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Venous Outflow Stenosis of the Brachiocephalic Fistula: A Single Entity, or is the Cephalic Arch Different?

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Abstract

Background: Cephalic Arch Stenosis (CAS) is emerging as an important cause of Brachiocephalic Fistula (BCF) failure. The optimal management strategy for dysfunctional AVF as a result of CAS is yet to be defined. Endovascular management is generally employed as first line treatment based upon success in other venous stenosis sites. We compare the outcomes of angioplasty in CAS to other venous stenoses causing BCF dysfunction.

Methods: 62 patients with dysfunctional BCF due to venous segment pathology were identified and proceeded to angioplasty. Lesions were categorized anatomically: 19 CAS, 22 venous outflow, 21 swing segment(<3cm of anastomosis). Anastomotic stenoses were excluded. Endovascular intervention was carried out in a standard fashion; 8-10mm balloon angioplasty at the interventionalist's discretion. Patients were followed prospectively by regular clinical and venous pressure monitoring of the fistula. Re-intervention was performed on clinical suspicion of recurrence.

Results: Mean duration of follow-up was 402 days. Patient demographics were comparable across the three groups except a lower incidence of diabetes in the cephalic arch cohort (15.7% vs. 28.2% vs. 25.0%). Swelling and aneurysmal fistulae were more common presenting complaints in CAS (15.7% vs. 2.6% vs. 0%). Mean length of cephalic arch stenosis was shorter(1.6cm vs.3.1cm vs.2.5cm). Primary patency of cephalic arch angioplasty was 68.8%, 43.7% and 31.0% at 3, 6 and 12 months respectively. Primary assisted patency was 87.5%, 81.0% and 43.0%. There was no significant difference in primary or primary assisted patency compared to other outflow stenoses. 2.3 interventions/ patient were required to preserve the access in the CAS cohort vs. 1.1 interventions/ patient for venous outflow stenosis and 1.3 interventions/ patient for swing segment stenoses.

Conclusion: CAS bears a different clinical presentation to other venous outflow stenoses. Despite being shorter, and apparently a more attractive target lesion, the hallmark is a requirement for repeated endovascular intervention when compared to other venous stenoses causing BCF dysfunction.

Keywords: Stenosis; Venous outflow; Brachiocephalic fistulae

Introduction

Creation of an autologous Arteriovenous Fistula (AVF) is the method of choice for haemodialysis [1]. AVF complications represent the leading cause of morbidity in this patient group [2], with venous stenosis the commonest cause of AVF dysfunction [3]. Around 40% of venous stenosis occurs within the first few centimetres of the AVF anastomosis [4], however the cephalic arch has been identified as a distinct site where stenosis readily and frequently occurs. Cephalic arch lesions have been identified in up to 77% of patients with Brachiocephalic Fistulae (BCF) [5], and to be responsible for 15% of AVF dysfunction [6].

The cephalic arch is the terminal part of the cephalic vein at the junction with the axillary vein to form the subclavian vein. It is thethe arching portion of the cephalic vein as it enters the deltopectoral groove, passes beneath the clavicle and turns sharply to pierce the clavipectoral fascia [7].

Cephalic arch stenosis is caused by intimal hyperplasia, in a similar fashion to stenosis at other cephalic vein sites [8]. Vascular smooth muscle cell proliferation, matrix deposition and intimal layer thickening evolves, to cause stenosis, haemodynamic disturbance and loss of flow in the AVF [9].

Factors contributing to stenosis development are high volume, turbulent flow from the AVF [10], pre-existing cephalic vein disease [11], the presence of cephalic arch valves [12,13], and the lack of compensatory dilatation of the cephalic arch vein due to anatomical restrictions [14].

Treatment data on cephalic arch stenosis is limited. Angioplasty [6], stent insertion [3,15] and surgical intervention [16,17] have all been proposed in small series, however primary patency rates are poor. Primary patency at 12 months is 23% with angioplasty and 39% with surgical intervention. Stent grafts appear to have higher patency (72% at 12 months), but risk compromising future vascular access.

The objective of this study is to characterise the symptomatic cephalic arch stenosis in brachiocephalic fistula dysfunction and compare epidemiology & endovascular outcomes to other venous stenoses afflicting the brachiocephalic fistula.

