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Endoscopic Superficialisation of Haemodialysis Arteriovenous Fistulas in Obese Patients – Safety, Feasibility, and Outcomes

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WHAT THIS PAPER ADDS

Second stage endoscopic superficialisation of haemodialysis arteriovenous fistulae expands surgical options in obese patients as it is a safe and effective minimally invasive procedure to reduce cephalic vein depth.

Objective: The aim was to evaluate the safety and feasibility of endoscopic superficialisation (ES) in patients with deeply located cephalic veins in well matured arteriovenous fistulae (AVF) and to present functional outcomes.
Methods: All patients with cannulation difficulties due to a deep lying cephalic vein of more than 6 mm but with an otherwise matured AVF with a straight needle access segment of at least 6 cm were included in this retrospective study. Procedure related safety, defined as completion of ES with no need for conversion to open surgery, and feasibility in terms of cephalic vein depth reduction were assessed. The primary endpoint was three successfully performed haemodialysis sessions using the endoscopically superficialised AVF during a minimum follow up of 12 months.
Results: From June 2013 to August 2017, 12 patients with a mean body mass index of 33.5 ± 3.9 kg/m^2 underwent ES as a second stage procedure following radiocephalic ($n = 5$) or brachiocephalic AVF ($n = 7$) creation. All procedures were conducted endoscopically. Ultrasound imaging 12 weeks post-operatively documented a reduction in the depth of the cephalic vein from a mean of 10.1 ± 1.4 mm to 4.3 ± 0.8 mm. The mean duration of the ES was 69 ± 26.0 min with 67% performed under locoregional anaesthesia. In all but one patient with a cephalic vein of poor wall quality leading to recurrent haematoma, haemodialysis was performed successfully following ES.
Conclusions: Endoscopic superficialisation of the cephalic vein is a safe and effective technique. Providing good functional results, ES represents an alternative approach for second stage superficialisation in obese patients.

Keywords: Arteriovenous fistula, Lipectomy, Obesity, Surgical procedure
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INTRODUCTION

In Switzerland, in common with the rest of the world, obesity has doubled in the last 25 years with 42% of the population considered obese (body mass index (BMI) > 30 kg/m^2) or overweight (BMI > 25 kg/m^2) in 2017. The Swiss European Renal Association – European Dialysis and Transplant Association (ERA-EDTA) data reported that 16.7% of all patients requiring dialysis had a BMI ≥ 30–34.9 kg/m^2, while 4.7% of all patients had a BMI ≥ 35–39.9 kg/m^2 and 2.3% had a BMI ≥ 40 kg/m^2 in 2017 (unpublished data). Considering that a higher BMI at the start of haemodialysis is associated with a lower likelihood of receiving a kidney transplant,[1] a functioning long term vascular access is of even greater importance. Establishing an autologous arteriovenous fistula (AVF) is the best option for patients requiring long term dialysis, yet its functionality remains a major challenge in obese patients.[2] Obesity has been identified as a specific patient related risk factor for the successful use of an AVF due to access dysfunction, even in well matured arterialised veins.[3,4] In these cases, superficialisation of the arterialised vein is indicated.[5] Conventional surgical techniques address superficialisation as a second stage procedure to enhance needling in such patients. The flap elevation procedure involves mobilisation of the outflow vein through a long parallel incision and the raising of a skin flap to bring the vein to a more superficial position.[6] Lipectomy has been described as an alternative superficialisation technique that implies the removal of subcutaneous fat tissue that overlies

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the outflow vein through transverse incisions.[7] In contrast to the elevation procedure, the deep surface of the vein is not exposed. Ultrasound guided liposuction was found to be an effective and less invasive method for superficialisation, though with some limitations relating to procedural complications.[8]

Based on endoscopic surgery for hernia repair[9] and video assisted basilic vein transposition,[10] and in connection with an affected patient who had refused open lipectomy, a minimally invasive technique for AVF superficialisation had been developed previously.[11] The aim was to obtain visual control of the vein during the entire procedure to minimise the risk of vessel wall damage. Optional clipping of large calibre tributaries and dissection of the overlying fascia were added subsequently.

