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Pilot single-arm study to investigate the efficacy and safety of endovenous Microwave ablations for treatment of varicose veins in Singapore – one year results of the *MAESTRO* registry

Tjun Yip Tang[1,2,3], Karen Ka Wing Chan[4], Charyl Jia Qi Yap[1], Sze Ling Chan[5], Shereen Xue Yun Soon[1], Vanessa Khoo[1] and Julian Chi Leung Wong[3,4]

Abstract

Objectives: Aim was to report a prospective two-centre Singaporean experience using Endovenous Microwave Ablation (EMA) to treat symptomatic primary great saphenous vein reflux. We evaluated 1-year safety, efficacy and patient satisfaction.

Methods: 50 patients (63 limbs; 29 females; mean age 58.0 ± 12.1 years) were included. Patients were reviewed at 2-weeks, 3-, 6- and 12-months and underwent Duplex ultrasound assessment. Three quality of life (QoL) questionnaires were completed.

Results: The truncal closure rates at 2-weeks, 3-, 6- and 12-months were 63/63 (100%), 59/59 (100%), 58/58 (100%) and 59/60 (98.3%), respectively. There was 100% technical success and no serious adverse events. There were sustained improvement of QoL questionnaire scores from 2 weeks to 12 months.

Conclusion: EMA is a safe and efficacious venous ablative technology at 12 months and is associated with a high rate of target vein occlusion and sustained QoL improvement.

Keywords

varicose veins, endovenous microwave ablation, quality of life

Introduction

The United Kingdom *National Institute of Health and Clinical Excellence* (NICE) and the *American Venous Forum* guidelines both currently still recommend endovenous thermal ablation as first-line treatment for symptomatic axial vein reflux.[1,2] Endovenous Radiofrequency (RFA) and laser (EVLA) ablation techniques have now replaced traditional open high tie and stripping surgery, previously considered the 'gold standard' therapy because they have allowed a faster return to normal daily activities and improvement in quality of life for patients.[3] There is Level 1a evidence to attest for the safety and efficacy of endothermal ablation[4] and long term RFA outcome data (15 years) have shown excellent durable technical and clinical successes.[5] However, there are also data suggesting that EVLA can be a more painful experience than RFA, with a higher degree of bruising for the patient[6] using the older laser fibres, although there is recent data to suggest comparable post-operative pain and improved quality of life (QoL) scores using the new 1470 nm laser with Tulip-Tip™ fibre.[7,8] Furthermore, depending on which type of RFA catheter utilized, there may well be a significant anatomical recurrence rate in the shorter term with RFA technology.[9] Despite tumescence use as a heat sink, thermal-related complications such as skin

[1]Department of Vascular Surgery, Singapore General Hospital, Singapore
[2]Duke-NUS Graduate Medical School, Singapore
[3]The Vascular & Endovascular Clinic, Gleneagles Medical Centre, Singapore
[4]Department of Vascular Surgery, National University Hospital, Singapore
[5]Health Services Research Centre, SingHealth, Singapore

Corresponding author:
Tjun Yip Tang, The Vascular & Endovascular Clinic, Gleneagles Medical Centre, 6 Napier Road, #08-08, Singapore 258499, Singapore.
Email: tjuntang@vascularclinic.sg

burns, nerve damage and endothermal heat-induced thrombosis do occur with RFA and EVLA.[10,11] Non-thermal, non-tumescent technologies such as cyanoacrylate glue embolization[12] and mechano-chemical ablation (MOCA)[13] were introduced into the endovenous arena to mitigate the need for tumescent infiltration and avoid heat-related injuries but glue has its own unique concerns of being a foreign body with potential risk of a hypersensitivity reaction[14] and infection/rejection.[15] MOCA recently demonstrated higher midterm anatiomical recurrence rates.[16]

Endovenous Microwave Ablation (EMA) is another type of endothermal ablation and has been widely used in the interventional oncology arena to treat malignancies percutaneously, especially for hepatic neoplasms.[17] The technology has been successfully implemented albeit with a hybrid technique with open high ligation to treat symptomatic refluxing great saphenous veins in China.[18–20] These studies have shown improved bruising and tissue induration post-operatively, compared to EVLA and open high saphenous ligation surgery. EMA seems to have all the advantages of RFA and the latest radial laser fibres and does not have to be in contact with the vein wall unlike RFA during treatment, which can be advantageous for the larger diameter veins, when the patient has to be placed usually into a steep reverse Trendelenberg position to help collapse the vein against the RFA catheter, with simultaneous manual compression over the thigh to remove as much blood from the saphenous vein and maximize tip contact against the vein wall. The power passes from the side of the EMA catheter tip directly into the vein wall. Microwave heats the water in the cells of the vein wall and causes protein denaturation and transmural cell death leading to irreversible venous occlusion and fibrosis.[21] Also the energy used from the microwave machine can be manipulated depending on size and location of the vein to the skin surface and does not emit any wavelength light, and hence, no laser precautions such as a performing the procedure in a laser proof room with eye protection are required. Other potential benefits of EMA include, significantly lower risks of skin burns due to the lower maximum temperature reached at the tip, which is approximately 85°C compared to 800°C (EVLA)[22] and 120°C (RFA).