Methods

Patients with dysfunctional AVF were identified and presented at a Multi-Disciplinary Team (MDT) meeting consisting of nephrologists, vascular access surgeons and interventional radiologists over a two year period. Dysfunctional radiocephalic and basilic fistulae were excluded

	Cephalic Arch	Venous	Swing Segment	P value
Age	59.11	51.3	56.3	0.32
Sex	63% Male	60% Male	83% Male	0.24
Current Smokers	4	n/a	n/a	
Diabetes Mellitus	15.7%	28.2%	25%	0.09
Previous cardiovascular event	21%	12.8%	16.7%	0.12
Medications				
Antiplatelet	47%	32%	33.3%	0.24
Statin	36%	41%	41.7%	0.43
Warfarin	2.1%	2.5%	0%	0.39

Table 1: Patient characteristics.

	Cephalic Arch	Venous	Swing Segment	P value
Arm Swelling	15.7%*	0%*	0%*	0.04
Aneurysmal AVF	15.7%*	2.6%*	0%*	0.03
Poor Flow	31.6%	71.8%*	22.2%*	<0.001
Failure to Mature AVF	21%	17.9%*	72.1%*	<0.001
Clotted AVF	15.7%*	8%*	5.6%*	0.04

Table 2: Presenting Complaints of Cephalic Vein Pathology in BCF. * < 0.05 Chi squared test.

from this study. All patients underwent Doppler and/or angiographic assessment to determine the cause of AVF dysfunction. Patients with arterial or anastomotic stenoses affecting the BCF were excluded from analysis. Patients with concomitant central vein stenosis (ipsilateral subclavian, innominate or superior vena cava) were similarly excluded. All patients with pathology affecting the cephalic vein segment of the BCF were included. 62 patients with BCF dysfunction due to cephalic vein disease were identified, and categorized into cephalic arch stenosis, swing segment stenosis (<3 cm from anastomosis), or venous outflow stenosis (stenosis affecting any other part of the cephalic vein). Patient demographics were collected to determine cardiovascular risk profile – smoking status, diabetes mellitus and previous cardiovascular events (myocardial infarction or stroke), along with antiplatelet use, statin use and anticoagulant use. Demographics were compared among subgroups using Mann-Whitney u test. Angioplasty outcomes were determined using the Kaplan-Meier method.

Angioplasty technique

Informed consent was obtained from the patient and the procedures were performed under local anesthesia with or without intravenous sedation as required.

Ultrasound guided puncture of the venous out flow was performed and a six French vascular sheath sited. This was followed by angiographic assessment of the cephalic arch stenosis. The stenosis was successfully crossed in all the patients using standard angiography catheters and hydrophilic glide wires.

The hydrophillic wire was then exchanged for a non-hydrophilic 0.035 guide wire and angioplasty performed using standard vascular angioplasty balloons. The balloons were inflated to 8 atm. Depending on the size of the adjacent normal venous segments, either a 8 mm × 4 cm or a 10 mm × 4 cm balloon were used. Procedural success was defined as less than 20 % residual stenosis on the post angioplasty angiogram. Significant residual stenosis post balloon angioplasty or presence of a flow limiting dissection were stented usingnitinol self-expanding stents of the same size as the balloon.

Success was defined as resumption of dialysis or regression of symptoms. All AVF were monitored clinically by a dialysis nurse coordinator. Routine US surveillance was not available.

Data collection for this study was approved by the Greater Glasgow & Clyde Clinical Effectiveness Board.

Results

The mean duration of follow-up was 402 days. 152 patients with dysfunctional AVF presented to the MDT over a two year period (73 BCF, 67 Radiocephalic Fistula (RCF) and 12 with complicated access issues). Of the 73 with BCF dysfunction, 62 were due to stenosis of the BCF cephalic vein: 19 patients were identified with cephalic arch stenosis, 22 with venous outflow stenosis and 21 with swing segment stenosis. Cephalic arch stenosis was responsible for 12.5% of AVF dysfunction in the overall cohort. In BCF dysfunction, cephalic arch stenosis accounted for 26%, venous outflow 30% and swing segment 29% of dysfunction. The other causes of BCF dysfunction were anastomotic stenoses and central vein stenoses (15%). No RCF dysfunction was attributable to cephalic arch stenosis.