This observational study presents the first results of endoscopic superficialisation (ES) of upper extremity AVFs in obese and overweight patients with deep lying cephalic veins that are difficult to cannulate. The safety, feasibility, and functional outcomes of this minimally invasive technique are reported, which represents a potentially alternative approach to facilitate AVF cannulation.

MATERIALS AND METHODS

Study design

All patients, between June 2013 and August 2017, in whom repeated cannulation performed by specialised haemodialysis nurses had not been feasible due to an ultrasound confirmed cephalic vein depth of >6 mm at least six weeks after AVF creation, with an otherwise matured AVF with a minimum cephalic vein diameter of 5 mm, a volume flow higher than 500 mL/min and a straight needle access segment of at least 6 cm, were included in this retrospective study with prospective data input. Patients presenting with scarred subcutaneous tissue between the arterialised vein and skin as a result of previous surgery or trauma, AVF with a tortuous cephalic vein, and fistulas that would need any kind of additional open surgical procedure were excluded. Further exclusion criteria were dual platelet treatment or therapeutic anticoagulation as haemostasis options during ES are limited, implying a high risk of conversion to open surgery.

Pre-operative data

For patient demographic data (sex, age, BMI) and haemodialysis status (e.g. pre-haemodialysis, haemodialysis using tunnelled central vein catheter (TCVC)) electronic charts were reviewed. Pre-operative parameters verifying information on AVF maturation (cephalic vein diameter and volume flow estimated by measurement in the ipsilateral subclavian artery) and verification of a straight needle access segment of minimum 6 cm at least six weeks after fistula creation were recorded. The depth of the cephalic vein was measured pre-operatively using ultrasound imaging at three (5—10—15 cm proximal to arteriovenous anastomosis) defined locations. The time from AVF creation to ES was calculated.

ES was performed as a second stage procedure in 12 patients with a mean age of 63 ± 11.5 years and a mean BMI of 33.5 ± 3.9 kg/m^2, made up of 10 obese (BMI > 30 kg/m^2) and two overweight patients (BMI > 25 kg/m^2). Seven patients presented with radiocephalic and five with brachiocephalic AVF with 67% on haemodialysis using a TCVC. The mean pre-operative cephalic vein diameter was 7.5 ± 1.9 mm with a mean depth of 10.1 ± 1.4 mm and mean volume flow of 790 ± 220.7 mL/min. Median time to ES after AVF creation was 158 days (range 87—1130 days).

Surgical technique

All procedures were performed in a standard manner by the same surgeon under locoregional or general anaesthesia. Using intra-operative ultrasound imaging, the course of the deeply situated outflow vein, the superficial fascia and the tributaries were marked on the patient's skin (Fig. 1A). Ultrasound guided tumescent anaesthesia was used in order to separate the vein from the overlying skin. Two small transverse incisions were made on either side of the vein 2—3 cm proximal to the anastomosis and distal to the straight segment of the AVF. Two 5 mm trocars (Karl Storz, Tuttlingen, Germany) were inserted 5—10 mm below the skin (Fig. 1B). A subcutaneous space was created by blunt dissection of the tissue after insertion of a 5 mm 30° endoscopic video camera (Karl Storz) and a 5 mm endoscopic suction device (Elefant; Coloplast, Humblebeak, Denmark). After identifying the vein, CO_2 with 12 mmHg to enhance visibility was applied continuously. Scars between skin and vein, which were caused by initial needling, and the superficial fascia were dissected with scissors (Microline, Beverly, MA, USA). Subsequently, excess fat overlying the vein was aspirated 2 cm laterally and medially under endoscopic control (Fig. 1C). Endoscopically controlled liposuction was continued until a ventral cavity of the needle access segment was formed (Fig. 1D). The dissection length over the vein is limited to approximately 15 cm due to straight and rigid endoscopic devices. When large calibre tributaries of the cephalic vein contributed to non-maturation, they were identified and clipped (LIGAMAX5, Johnson & Johnson, Ethicon, Bridgewater, NJ, USA). Finally, a suction drainage was inserted in the operating field and removed 24 h post-operatively. Material costs for ES amount approximately 200 Euro if reusable trocars are used. An additional cost of approximately 280 Euro must be added when endoscopic clips are applied to close large calibre tributaries.

