing thrill. The patient was taken back to theatre for re-exploration if there was a significant reduction in the intensity of the thrill according to the operating surgeon.

Technical success was defined as the successful preservation of flow in the AVF with a thrill on post-procedural physical exam and attainment of target systolic pressures usually in the range of >60mm Hg. Clinical success was defined as complete resolution of symptoms and signs of HAIDI with preservation of dialysis access in the one-month postprocedural period. In patients presenting with tissue loss secondary to HAIDI, clinical success was taken as complete resolution of symptoms and satisfactory healing of the ulcers/amputation wounds. Patients with persistent signs and symptoms of HAIDI within one month of initial treatment were classified as having “persistent” HAIDI. Patients who developed recurrence of symptoms or signs after one month were classified as having “recurrent” HAIDI. Patients were classified to have had “true” steal syndrome if they had clinical features of HAIDI with significantly lower resting finger pressures compared to their systemic blood

pressure and exhibited a significant improvement in symptoms and/or pressures on compression or banding. In patients who showed a poor response to banding or compression, the absence of concomitant Carpal Tunnel Syndrome(CTS) and chronic ischemic monomelic neuropathy was ruled out by Nerve conduction studies(NCS) and severe stenotic lesions in the radial or ulnar arteries were ruled out by a diagnostic angiogram.

Post intervention primary patency was defined as the time period from banding to any intervention designed to maintain or re-establish patency or to access thrombosis or the time of measurement of patency. Assisted primary patency was defined as the time period from banding to time of measurement of patency, including intervening surgical or endovascular interventions, designed to maintain the patency of the access. Secondary patency was defined as the time period from banding to access abandonment or time of measurement of patency, including intervening manipulations (surgical or endovascular interventions) designed to re-establish the functionality of thrombosed access.(27)

All statistical analyses were performed using Statistical Package for the Social Sciences(SPSS Inc;Chicago,IL,USA) 23.0 software. Time to event data were presented as Kaplan-Meier survival curves. Comparative hypothesis testing was using Chi-squared, one-way ANOVA and log-rank testing. Data were analysed at a 95% confidence interval, and statistical significance was set at $p<0.050$.

Results:

1459 patients underwent AVF formation between 2008-2021 out of which 57 patients developed hand ischemia (4%) .46 patients underwent this banding procedure for HAIDI from 2008-2021. The baseline characteristics of the cohort are presented in Table 1. Presenting symptoms included pain/cramping involving the hands and fingers during dialysis or at rest, numbness or tissue loss. Physical examination revealed a combination of delayed capillary refill, cyanosis and poor or absent radial pulses with a varying degree of neurological dysfunction, and/or tissue loss over the finger tips. 33(72%) patients with DASS had a brachiocephalic AVF. The mean follow-up of the cohort was 843±103 days(mean ±SD) The median age of the AVF at the time of banding was 15.5 months(IQR 25)

Technically successful banding was achieved in all patients and 39 (85%) saw a clinical improvement with 34(74%) having complete resolution of symptoms. Five patients had some residual symptoms but required no

further intervention. Three patients had recurrence of symptoms 3 months, 8 months and 13 months following banding and underwent repeat banding, which successfully treated the recurrent symptoms. 7 patients underwent re-banding for recurrence of symptoms and 4 subsequently requiring access ligation due to refractory symptoms. 2 patients needed surgical revision after 1 year of banding in the form of a basilic jump graft creation and proximalization to improve the flow rate during HD. Four patients saw no benefit following technically successful banding or ligation of the fistula and were subsequently diagnosed with an entrapment neuropathy. All four patients presented with rest pain with a mean resting finger pressure of 57.8±20.8 mm Hg(mean ±SD) and mean final pressure of 93.1±12.5 mm Hg(mean ±SD) . The comparison of attributes based on response to banding is elaborated in table 2

The post-intervention primary access patency was 100%,98%,78% and 61% at 30 days,60 days,180 days and 1 year respectively. The rates of post intervention primary, assisted primary and secondary patency at various time points are elaborated in table 3. The median post intervention primary patency was 1032 days. The median assisted primary and secondary patency were 1189 days and 2199 days respectively. In this cohort, the functional patency of the AVFs with satisfactory HD pressures were confirmed throughout their patent lifetime. The survival curves obtained for the analysis is depicted in figure 4.