Compared to those with pathology at other cephalic vein sites, there were significantly fewer patients with diabetes mellitus, despite homogeneity between other characteristics. Other indicators of cardiovascular risk profile (previous cardiovascular events, smoking status and the use of antiplatelet, statin and anticoagulants) showed no statistically significant difference between the groups. Characteristics are summarised in Table 1.

11 patients with cephalic arch stenosis had previously had central venous catheterization, with an average number of 2.05 lines for a duration 6.55 months. 7 patients had previously had a central venous catheter on the affected side.

Cephalic arch stenosis presented with a range of symptoms (Table 2), though was more likely to cause arm swelling or an aneurysmal AVF than other cephalic vein stenoses.

Stenosis morphology

12 patients presented with an isolated cephalic arch stenosis. 3 had stenosis that extended beyond the cephalic vein - axillary vein junction into the distal subclavian. 1 patient had sequential cephalic arch stenoses, and 3 patients were found to have a distinct central stenosis in addition to the cephalic arch stenosis. The mean length of the stenosis was 1.6 cm (0.5 cm to 8 cm). The longer stenoses were those that extended into the distal subclavian beyond the axillary-cephalic junction. Venous collateralization around the stenosis was identified in 4 patients. Mean length of venous outflow stenosis was 3.1 cm, and 2.5 cm in swing segment stenosis.

Outcomes of endovascular intervention

In total 43 angioplasty procedures were performed for cephalic arch stenosis. Primary patency was 68.8%, 43.7% and 31% at 3, 6 and 12 months respectively. Primary assisted patency was 87.5%, 81% and 43% at 3, 6 and 12 months. 2.3 interventions per patient were required. No significant difference in primary and primary assisted patency rates were seen between cephalic arch stenosis, venous outflow stenosis and swing segment stenosis (see Figures 1 and 2), however fewer interventions per patient were required: 1.1 for venous outflow stenosis and 1.3 for swing segment stenosis.

Discussion

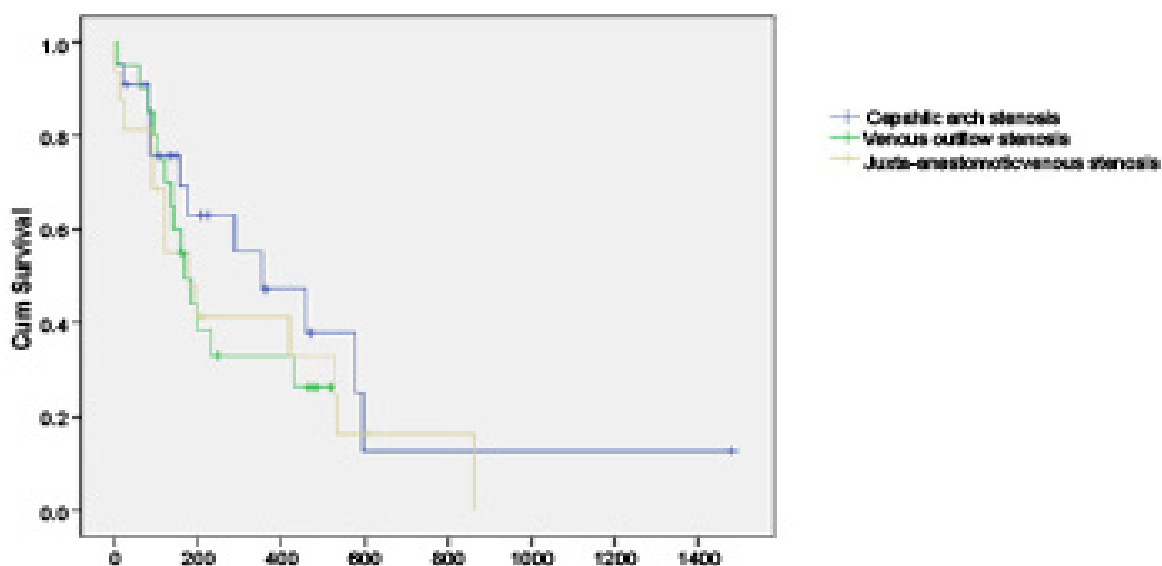The epidemiology of cephalic arch stenosis is becoming clear, and it