Intra- and post-operative data

The type of anaesthesia, the duration of the procedure and need of conversion to open surgery were assessed intra-operatively. Ultrasound imaging was performed 14 days and three months post-operatively in all patients by a qualified vascular surgeon or angiologist. The depth of the

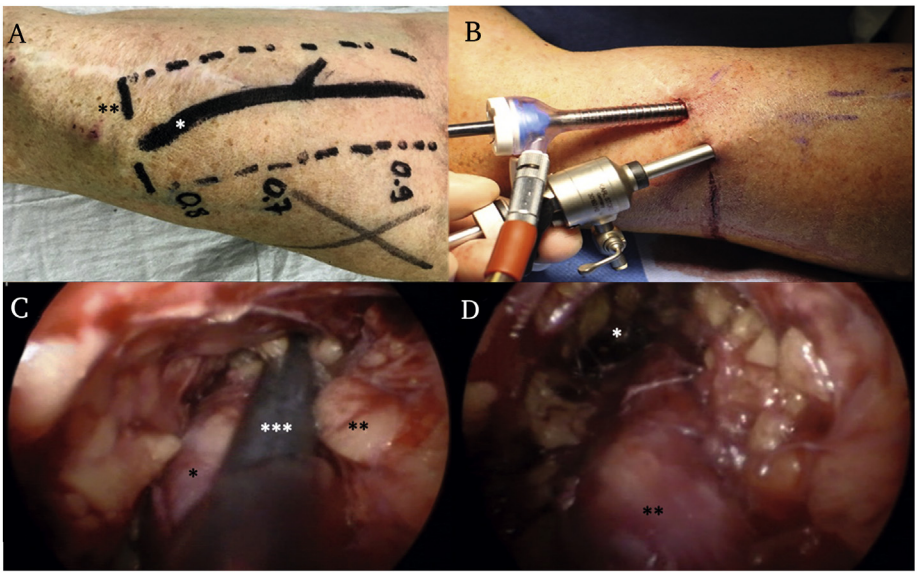

Figure 1. Endoscopic superficialisation demonstrating (A) pre-operative planning with the cephalic vein* and location of incisions** marked at the forearm, (B) positioning of trocars, (C) endoscopic view of cephalic vein*, subcutaneous fat** and suction device***, (D) creation of subcutaneous cavity* with visual control of the cephalic vein**.

cephalic vein was measured at pre-operatively defined locations. Cephalic vein diameter and volume flow were recorded. Length of hospital stay and any wound complications treated conservatively or surgically were evaluated during a mean follow up of 17 ± 1.3 months.

Outcome definitions

Procedure related safety was defined as completion of ES with no need for conversion to open surgery resulting from cephalic vein damage. Effective reduction of cephalic vein depth determined the feasibility of the technique.

The primary endpoint was three successfully performed haemodialysis sessions using the endoscopically superficialised AVF during a minimum follow up of 12 months. The dialysis session was defined as successful or sufficient when the vein could be cannulated with two needles and a blood flow of at least 300 mL/min was achieved.

Ethics approval

The ethics committee of central and north western Switzerland (EKNZ) approved the study. It was conducted according to the Swiss federal act on research involving human beings (Human Research Act, HRA) and the guidelines of good clinical practice (GCP).

Statistical analysis

Descriptive statistics and a paired samples *t* test to compare pre- and post-procedure values (vein diameter, vein depth, and volume flow) were conducted using SPSS software (IBM® SPSS® Statistics Version 22). Patient and fistula related continuous variables are presented as mean ± SD and median (range).