A Youden index calculation estimated that pre-procedure finger pressures of 41mmHg or below was highly specific for patients with “true” steal-syndrome and were more likely to completely respond to banding(Chi-square test; p=0.016). Also, a diagnosis of steal syndrome was highly unlikely if the opening finger pressure were greater than 63.5mmHg(Chi-square test;p=0.022).

One patient in our cohort developed a cutaneous sinus following banding requiring revision surgery to excise the sinus. No other procedure related complications were seen in this cohort.

Discussion:

Many groups have published results of surgical interventions, including banding or plication of the AVF vein, MILLER procedure, distal revascularization-interval ligation(DRIL) procedures, or revision to create a distal inflow(RUDI) to treat HAIDI with varying success(13,17,28). Although banding was the first procedure described to treat HAIDI, it has historically resulted in mixed outcomes, with loss of access due to post-operative thrombosis reported as a frequent complication. Most existing banding techniques use a pre-

fashioned, fixed diameter band.(29,30) The other quantitative and dynamic methods of banding describe techniques which rely on pre-operative estimation of the desired flow-rate or indirect calculation of the desired haemodynamic conditions(31–35). Other banding techniques such as the DYBAND and the Computational Flow Dynamic Model described by Sturm et al have reported promising outcomes in limited cohorts of five patients each(36,37). Although high flow rates in AVF(>1500ml/min) have been postulated to contribute to steal, there is no evidence to suggest a positive correlation between HAIDI and flow-rates.(38)(5)(39) Therefore, flow-rate based calibration of the banding technique has a higher risk of being unsuccessful.

This novel surgical technique first described by our unit in 2013(20), describes a method of dynamic adjustment based on real-time finger pressure monitoring, in comparison to existing banding techniques. The ability to adjust and maintain the band diameter allows for the precise adjustment of the pressure and flow rate, ensuring an optimised and patient- specific solution. A 5-mm ‘‘branch’’ size on the Christmas tree allows a controlled change in vessel diameter by approximately 1.6mm increments and greater control is possible when placing the fixing sutures. This allows close control of the diameter change in the outflow vein of the AVF. The perfusion pressures are used in combination with the clinical acumen of the operating surgeon to balance a palpable AVF thrill with distal perfusion pressures, which has been shown to be effective. This procedure has the added benefits of being the least invasive of the surgical interventions for HAIDI requiring less operating time and only minimal local anaesthetic infiltration. In addition, the mature fistula can be accessed immediately for dialysis.

The patency rates reported following this banding technique are comparable to the natural patency of AVFs as described in recent articles (40–42). A systematic review examining the efficacy of revision using distal inflow (RUDI) by Kordzadeh et al(43) suggested a median 12-month patency of 82% as compared to 86% following banding in this cohort. Sheaffer et al(15) in their review of outcomes following the MILLER procedure reported a primary access patency of 52 to 100% at three months post procedure and a secondary access patency of 77% to 90% at 2 years across all four cohorts which is comparable to the results from this cohort. Although the MILLER procedure is suitable for high-flow AVFs causing DASS or heart failure, it is not recommended for low-flow AVFs causing HAIDI.

In this cohort, three diabetic patients developed recurrence of symptoms which resolved completely after repeat banding. These patients underwent finger pressure measurements when they presented to clinic with recurrent symptoms which demonstrated that there was no significant change in finger pressures compared to the pressures documented at the end of the procedure. They underwent a repeat procedure with further constriction of the outflow limb resulting in a higher finger pressure which completely resolved their symptoms. This could be because of a more conservative approach in deciding the target pressures at the initial operation and possible progression of distal arterial disease secondary to diabetes. More-over, the vascular tree between small arteries through capillaries and into small veins cannot be adequately assessed for clinical decision making via any currently available technique. The quality of this system is highly variable and can dictate outcome. In this cohort, four patients who presented with predominantly rest pain were subsequently diagnosed to have carpal tunnel syndrome following a poor response to banding. An accelerated pathway to NCS for patients triaged to have HAIDI should be considered within access services because of the need for rapid intervention. Given the very low risk of patency loss and low morbidity associated with this procedure, banding could potentially be diagnostic for confirming HAIDI and/or therapeutic in patients with atypical presentations. An expedited work up for steal syndrome as in this cohort, coupled with an expedited access to NCS could avoid the risk of progressive irreversible neurological damage on upper limb function as a result of the delay caused by the work-up. Banding has been historically avoided in low flow AV fistulae due to the risk of access thrombosis.(30,44,45). We aimed to circumvent this limitation by modifying the technique to accommodate serial adjustments of the rachet with real time photo-plethysmography. This ensured that there was sufficient flow in the AVF to support dialysis despite banding