The aim of this study was to report a collaborative, prospective two-centre Singaporean experience using the ECO Varicose Veins Therapeutic Unit (Nanjing ECO Microwave System Co., Ltd, Jiangsu, China) for EMA, to treat symptomatic primary great saphenous vein (GSV) reflux. We evaluated 1-year safety, efficacy and patient satisfaction.

Methods

Trial design and patients

Microwave Ablations for Treatment of Varicose Veins in Singapore (MAESTRO) was a real-world, prospective, single arm, dual-centre, dual investigator registry investigating the utility of EMA in a cohort of multi-ethnic Asian patients with chronic venous insufficiency and varicose veins from Singapore. Primary endpoints were technical success at the time of the procedure, and anatomical success, reported as complete axial vein closure at 2-weeks, 3-, 6- and 12-months. MAESTRO's flowchart diagram is depicted in Figure 1 and has been registered on ClinicalTrials.gov: NCT04524793.

Adult patients (age >21 years) with symptomatic venous reflux disease in the GSV and/or anterior accessory saphenous vein (AASV) with associated moderate to severe varicosities and CEAP (clinical, aetiological, anatomical and pathophysiological elements) classification,[23] C2–C6 disease were included. Significant saphenous vein reflux was defined as retrograde venous flow of >0.5 seconds,[24] assessed in the standing position with Duplex colour ultrasound (EPIQ 7G, *Philips Healthcare Solutions*, WA, US). GSV diameter was measured with the patient standing up, at three levels (proximal thigh near SFJ, mid-thigh and distal thigh just above the knee). Mean GSV diameter was defined as the average of the above three measurements in keeping with previous methodology used.[25] AASV mean diameters were defined as the average of 2 measurements: vein proximal thigh near SFJ and mid-thigh level. In addition, patients had to have one or more of the following symptoms: aching, throbbing, heaviness, fatigue, pruritus, night cramps, restlessness, generalized pain or discomfort, swelling. Patients who have GSV or AASV diameters of 3 mm to 12 mm in the standing position were included. Symptomatic peripheral arterial disease (ABPI <0.8), pregnancy, sepsis, history of deep vein thrombosis or pulmonary embolism, recurrent varicose veins, current and daily use of narcotic analgesia or NSAIDS to control pain associated with venous disease were exclusion criteria.

All patients were seen prior to intervention by two vascular specialists based at 2 vascular centres (Singapore General Hospital (PI = TYT) and National University Hospital (PI = JCLW)) in Singapore and who are both very experienced endovenous practitioners and regularly perform endothermal ablation as part of their venous practice. EMA was introduced into Singapore in March 2020 and to date the 2 centres have performed more than 150 truncal ablations using the device. A thorough history and clinical examination were performed and included CEAP and baseline revised Venous Clinical Severity Score (rVCSS)[26] evaluation of the index leg. In addition, patients completed 3 quality of life surveys – EuroQol-5 Dimension questionnaire (EQ-5D),[27] Aberdeen Varicose Vein Questionnaire (AVVQ)[27] and Chronic Venous Insufficiency quality life Questionnaire-14 (CIVIQ-14).[28] Enrolment took place over 12 months (March 2020–March 2021). Both participating sites obtained Central Institutional Review Board approval (CIRB ref number: 2020/2371) and the study was registered on ClinicalTrials.gov (NCT04524793). This study was conducted in accordance with the ethical principles of the