RESULTS

The mean operation time was 69 ± 26.0 min with 67% of patients having locoregional anaesthesia. ES was feasible in all 12 patients and no conversion to an open procedure was required. In two patients, ES was prolonged (mean operation time 100 min) by diffuse scar tissue between the skin and the underlying vein caused by multiple unsuccessful punctures pre-operatively. In two patients with a cephalic vein diameter of barely 6 mm, a large calibre tributary was identified and clipped. No case of surgical site infection or any other wound complication such as skin necrosis was observed. The duration of the hospital stay ranged from 1 to 5 days (mean 2 ± 1.3 days).

Post-operative ultrasound imaging showed a mean cephalic vein depth of 4.3 ± 0.8 mm and a volume flow of 1077 ± 471.6 mL/min (Table 1). Successful haemodialysis using the superficialised cephalic vein was performed in 11 patients (92%) during the minimum follow up of 365 days (mean 507 ± 359.8 days). In those patients who underwent dialysis through a TCVC at ES, the mean time to use the superficialised AVF was 39 ± 7.0 days. One pre-dialysis patient presented with a deep lying (10 mm) but otherwise matured radiocephalic AVF (vein diameter 5.5 mm, volume flow 700 mL/min) after proximalisation. ES was performed assuming that the depth of the arterialised vein impeded successful cannulation. In spite of a reduction in cephalic vein depth to 3 mm, cannulation was still complicated due to poor vein wall quality resulting in recurrent haematoma. The cephalic vein diameter remained unchanged at 5.5 mm even after dilatation of two stenotic lesions of the proximal cephalic vein and the radial artery. This unsatisfactory situation prompted the creation of an

Table 1. Patient characteristics and procedure outcomes

Patient	Age (years)	AVF	Cephalic vein depth (mm)		Cephalic vein diameter (mm)		Volume flow (mL/min)		HD prior to ES	Time to HD (days)
			Before ES	After ES	Before ES	After ES	Before ES	After ES		
1	80	BC	10	4.5	9	20	700	1 300	Yes	35
2	64	RC	10	4	7	10	1 200	1 500	No	426
3	84	BC	10	5.5	11.5	12	650	1 000	Yes	38
4	47	BC	12	3	9	7	600	650	Yes	31
5	53	RC	9	5	5	7	550	800	Yes	31
6	61	BC	10	3.5	8	8	1 000	1 800	No	539
7	50	RC	13	5	6	7.5	750	830	Yes	47
8	65	RC	9	4.5	7	15	900	1 000	Yes	47
9	70	RC	11	5	9	7	800	850	No	209
10	64	BC	9	5	7	9	1 100	2 000	Yes	34
11	53	RC	8	4	5.5	6	500	550	Yes	46
12	69	RC	10	3	5.5	6	700	650	No	Na
Summary statistics										
Mean±SD	63±11.5		10.1±1.4	4.3±0.8	7.5±1.9	9.5±4.2	790±220.6	1 077±471.6		135±181.1
p value (before vs after)			<.001		.09		.009			

AVF = arteriovenous fistula; BC = brachiocephalic; ES = endoscopic superficialisation; HD = haemodialysis; RC = radiocephalic; SD standard deviation; HD prior to ES = haemodialysis using tunnelled central vein catheter prior to endoscopic superficialization. Post-procedure outcomes at 3 months after ES.

alternative vascular access. In one patient with a history of cerebrovascular events, the superficialised AVF was located in the paraplegic upper arm. After initially successful haemodialysis this patient developed hyperaesthesia at the puncture sites and the AVF had to be abandoned 88 days after ES. One patient died of unrelated causes 536 days after ES with a functioning superficialised AVF. Three patients needed percutaneous transluminal angioplasty of the cephalic vein due to stenosis during the follow up period. One patient developed a type I symptomatic aneurysm (Balaz classification[12]) more than four years after ES and was treated by partial aneurysmorrhaphy.