The methodological limitation of this technique is the use of prosthetic material which theoretically increases the risk of infection, although none of the patients in this cohort developed surgical site infection. Although none of the patients in this cohort developed typical features of IMN, it is clinically difficult to differentiate between chronic IMN, HAIDI and carpal tunnel syndrome in patients with atypical presentation. Although pre-operative nerve conduction studies(NCS) could potentially help in confirming the diagnosis, it's routine use is controversial given that all patients with HAIDI would have some degree of neurological dysfunction. Moreover, waiting periods for NCS could further delay intervention. Although PPG is a reliable method of estimating distal arterial perfusion(26) , the availability of pre-operative, intra-operative and post-operative

flow-rate would have been insightful. Although all patients who underwent banding for HAIDI exhibited obvious signs of distal ischemia, an objective assessment using the hand-ischemia questionnaire could have provided more data regarding the clinical presentation(39).

This cohort study has the longest follow-up of outcomes following any procedure performed to address HAIDI and this adjustable dynamic method of AVF banding demonstrates a sustained efficacy in patients with HAIDI in the long term with a very low risk of patency loss.

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Table 1: Baseline characteristics of the Cohort

Attribute	Value
Age – Median[Range]	63 [23-89]
Male	19(41%)
Cause of Renal failure DM Nephropathy HTN Nephrosclerosis Autoimmune Urological including PKD/Reflux/stone/infection Unknown Non-DM associated Nephropathy	 19(41%) 4(9%) 1(2%) 9(20%) 4(9%) 9(20%)
Comorbidities Diabetes Hypertension Ischemic Heart Disease Cerebrovascular disease	 20(44%) 29(63%) 23(50%) 7(15%)
Smoking	18(39.1%)
Type of AVF Brachiocephalic Radiocephalic Brachiobasilic	 33(72%) 9(20%) 4(9%)
Grade of DASS I: Pale/Blue/Cold hand without pain II: Pain during exertion and/or haemodialysis III: Rest pain IV: Ulceration/Necrosis/Gangrene	 1(2%) 5(11%) 29(63%) 11(24%)

1 Table 2: Comparison of attributes based on response to banding

Attribute	Complete response (n = 34)	Partial response with no further intervention (n =5)	Poor response requiring further intervention (n=7)	P value
Age in years Median(IQR)	71(18)	53(27)	61(16)	0.045
Age of AVF at the time of banding in Months Median(IQR)	26(35)	16(15)	12(15)	0.842
Type of Access Brachiocephalic Radiocephalic Brachio-basilic	24 (70.6%) 7 (20.6) 3(8.8%)	5(100%) 0 0	4(57.1%) 2(28.6%) 1(14.3%)	0.601
Previous ipsilateral access	7(20.7%)	3(60%)	1(14.3%)	0.126
Grade of ischemia I II III IV	4(11.8%) 1(2.9%) 20(58.8%) 9(26.5%)	1 (20%) 0 (0%) 3(60%) 1(20%)	0 0 6(85.7%) 1(14.3%)	0.858
Opening pressure(PPG) mmHg Mean ± SD	42.3 ± 17.5	57.8 ± 29	57.8 ± 20.8	0.091
Occluded pressure(PPG) mmHg Mean ± SD	100 ± 21.9	144.6 ± 28.4	121 ± 21.6	0.003
Final Pressure(PPG)				

mmHg Mean ± SD	81.9 ± 14.5	108.6 ± 23.2	93.1 ± 12.5	<0.001
Δ Pressure Final – Initial pressure (mmHg) Mean ± SD	37.27 ± 14.67	51.6 ± 37.07	36.7 ± 14.3	0.268
Length of Patency(Days) Median(IQR)	566(745)	352(1203)	412(253)	0.376

Table 3:Patency rates at different time points following banding

Patency following "Christmas Tree Banding"	30 days	60 days	180 days	1 year
Primary-Patency	100%	98%	78%	61%
Assisted Primary-Patency	100%	98%	85%	67%
Secondary-Patency	100%	98%	85%	70%