Figure 1: Primary patency of cephalic arch, venous outflow, and swing segment post angioplasty. (p=0.56).
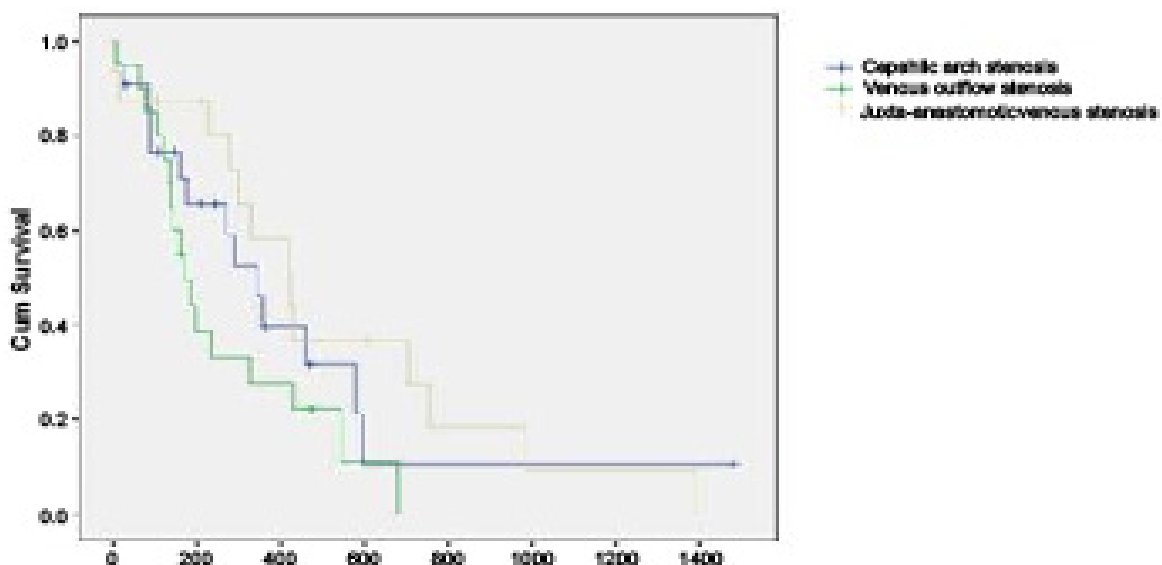

Figure 2: Primary-assisted patency of cephalic arch, venous outflow, and swing segment post angioplasty. (p=0.11).

is emerging as a significant cause of BCF dysfunction. We demonstrated a prevalence of 12.5% amongst all dysfunctional AVF and 26% amongst dysfunctional BCF, indicating a similar prevalence to venous outflow and swing segment disease. The prevalence amongst all dysfunctional AVF is in keeping with previously reported data [6], however one study indicated the prevalence in BCF to be much higher at 77% [5]. Not all of these led directly to AVF dysfunction however. Pre-existing intimal hyperplasia [11] in the cephalic vein may cause lesions that can be detected radiologically but do not or have not yet evolved to cause BCF dysfunction.

Only 12.5% of patients with cephalic arch stenosis had diabetes mellitus, significantly less than the other cohorts. It is a surprising finding, given that patients with diabetes are normally at higher

risk of developing stenotic disease [18]. In addition diabetes and hyperglycemia has been shown to have significant impact upon both endothelial dysfunction and proinflammatory pathways of atheroma [19]. Despite this, a lower than predicted incidence of diabetes in those with cephalic arch stenosis has been a consistent finding in multiple other studies [5,20,15]. Hammes et al. have proposed that patients with diabetes have a wider cephalic arch than those without, thus reduced haemodynamic stress in this area [21]. Certainly it appears that the tight angle of the cephalic arch, with localised turbulent flow, may play an overwhelming role in the development of stenosis, overwhelming traditional risk factors implicated in vascular stenosis formation.