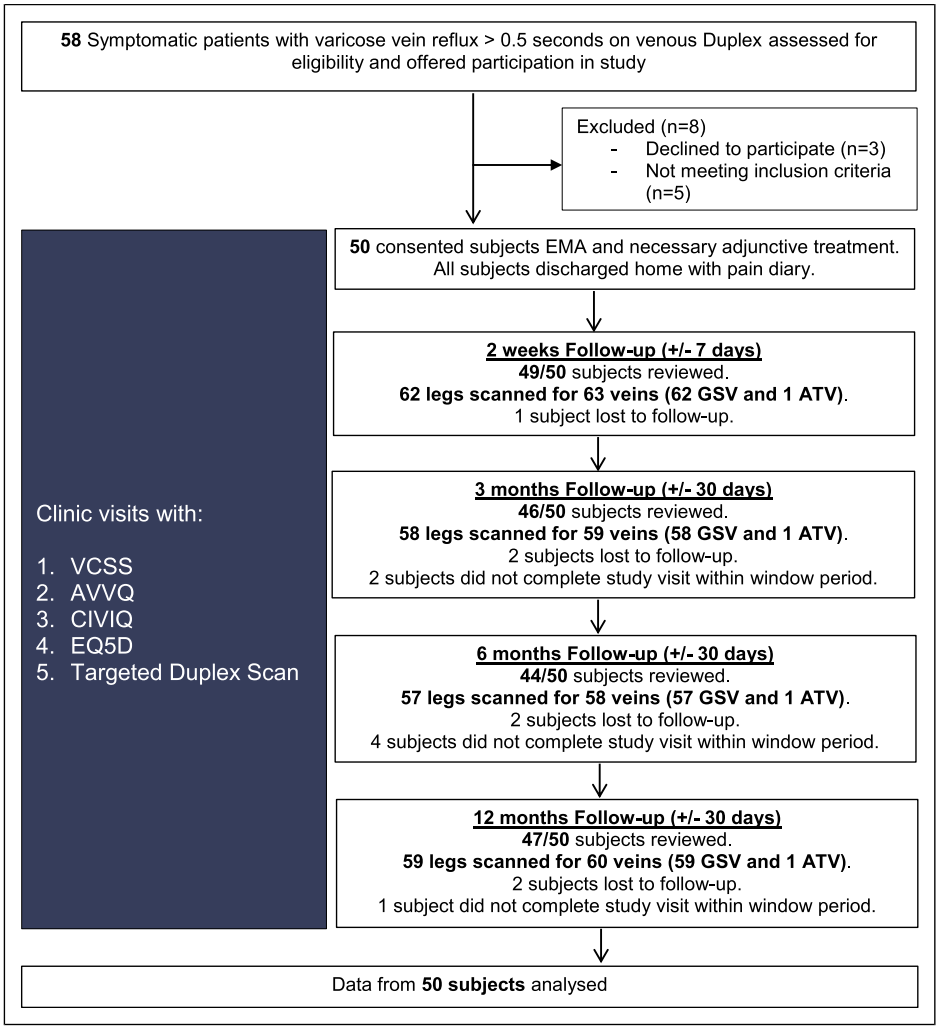

Figure 1. Study flow chart.

Declaration of Helsinki and was consistent with good clinical practice.

Each patient provided trial-specific informed consent prior to the procedure and received a procedure-specific information leaflet produced by the company in their native language, which explained the technique including risks and side effects. Patients who did not want to be treated with EMA were routinely offered treatment with RFA, EVLA, mechano-chemical ablation, cyanoacrylate glue embolization or open surgery. There was no deliberate selection bias to only perform the operation with favourable saphenous vein anatomy and all treatment options were offered as part of informed consent.

Endovenous microwave ablation technique

It is usual practice of both operators to perform the procedure under local anaethetic with sedation unless concomitant phlebectomies were required in which case a regional or general anaethetic was employed. The patient was positioned supine with a body warmer and with a sandbag wedged under the knee to enhance access to the GSV. *T*he index leg was disinfected with ChloraPrep™ (BD, Berkshire, UK) and sterile drapery applied. The truncal vein was accessed under ultrasound guidance using a Seldinger technique to introduce a micro-catheter 4F introducer sheath (*Angiodynamics Inc*, Queensbury, NY, US) exchanged for a 6Fr introducer sheath, typically at the most caudal extent of the venous reflux based on the pre-operative Duplex scan. The 2 mm microwave antenna was passed up the truncal vein directly under ultrasound guidance and placed carefully 2 cm below the sapheno-femoral junction (SFJ) or just below the inferior epigastric vein, whichever was more caudal. Accurate tumescence infiltration ((1000 mL 0.9% normal saline, 20 mL lidocaine 1%, 8.4% 10 mL sodium bicarbonate and 1 mL adrenaline 1:1000) was placed as a heat sink from SFJ to sheath and the tumescence was used carefully to push the vein off the skin surface if the GSV had a suprafascial component to minimize risk of dermal burns.

Before starting ablation, the patient was placed into the reverse Trendelenberg position to help empty and collapse the vein against the EMA antenna. A set protocol for the microwave setting on the generator was used, different from the previous publications from China and Thailand. Technical parameters of the generator system (model ECO-100E2) have recently been presented.[29] The machine was set at 40W (pulse mode) and 7 s duration for each cm of GSV treated. The antenna was withdrawn 1 cm after each cycle was completed and the process was repeated. The top 5 cm of GSV was given 2 treatments, very similar to the technique of RFA. The GSV is usually 'cold' when the procedure is commenced so after the first 3 cm of treatment, the ultrasound was used to check adequate vein wall contraction. If there were any concerns about closure, 3 cycles of ablation were used for the first 3 cm of GSV. If the first 5 cm of vein were larger than 10 mm in maximum diameter, a 40W – 9 s setting was used for this part of the vein. If there were concerns of potential skin burn even if good tumescence was given to push the GSV off the surface, the power remained the same but the time of each cycle duration was reduced to 5 s.

Concomitant phlebectomies were left up to the discretion of the specialist in consultation with the patient. Antibiotics at induction were routinely given. A full-length compression bandage (Class II; Coban LiteTM) was applied to the treated limb(s) from the foot to the groin only if phlebectomies were also performed and removed after 48 h by the patient. Post-operative compression hosiery was not mandatory but was advised for 2 weeks to be worn during the daytime only. The patient was asked to ambulate for 10 min before discharge from hospital and a single dose of low molecular weight heparin was given immediately post-operatively. The patients were prescribed a 1 week's course of Arcoxia™ (Merck and Co., NJ, USA) for analgesia and advised to return to their work and normal activities as soon as they felt capable to do so.