Legends for illustrations:

Fig 1: (a) The upper limb is sterilized and draped with the Photoplethysmography(PPG) probe in place and ensuring the exclusion of the PPG equipment from the surgical field ; (b) pre-operative real-time digital perfusion pressure traces obtained by PPG

Fig 2: Graphic representation of the “Christmas Tree” banding technique; 2(a) The upper limb is suitably positioned with the PPG probe in place; 2(b) The polyethylene terephthalate(Dacron™) patch is fashioned in the form of a Christmas Tree ; 2(c) The band is sited around the draining vein and the ‘‘ratchets’’ progressively tightened until they begin to restrict the vein

Fig 3: Surgical set-up; 3(a): The upper limb is positioned on table with the PPG equipment in place; 3(b): The outflow limb is suitably dissected; 3(c) to 3(f): Fashioning of the polyethylene terephthalate(Dacron™) patch; 3(g): The fashioned band is sited around the draining vein and progressively tightened; 3(h): Serial on-table finger pressure measurement until the target pressures are reached; 3(i): The band is secured with Prolene™ sutures; 3(j): Final position of the “Christmas tree” band; 3(k):Final checking of the finger systolic pressures prior to closure.

Figure 4: Post-intervention survival curves obtained by the Kaplan-Meier method; Post banding median primary patency of 1032 days, median assisted primary patency of 1189 days and secondary patency of 2199 days.

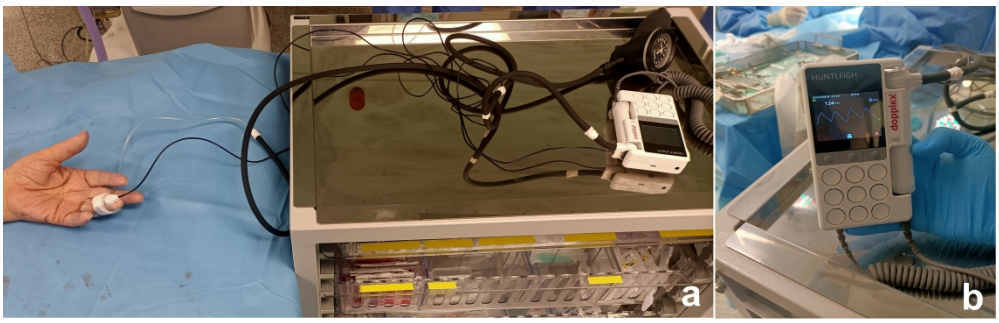


Fig 1: (a) The upper limb is sterilized and draped with the Photoplethysmography(PPG) probe in place and ensuring the exclusion of the PPG equipment from the surgical field ; (b) pre-operative real-time digital perfusion pressure traces obtained by PPG

1886x601mm (72 x 72 DPI)