The symptom profile of cephalic arch stenosis varies significantly different to those occurring more distally. There is a higher incidence of

arm swelling or aneurysmal fistula, as well as a clotted avf. Poor flow as a primary complaint is higher in venous outflow disease. Fistulas with swing segment disease tended to present with failure to mature. This new data on the symptom profile of cephalic stenosis sites is helpful in the initial clinical assessment of dysfunctional AVF and planning of investigations.

In this cohort, primary long term patency of endovascular intervention was disappointing; though 12 m onth primary assisted patency rates of 43% were achieved. Whilst not significantly different to outcomes of other cephalic vein pathology, a much higher re-intervention rate (2.3 per patient) was required to achieve this. The twelve month primary assisted patency rates of this study are lower than those achieved in others [6], however we included patients with clotted AVF and AVF that had failed to mature. In addition, ultrasound surveillance was not available, which may explain the lower figures.

Aside from standard angioplasty, other techniques have investigated. The use of cutting balloons as opposed to standard angioplasty was analysed in one paper [20]. While secondary patency was not significantly higher than in other angioplasty studies, the frequency of reintervention was reduced to 0.9 per patient per dialysis year. The use of a cutting balloon may confer some benefit.

Stent graft insertion for recurrent cephalic arch stenosis has been recommended by some investigators. One study of 11 patients demonstrated 6 month primary patency to be 82% with a Viabahn stent [3]. Another study retrospectively compared stent grafting with bare metal stents [15], finding primary patency to be 32% at 12 months with Viabahn stents compared to 0% with bare metal stents. Stent grafting should be considered with recurrent cephalic arch stenosis.

Conventional surgical options are patch angioplasty or fistula transposition to the basilic/axillary venous drainage. Surprisingly there is little published literature on these techniques. In one prospective trial [16], patients with cephalic arch stenosis underwent transposition of the fistula to the basilic or axillary outflow system. Outcomes with respect to primary patency were disappointing, with all 13 patients developing an anastomotic stricture. Compared to the cephalic arch stenosis, these strictures were more amenable to endovascular treatment, with 92% secondary patency at one year, with only 1 intervention per patient per year being required. A retrospective review including 7 patients who underwent transposition for cephalic arch stenosis [17] demonstrated 90% AVF patency at 39 months. Outflow transposition should be considered in patients with a mature AVF and recurrent cephalic arch stenosis.

The hallmark of cephalic arch stenosis treatment is the requirement for multiple reinterventions to maintain patency. Despite generally being short, focal lesions that under normal circumstances respond well to endovascular intervention, primary patency rates are low. This is likely due to the ongoing pathophysiological mechanism of turbulent flow within a segment of vein with restricted capacity to dilate and accommodate. To counter this, flow reduction surgery has been proposed.22 Application of a band to the brachiocephalic fistula to reduce the flow appeared to improve secondary patency to 97% in 6 patients with cephalic arch stenosis, with the number of interventions per year required reducing from 3.34 to 0.9.

This study is limited by the small numbers included in the analysis. This prevented multivariate analysis to evaluate the influence of confounding variables such as previous cardiovascular events on angioplasty outcomes, though the groups appeared homogenous aside from the lower incidence of diabetes mellitus in the cephalic arch stenosis cohort. No previously published studies are significantly larger than this however, with the largest other angioplasty study being of 26 patients [6].

There are alternatives to repeat angioplasty in patients with recurrent cephalic arch stenosis, however it remains the treatment of choice in our unit. The real life outcomes are that the original vascular access was maintained in 47% of our patients to close of study, transplant or death. Haemodialysis patients often have limited vascular access options, and preservation of autologous vascular access for as long as possible is the gold standard of treatment. Studies of alternatives to angioplasty are currently limited by small patient numbers, but may provoke change in practice in the future.

Conclusion

Cephalic arch stenosis is a common cause of BCF dysfunction. The symptomatic and epidemiological profile varies from other venous stenoses afflicting the BCF. The hallmark of endovascular treatment is the requirement for frequent reintervention to maintain patency. Further research is required in the form of randomized control trials to determine the optimum management.

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