Post-procedural follow-up

Clinical assessments were planned at 2 weeks, 3-, 6- and 12-months after treatment. Each follow-up visit included a Duplex ultrasound scan to ensure anatomical closure, defined as loss of vein patency and absence of blood flow. The rVCSS, EQ-5D, AVVQ and CIVIQ-14 surveys were completed to assess improvement in quality of life.

The pain score over the first 14 post-operative days using the Visual Analogue Scale[30] was also charted. Occurrence and severity of adverse events was also documented at each follow-up visit. Patients also completed a brief questionnaire about treatment satisfaction and whether they would have the operation again if required to, which has been previously described in detail.[31] After 3 months, patients were asked to quantify their satisfaction of the treatment on a 10-point score. Data were collected prospectively onto a secure computer database using a dedicated proforma, with a telephone questionnaire conducted if required for subsequent clinic follow-up non-attendence.

Definitions

Technical success was defined as the ability to perform the procedure as planned and achieve immediate occlusion after the ablation.

Anatomical success was defined as the occlusion of the treated truncal vein(s).

Recurrence or treatment failure was defined as a re-opening of a segment > 5 cm in length in keeping with previous reporting.[32]

Statistical analysis

Descriptive analysis was performed for baseline variables, with continuous variables reported as mean and standard deviation, or median and range, as appropriate, and categorical variables as absolute number and percent. Linear mixed models were used to assess changes in rVCSS, EQ-5D, AVVQ and CIVIQ-14 scores over time, accounting for patient-level correlations between repeated measurements. Statistical significance was assumed at $p < .05$. All analyses were performed in R version 3.5.1[33] by an independent biostatistician (SLC), who was blinded to the patients' clinical details.

Results

Patient characteristics

58 patients were screened for *MAESTRO* and 50 (86.2%) patients were enrolled. 29/50 (58%) were females and mean age was 58.0 ± 12.1 years. The majority of the patients were Chinese (68%) in origin. The most frequent presenting CEAP clinical class was class 2 (56%) and class 3 (28%). The most common primary symptoms were swelling (56%) and pain (36%). The median duration of symptoms prior to presentation was 23 (IQR 9–24) months. Only 24% were on some anticoagulation/antiplatelet medication. Table 1 shows subject demographics and baseline characteristics.

Procedural details

63 legs (64 truncal veins) were treated. 36 (57.1%) were treated for unilateral GSV incompetence, 26 (41.3%) as a bilateral GSV ablation and 1 (1.6%) combined unilateral GSV and AASV procedure (Table 2). 36/63 (61.9%) of treated legs had concomitant phlebectomies. 47/63 (74.6%) legs had complete above and below knee GSV reflux and interestingly 33/63 (52.4%) legs had some degree of deep venous reflux. 10/63 (15.9%) legs had some suprafascial extension of their GSV during its course. The most common sites of puncture

Table 1. Demographic and baseline characteristics.

Characteristic	Number of subjects at baseline (n = 50)
Gender, *n* (%)	
Male	21 (42.0)
Female	29 (58.0)
Mean age**, years (±SD)**	58.0 ± 12.1
Mean body mass index**, (±SD)**	26.2 ± 3.7
Ethnic group	
Chinese	34 (68.0)
Malay	4 (8.0)
Indian	8 (16.0)
Others	4 (8.0)
Comorbidities	
Hypertension	26 (52.0)
Hyperlipidaemia	23 (46.0)
Diabetes mellitus	14 (28.0)
Ischaemic heart disease	10 (20.0)
Smoker	2 (4.0)
Primary symptoms	
Pain	18 (36.0)
Aching	4 (8.0)
Swelling	28 (56.0)
Heaviness	14 (28.0)
Burning	1 (2.0)
Itch	3 (6.0)
Ulcer	7 (14.0)
Varicosities	28 (56.0)
Cramps	16 (32.0)
Others (e.g. bleeding)	6 (12.0)
Duration of symptoms (months), median (IQR)	23 (9 – 24)
Medication history	
Aspirin	6 (12.0)
Clopidogrel	5 (10.0)
Warfarin	1 (2.0)
	Number of legs treated (n = 63)
CEAP category, *n* (%)	
C2 (varicose veins)	28 (56.0)
C3 (oedema)	14 (28.0)
C4 (pigmentation//induration)	12 (24.0)
C5 (healed venous ulcer)	1 (2.0)
C6 (ongoing venous ulcer)	7 (14.0)

were between the proximal and mid-calf area in 72.9% cases. The mean ablation time was 5.3 ± 1.3 minutes and median operating time was 55 (IQR 42.5–66.5) minutes. All cases were performed on a day surgery basis.

Outcomes

There were no device – related complications and the microwave antenna was delivered without incident to its intended position in the truncal vein in all cases (100% technical success). 7/63 legs (11.1%) necessitated the use of a double puncture technique to allow the antenna to be manoeuvred up to the SFJ, mainly due to the tortuosity of the vein in the below knee segments of the GSV. All patients had immediate on table completion Duplex ultrasound to document successful obliteration of the treated segment and lack of deep vein thrombosis as shown by the compressibility test in the common femoral vein.