DISCUSSION

This small series demonstrates that ES is effective in obtaining a functional AVF in obese and overweight patients with cannulation difficulties due to deep lying cephalic veins. It is safe as all superficialisation procedures were carried out endoscopically with no need for conversion to open surgery. There were no procedure related complications. A reduction of the cephalic vein depth by mean 5.8 mm was achieved in all patients. Interestingly, both the post-procedure cephalic vein diameter and volume flow increased three months after ES (Table 1). This positive effect was attributed to the dissection of the vein's ventral surface and the creation of a cavity. These results correspond with the increase in mean vein diameter and volume flow one month after open lipectomy reported by Bourquelot *et al.*[7] The observed post-procedure volume flow changes are more pronounced and thus support the observation that additional AVF maturation occurs after ES.

In the hands of a surgeon with laparoscopic or endoscopic experience, ES can be performed safely. However, several pitfalls were encountered during the ES procedure that may cause problems or lead to conversion. Firstly, the incisions made to introduce the trocars need to be slightly smaller than the trocar diameter to ensure that CO_2 pressure of 12 mmHg remains constant which enhances visibility. Additionally, this measure will stabilise the position of the trocars 5—10 mm below the skin during the exchange of endoscopic devices. Secondly, the creation of the initial cavity by blunt dissection has to be performed carefully as this is the only step where there is no visual control of the cephalic vein. A key feature to prevent venous injury during the procedure is the continuous visual control delivered by the endoscopic 30° camera. Thirdly, ES is less demanding if the deep vein segment has not been repeatedly cannulated previously. Scar tissue between skin and vein complicates endoscopic dissection and may result in difficulties creating a subcutaneous space. Potential candidates for ES are patients with a rare condition where the cephalic vein lies entirely or partly below the superficial fascia, complicating cannulation. Its dissection during ES is feasible once the arterialised vein has been identified. In the case of minor bleeding, biphasic electrocoagulation can be applied safely. Vascular surgeons with no laparoscopic or endoscopic experience will require hands on training to be able to perform ES. However, the approach is straightforward and the learning curve is expected to be steep.

AVF usage is associated with lower BMI, and secondary procedures in obese patients are more frequently needed in order to achieve functionality.[13] Similarly, Miller *et al.*[3] reported that AVFs in patients with a BMI $\geq$27 kg/m^2 were less likely to mature into a functional access (55% for non-obese *vs*. 34% for obese, odds ratio = 0.43; p = .07). One reason for poorer functional AVF results is the deep localisation of superficial veins that are often covered by overlying subcutaneous fat. These veins are often of good

quality as their deep location protects them from routine punctures. Following the European Vascular Access Guidelines[5] arterialised but otherwise well matured veins located deeper than 6 mm under the skin require superficialisation if cannulation is not feasible. Ultrasound guided needling of a deep lying AVF may facilitate puncture but development of post-haemodialysis haematomas may complicate further AVF use.

A growing population of obese end stage renal disease patients with deeply located superficial veins has resulted in numerous approaches addressing the issue of AVF cannulation.[14] Conventional, second stage open surgical procedures[7,15] are popular and are effective in reducing the distance between skin and arterialised veins though at the cost of generic side effects such as longer scars and the probability of wound complications. Minimally invasive tunnelling of the deep lying cephalic vein showed encouraging results but bears all the risks of a redo anastomosis. The least invasive method to have been proposed is ultrasound guided liposuction,[8] although, the authors concluded that due to the substantial risk of serious surgical complications such as skin necrosis and significant haematomas, it is not an ideal method. The endoscopic approach was developed according to patient preference for minimal invasiveness and with the need to have visual control of the operating field. In contrast to the recently presented one stage superficialisation,[16] all the matured AVF procedures were secondary.

Limitations

This retrospective, single surgeon study involved a small number of patients. However, the limited data provide important insights into safety, feasibility, and outcomes of ES. Perhaps the most important implication of this study is to reinforce the need for a multicentre randomised trial of superficialisation techniques.

CONCLUSION

This small series of patients indicates that endoscopic superficialisation is an effective procedure to obtain a functional AVF in obese patients with a deep lying cephalic vein with no procedural complications, including cephalic vein damage or wound healing impairment. ES represents an alternative method for second stage superficialisation.

CONFLICT OF INTEREST

None.

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