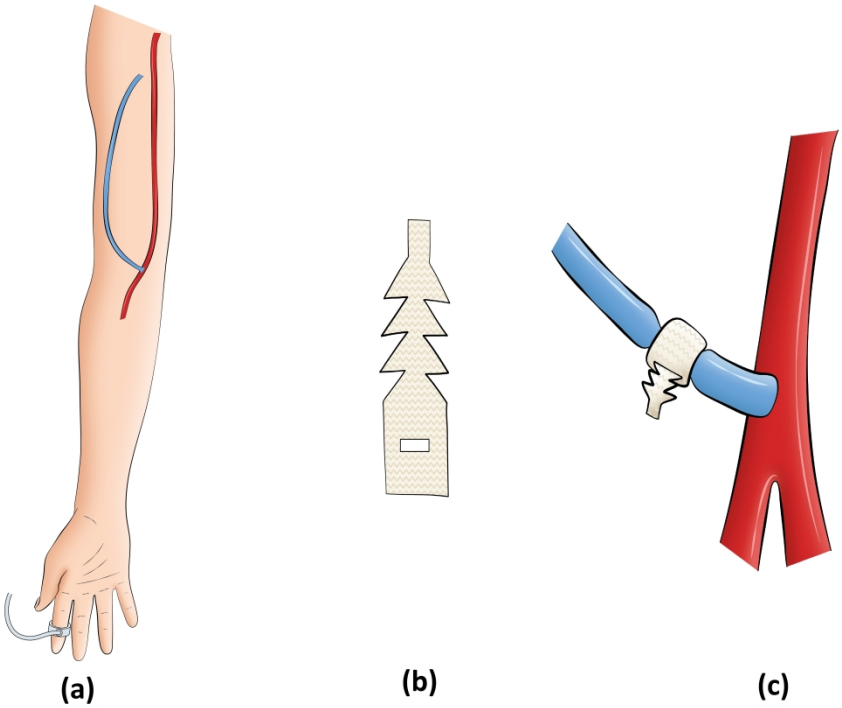


Fig 2: Graphic representation of the "Christmas Tree" banding technique; 2(a) The upper limb is suitably positioned with the PPG probe in place; 2(b) The polyethylene terephthalate(DacronTM) patch is fashioned in the form of a Christmas Tree ; 2(c) The band is sited around the draining vein and the "ratchets" progressively tightened until they begin to restrict the vein

377x279mm (450 x 450 DPI)

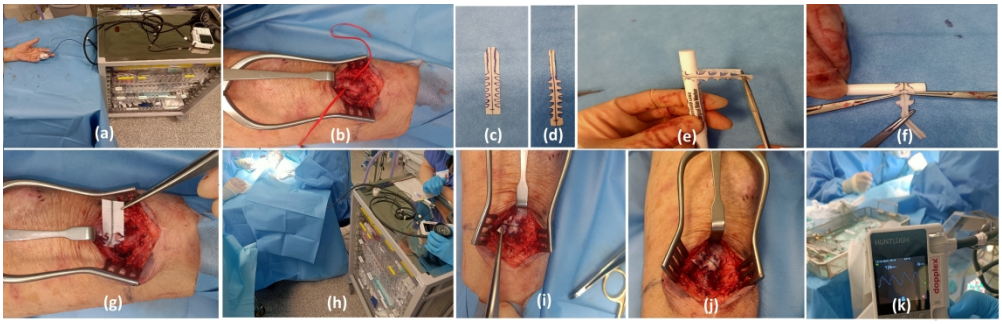
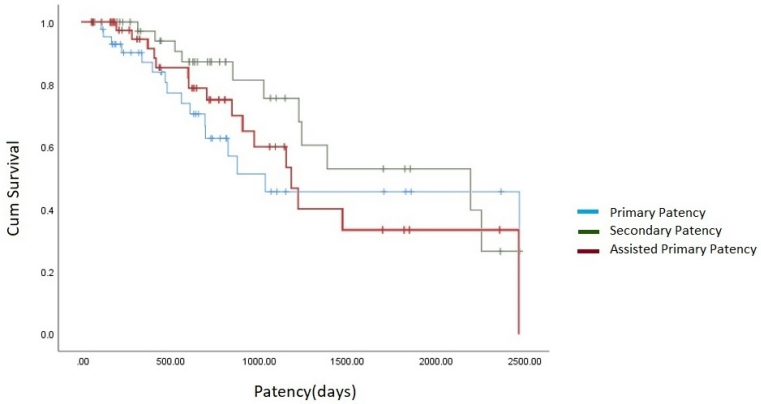


Fig 3: Surgical set-up; 3(a): The upper limb is positioned on table with the PPG equipment in place; 3(b): The outflow limb is suitably dissected; 3(c) to 3(f): Fashioning of the polyethylene terephthalate(DacronTM) patch; 3(g): The fashioned band is sited around the draining vein and progressively tightened; 3(h): Serial on-table finger pressure measurement until the target pressures are reached; 3(i): The band is secured with ProleneTM sutures; 3(j): Final position of the "Christmas tree" band; 3(k):Final checking of the finger systolic pressures prior to closure.

1763x558mm (72 x 72 DPI)



Numbers at risk (Number censored)

Post intervention Patency	30 days	60 days	180 days	360 days	720 days
Primary	46(1)	44(2)	36(1)	28(0)	15(2)
Assisted Primary	46(1)	44(2)	39(1)	31(0)	19(2)
Secondary	46(1)	44(2)	38(2)	31(0)	19(2)

Figure 4: Post-intervention survival curves obtained by the Kaplan-Meier method; Post banding median primary patency of 1032 days, median assisted primary patency of 1189 days and secondary patency of 2199 days

217x141mm (144 x 144 DPI)