At 2 weeks, 3-, 6- and 12-months, the occlusion rates of the axial veins treated were 63/63 (100%), 59/59 (100%), 58/58 (100%) and 59/60 (98.3%), respectively (Table 3). The one anatomical recurrence was for a below the knee segment treated for a medial malleolus ulcer. There was no need for re-intervention because the wound had healed with concomitant compression by 7 weeks. All venous ulcers (7/63 = 11.1%) had healed by 10 weeks after EMA with

Table 2. Procedural details.

Characteristic	Number of legs (n = 63)
Incompetence	
Above knee (AK) only	15 (23.8)
Complete GSV insufficiency	47 (74.6)
Reflux in	
GSV	47 (74.6)
GSV and SSV	12 (19.0)
Anterior accessory vein reflux	1 (1.6)
Deep vein reflux	33 (52.4)
Unilateral GSV treated	36 (57.1)
Bilateral GSV treated	26 (41.3)
GSV + ATV treated	1 (1.6)
Total number of GSV treated	63 (100.0)
Vein diameter (mm), mean ± SD	
Proximal	7.32 ± 2.27
Mid	6.15 ± 3.34
Distal	5.02 ± 1.90
Treatment zone maximum diameter (mm)	6.83 ± 2.66
Suprafascial outing	10 (15.9)
Location of suprafascial outing	
Thigh	6 (60.0)
Knee	3 (30.0)
Calf	1 (10.0)
Concomitant avulsions (%)	36 (61.9)
Median operating time (min), median (IQR)	55 (42.5 – 66.5)
Technical success	63 (100.0)
(GSV)	
Legs treated	
Number of legs treated	63
Left leg	26 (41.3)
Right leg	37 (58.7)
Mean treated length, mm (±SD)	439 ± 112
Double puncture technique, *n* (%)	7 (11.1)
Puncture site, *n* (%)	70
Proximal thigh	1 (1.4)
Mid-thigh	4 (5.7)
Distal thigh/knee	9 (12.9)
Proximal calf	34 (48.6)
Mid-calf	17 (24.3)
Distal calf	4 (5.7)
Ankle	1 (1.4)
Mean ablation time, mins (±SD)	5.3 ± 1.3
Mean number of cycles (±SD)	45.4 ± 10.2
Mean energy, Joules (±SD)	12536 ± 4463.9

GSV: great saphenous vein.

continued 2–4 layer compression and optimal wound care at the specialist vascular clinic.

Adverse events

No major adverse events were observed, that is, pulmonary embolism, transient ischaemic attack, permanent nerve injury, skin necrosis, infection or pigmentation except for one case of clot found extending into the common femoral vein (AVF EHIT Class II) at the 2 weeks follow-up time-point on a unilateral GSV EMA. The size of the proximal GSV was approximately 6 mm in maximum diameter and the procedure was otherwise routine in nature. It was not one of the first 10 cases and therefore cannot be attributed to

Table 3. Outcomes and adverse events.

	Number of occluded vessels	Percentage
Patency of treated vessel		
2 weeks	63/63	100.0
3 months	59/59	100.0
6 months	58/58	100.0
12 months	59/60	98.3
Adverse events	Number of adverse events	Percentage
Phlebitis		
2 weeks	6/62	9.68
3 months	4/58	6.90
6 months	0/57	0.0
12 months	0/59	0.0
Bruising		
2 weeks	24/62	38.7
3 months	5/58	8.6
6 months	0/57	0.0
12 months	0/59	0.0
Deep vein thrombosis	1/62	1.6
Access site infection	0/62	0.0
Skin burn	0/62	0.0
Transient numbness in treatment zone	6/62	9.7
Device-related adverse events	0/62	0.0

a learning curve issue but may well represent some spillage of clot from the SFJ as the rest of the GSV was completely occluded and there was no issue immediately post procedure. The patient was asymptomatic in terms of leg swelling at 2 weeks but was prescribed a 8-weeks course of Rivoroxaban (Xarelto™, Bayer AG, NJ, USA). A follow-up ultrasound showed complete resolution of the clot and deep vein patency. The patient was also asymptomatic and very satisfied with the outcome. Transient superficial thrombophlebitis was reported in 6/62 (9.7%) legs at 2 weeks, which had all resolved by 6 months (Table 3). There were 24/62 (38.7%) of bruising at the 2-weeks interval, which had all fully resolved by 6 months. There was some degree of transient numbness in the treatment zone in 9.7% cases at 2 weeks but all had resolved by the 3-months interval.

Pain score, Patient Satisfaction and QoL Improvement

All procedures were very well tolerated with an overall median pain score of 3 (IQR 1–3.5) on a 10-point scale, documented on the morning afterwards. The median VAS pain score dropped to 0 (IQR 0-2; $p < .0001$) by day 9. There was no difference between pain scores of patients who underwent concomitant avulsions and those who did not on POD 1 (Median pain score: 3 (1–3) versus 4 (2.75–5.5), $p = .248$) and POD 14 (Median pain score: 0 (0–0) versus 0.5 (0–2.25), $p = 0.267$) (Figure 2).

The mean time to return to normal daily activities was 0.85 (±1.0) days and there was no difference whether a unilateral or bilateral procedure were performed. Return to work was longer at a mean time of 6.8 (±3.4) days but this may have been down to patient personal choice and again no difference whether more than one leg was treated at the same sitting. Mean time to stopping compression post-operatively was 8.6 (±3.9) days, earlier than the recommended time of 2 weeks given.

After 3 months, median patient satisfaction of the treatment was 9.0 (IQR 8.0–10.0) (Table 4). Overall, at one year, 95.7% patients were very satisfied with their treatment. 100% patients expressed that their symptoms had either somewhat or were much improved and the appearance of their legs were much or somewhat improved in 89.4% cases. 97.9% patients indicated they would either probably or definitely recommend the procedure to friends or relatives for the same problem.

Table 5 and Figure 3 summarize rVCSS, AVVQ, CIVIC-14 and EQ-5D scores at baseline, 2 weeks, 3-, 6- and 12-months visits. In general, there were improvements in all four measures, which were significant between baselines and at 2 weeks and 3-, 6- and 12-month time intervals ($p < .05$) except for the rVCSS and AVVQ scores. Interesting a significant improvement was only seen between the 2 weeks and 3 months follow-up visits with the rVCSS and AVVQ scores only and to a lesser degree albeit non-significant with the other scoring methods. The peak in improvement was at 3 months and the effect was

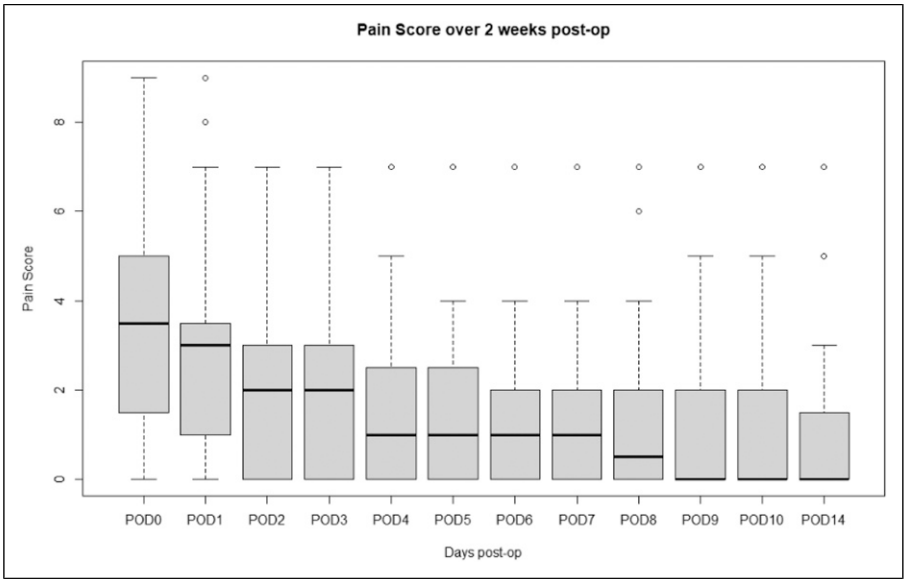

Figure 2. Two-week pain diary. POD-Post-op Day.

Table 4. Overall patient satisfaction.

		N (%)			
Time	No. of patients who responded	Extremely/very satisfied	Definitely/probably choose as treatment in event of recurrence	Appearance much/ somewhat improved	Symptoms much/ somewhat improved
12 months	47	45 (95.7)	46 (97.9)	42 (89.4)	47/47 (100.0)

sustained through to 12 months. There was no difference in QoL improvement scores between those who had microwave ablation alone and those who had EMA and phlebectomy treatment.

Discussion

The main findings of *MAESTRO*, a dual-centre collaborative prospective registry from Singapore showed that EMA for primary GSV incompetence treatment of varicose veins was safe, technically feasible, efficacious, with a high patient satisfaction rate, as applied to a real-world multi-ethnic (predominantly Chinese) Asian population. The primary objective was to determine technical success – this was 100%, and there was immediate truncal vein occlusion after the procedure sustained through to 1 year follow-up. Only one GSV had anatomical recanalization in this series – between the 6 and 12 months timepoint based on a strict Duplex-defined ultrasound criterion (>5 cm continuous length of GSV reopening), which was asymptomatic in nature and did not require further reintervention. This is in keeping with previous EMA data from Thailand, China and Greece but with certain caveats to highlight.

Subwongcharoen et al.*'s* seminal work in 2009 showed the technical feasibility of EMA in 20 patients with GSV incompetence.[34] They used a rudimentary generator to output radiofrequency in the microwave spectrum and used a cut down rather than a percutaneous technique to access the GSV at the knee level. By using a 50W power setting, they felt they were able to ablate the GSV safely with a 100% occlusion rate at 1 week but this dramatically fell to 65% at 6- and 12-months although most patients were satisfied with the result and there were no clinical recurrences or major complications such as DVT, permanent nerve injury or skin necrosis reported. Using an explanted human saphenous vein and a live swine hindlimb model, they determined that the optimum power setting for EMA was between 50W-60 W, which resulted in transmural destruction of the vein wall (all three layers) but with minimal perivessel tissue injury (maximum radial spread of 4.5 mm).

Mao *et al* compared EVA with EMA in treating refluxing GSV and found less bruising with EMA using the same 50W setting as Subwongcharoen et al., and this may be related to how the laser fibre tip can reach a temperature of 800° and cause comparatively more wall perforation and blood extravasation upon contact. However, they describe

Table 5. Follow-up clinical assessments.

Assessments	Median (IQR)	*p* value (baseline – 2 weeks/3/6/12 months)	*p* value (2 weeks –3/6/12 months)	*p* value (3–6/12 months)	*p* value (6–12 months)
VCSS					
Baseline	5.00 (3.00–6.00)				
2 weeks	4.50 (2.00–6.00)	0.978			
3 months	1.00 (0.00–1.75)	<0.001*	<0.001*		
6 months	1.00 (0.00–1.25)	<0.001*	<0.001*	0.999	
12 months	0.00 (0.00–2.00)	<0.001*	<0.001*	0.996	0.999
EQ-5D TTO SG					
Baseline	0.44 (0.23–0.85)				
2 weeks	1.00 (0.69–1.00)	<0.001*			
3 months	1.00 (0.85–1.00)	<0.001*	0.566		
6 months	1.00 (0.85–1.00)	<0.001*	0.576	0.999	
12 months	1.00 (1.00–1.00)	<0.001*	0.441	0.999	0.999
EQ-5D health score					
Baseline	70.0 (60.0–80.0)				
2 weeks	80.0 (70.0–90.0)	0.007*			
3 months	82.5 (80.0–90.0)	<0.001*	0.147		
6 months	82.5 (80.0–90.0)	<0.001*	0.392	0.988	
12 months	90.0 (80.0–97.5)	<0.001*	0.002*	0.608	0.323
AVVQ					
Baseline	13.8 (9.98–24.6)				
2 weeks	16.0 (11.2–20.7)	0.954			
3 months	6.56 (2.86–13.6)	<0.001*	<0.001*		
6 months	3.94 (0.97–9.98)	<0.001*	<0.001*	0.603	
12 months	3.70 (0.00–7.49)	<0.001*	<0.001*	0.061	0.756
CIVIQ-14					
Baseline	11.6 (6.70–21.9)				
2 weeks	5.36 (0.00–14.3)	0.004*			
3 months	0.00 (0.00–5.36)	<0.001*	0.280		
6 months	0.89 (0.00–5.80)	<0.001*	0.678	0.972	
12 months	1.79 (0.00–7.14)	<0.001*	0.793	0.916	0.999

VCSS: venous clinical severity score; *EQ-5D*: EuroQol-5 dimension; TTO: time trade-off; *AVVQ*: aberdeen varicose vein questionnaire; *CIVIQ-14*: chronic venous insufficiency quality life questionnaire-14.
* Significant at $p \leq .05$.

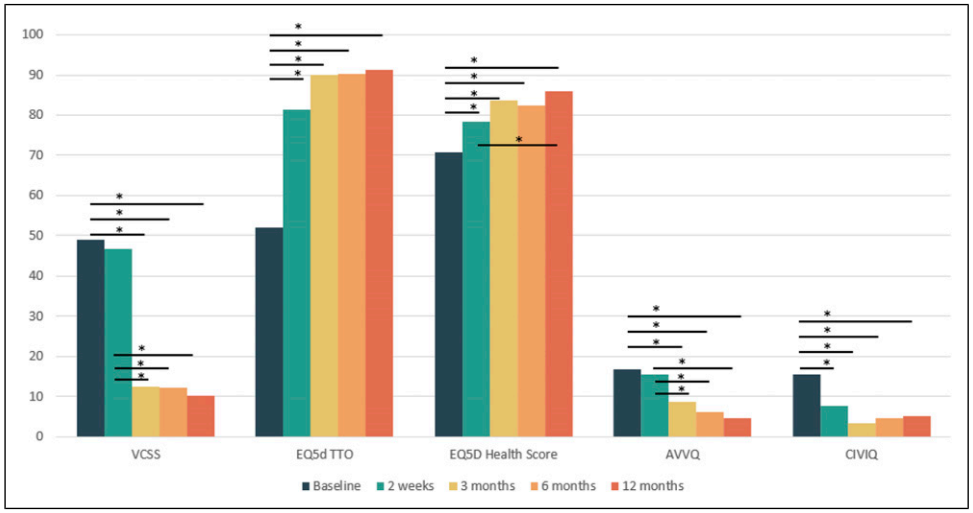

Figure 3. Mean QOL Scores.
VCSS scaled up by power of 10 and EQ5d-TTO scaled up by power of 100 for illustration purposes. * Significance at $p \leq .05$.

non-routine use of tumescent anaesthesia unless the GSV was close (<7 mm) to the skin and their pullback rate was slower (3 cm/minute) than our protocol resulting in more energy applied than may be required, especially with a higher 50W power setting (compared to our 40W). Although they achieved a comparable >99% and 95% occlusion rate post-operatively at one week and 6 months, respectively, their complication rates of approximately 10% of skin burns, 11% paraesthesia and 17% tissue induration were unacceptably high and may reflect inadequate tumescent analgesia and the higher power setting on the generator and the slower pullback rate resulting in more energy dispersed in total. Furthermore, there may have been a higher incidence of nerve injury (saphenous nerve) as all GSV were accessed around the medial malleolus, which was not necessary – especially for the majority of patients who presented with CEAP 2 or 3 disease. In comparison, we used a generator protocol of 40W pulse setting; 7 seconds per cycle and 1 cm pullback rate per cycle (first 5 cm below SFJ were treated twice) and the majority of the percutaneous access punctures were performed in the proximal and mid-calf area under ultrasound guidance and careful tumescence was given around the gsv along its entire course up the leg. This resulted in immediate closure of the entire GSV treated, which was durable to 1 year. There were no incidences of skin burns, permanent scleroma and all degrees of bruising had almost settled by 3 months, which may have been attributed to the avulsion process per se (nearly 2/3 cases had comcomitant phlebectomies) and all parasthesia were transient in nature and had resolved by 3 months.

The most recent EMA data offering for symptomatic varicose vein ablation is the prospective, single-centre study of European patients from Karnabatidis *et al* from Greece.[29] They showed that EMA achieved a 95.3% GSV occlusion rate at 1-year in a similar sized cohort of patients (n = 50), which also translated to a high clinical success rate of 100% documented by CEAP grade improvement. The group used the same ECO model generator and set it at 60W power setting similar to the studies reported from Thailand and China. They did not report any nerve injury or skin burns but limited their initial access above the mid-calf and provided tumescence in every case. The median pain score was low 24 hours post procedure (VAS = 2), which was lower than our median of VAS = 3, but this can be explained by the fact that they did not do any concomitant avulsions, whereas two thirds of our cohort did have and reflects everyday practice in Singapore. The majority of the patients in both cohorts returned to normal daily activities within 1 day, which is more than satisfactory considering a thermal based technology was used. The pain scores and return to normal daily activities were better and faster than previous RFA and EVLA data published[35] and comparable to non-tumescent non-thermal venous ablative techniques.[16,31]

Yang et al. demonstrated that endovenous microwave ablation had similar occlusion and clinical success rates

Compared with EVLA, but significantly shorter procedural time, lower complications such as brusing and temporary parasthesia, and pain scores, similar to those achieved in MAESTRO.[18] What we found from our data is that the initial access puncture can be performed lower down in the leg without much concern of risk of parasthesia, although accurate tumescence is important before ablation. A third of the punctures was mid-calf down to ankle and although there was some temporary numbness they all resolved at 3 months. 11% cases were CEAP 6 and all had healed by 10 weeks, which suggests that ablating the venous reflux right down to the ulcer using EMA is an effective technique without significant complication.

Strengths and limitations

Strengths of MAESTRO is that it is a prospective multi-centre multi-ethnic cohort with tight follow-up and minimal attrition rate. Furthermore, it is unique with 4 different measures of clinical outcome showing general improvement at 2 weeks and 3 months after EMA. Inclusion and exclusion criteria were not strict and the cohort is reflective of a real life venous registry practice in Singapore. What is different from MAESTRO compared to quoted EMA studies is the use of a different microwave generator protocol for ablation, which is less aggressive (40W vs 60W) and minimizes thermal-related injuries but achieved comparable if not superior and longer length ablation rates. Limitations of the study include being a single-arm study with a comparatively short follow-up of 1 year, lack of randomization and with no comparator device group. Results may also be confounded by those who had concomitant phlebectomies, which was left to the discretion of the primary operator after discussion with the patients and with no set selection objective criteria, although there were no difference in pain scores and QoL outcomes if you compare those who had EMA truncal ablation alone with those who also had side branch avulsions. Randomized trials with a prolonged follow-up protocol are clearly indicated to compare closure rates directly with other endovenous modalities. These trials should look at other aspects such as cost savings associated with the use of EMA, which are not yet reported but will definitely play an important role in acceptance of this new technology.

Conclusions

Endovenous microwave ablation is a safe and efficacious modality to ablate refluxing great saphenous veins in Asian patients in the short-term (1 year). The procedure can be

safely expanded to bilateral procedures along with adjunctive phlebectomies, which are well tolerated. There is a high satisfaction rate and peri-procedural pain is low. Early results are promising but further evaluation and longer term follow-up are required. We have shown with a newly instituted protocol of reducing the power on the generator to minimize the risk of thermal-related injuries that the efficacy and clinical outcomes remain very satisfactory.

Authors' contributorship

TYT/JCLW was primarily involved in study design, protocol development, implementation and analysis of the data at study site, as well as patient recruitment. KKWC, CJQY, SSXY, VK were involved in patient recruitment and edited the final draft of the manuscript. CJQY, SSXY, VK coordinated the project and patient communication and were involved in manuscript preparation with TYT. SLC aided with the data analysis and statistical prowess. All authors have read and approved the final manuscript.

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Guarantor

TYT/JCLW

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ORCID iDs

Tjun Yip Tang https://orcid.org/0000-0002-8524-7912
Charyl Jia Qi Yap https://orcid.org/0000-0002-8606-0842
Shereen Xue Yun Soon https://orcid.org/0000-0003-3057-5983

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