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Ultrasound-guided radiofrequency ablation for treatment of Morton's neuroma: initial experience

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AIM: To assess the efficacy and safety of ultrasound-guided radiofrequency ablation (RFA) for treatment of symptomatic Morton's neuroma.

MATERIALS AND METHODS: Patients with symptomatic Morton's neuroma of the foot were referred for treatment with RFA, prior to consideration for surgery. All neuromas were proven by ultrasound imaging and had a trial of conservative management including orthotic support and/or steroid injections. Ultrasound-guided RFA was performed as an outpatient procedure under local anaesthetic. Patients were followed up at 8 weeks and 8 months. Outcomes were assessed with a visual analogue scale (VAS) score, Manchester–Oxford Foot and Ankle Questionnaire, overall patient satisfaction, and complications.

RESULTS: Twenty-two neuromas were treated with RFA under ultrasound guidance. The VAS score at 8 weeks was significantly lower than the VAS score pre-procedure ($p<0.001$, Wilcoxon signed ranks test) and the VAS score at 8 months was significantly lower than the VAS score at 8 weeks ($p=0.008$, Wilcoxon signed ranks test). At 8 months, 89% of treated patients were satisfied with the procedure outcome. No significant adverse effects were recorded.

CONCLUSION: Ultrasound-guided RFA is safe, with excellent initial results in treatment of symptomatic Morton's neuroma. Further studies on long-term outcomes and comparison to other management options will be required to establish its role in management of symptomatic Morton's neuroma.

Introduction

Morton's neuroma is a common cause for central metatarsalgia in patients presenting to a foot and ankle clinic. The condition is 10 times more common in women than men with a mean age at presentation of 50 years.[1] Originally described as swelling of the third interdigital nerve, histologically these represent proliferative fibrosis of perineural tissue. Causes include chronic repetitive trauma, ischaemia, inflammation, and entrapment at the anterior edge of deep transverse metatarsal ligament.[2–4]

Radiofrequency ablation (RFA) is widely used for treatment of solid-organ tumours, cardiac arrhythmias, and

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spinal facet joint pain.[5–7] Nociceptive pain signals are interrupted when a high-frequency current raises the tissue temperature above 70°C, causing electrocoagulation and cell death of a specific volume of biological tissue, depending on size of active needle tip (length and diameter) and duration of heating.[8,9] Previous studies have demonstrated success in the use of RFA, reducing the need for surgery in up to 80% of patients.

The aim of the present study was to assess the efficacy and safety of ultrasound-guided RFA for treatment of symptomatic Morton's neuroma, when conservative measures fail to relieve symptoms. The present study describes the experience of setting up a soft-tissue ablation service in a large teaching hospital.

Materials and methods

Patients with symptomatic Morton's neuroma of the foot were referred for treatment with RFA from the hospital Foot and Ankle Clinic, prior to consideration for surgery. The procedure was approved for clinical practice following a formal Trust Review Board for Novel Therapeutics review, in conjunction with National Institute for Health and Care Excellence (NICE) guidelines on RFA for treatment of Morton's neuroma.[10]

Clinical history included burning pain at the plantar aspect of metatarsal heads or neurological pain in the web space radiating to the toes. Clinical provocation tests were performed by a foot and ankle orthopaedic surgeon. All neuromas were proven by ultrasound imaging by the presence of a well-defined hypoechoic lump in the web space correlating with symptoms on dynamic imaging. All patients had a trial of conservative management, including orthotic support and steroid injections in the past. RFA was offered as a treatment option prior to considering surgical excision, when conservative measures failed.

Written informed consent was obtained from each patient prior to the procedure. Each patient was provided with an information sheet pre-procedure, detailing the currently known efficacy and adverse effects of RFA and NICE guidelines. Written consent for use of anonymised images and treatment outcome data were obtained from all patients. If there was more than one symptomatic neuroma on the same foot, these were treated at two separate appointments.

Ultrasound-guided RFA for Morton's neuroma was performed as an outpatient procedure under local anaesthetic. The presence of a neuroma was reconfirmed by diagnostic ultrasound imaging with a linear 9–12 MHz probe (Siemens IU22) at the symptomatic web space. A grounding pad was firmly applied to the thigh. An intermetatarsal approach through the web space was used to infiltrate 1% lidocaine local anaesthetic, with aseptic precautions. A 22 G, 5 mm length active tip radiofrequency probe, connected to a Neurotherm NT2000iX radiofrequency generator (Abbott Medical UK Ltd), was then introduced in-plane under real-time ultrasound guidance into the neuroma (Fig 1). Under continuous real-time ultrasound imaging, up to ten 1-minute cycles of continuous RF were applied at 80°C with a demonstrable ablation zone, seen as increased echogenicity surrounding the needle tip in the neuroma indicating liquefaction (Figs 2 and 3). This duration of treatment was followed based on previous authors reporting a total of 10 minutes of continuous radiofrequency for Morton's under ultrasound guidance. The neuroma was targeted to ensure a large ablation zone occupying most of the neuroma cross-section at real-time ultrasound imaging, given the nerve itself cannot be distinguished at ultrasound within the neuroma. In smaller neuromas, the treatment was limited to 3–5 cycles if an adequate ablation zone was achieved at real-time ultrasound imaging. When there was a bursa neuroma complex, the radiofrequency needle was positioned in the centre of the hypoechoic lump under ultrasound guidance, avoiding the peripheral fluid components, which could be better identified following injection of local anaesthetic prior to lesioning with continuous radiofrequency.

Patients were followed up prospectively at 8 weeks and 6–8 months post-treatment. Outcomes were assessed with a visual analogue scale (VAS), Manchester–Oxford Foot and Ankle Questionnaire, and overall patient satisfaction with the procedure and its outcome. Telephonic follow-up at 8 months was performed for overall patient satisfaction with the procedure and its outcome. Adverse events, if any, were recorded. The study was approved by the Trust Novel Therapeutics Committee. Written informed consent was obtained from all patients for outcome data and images included in this study.

Results

Twenty-two neuromas in 18 patients (F:M = 14:4) ranging in age between 22–79 years (average 57) were

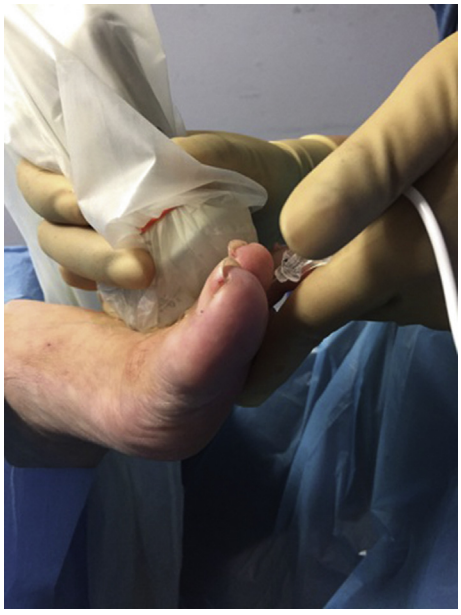

Figure 1 Radiofrequency needle positioned with real-time ultrasound imaging during RFA of Morton's neuroma under ultrasound guidance.

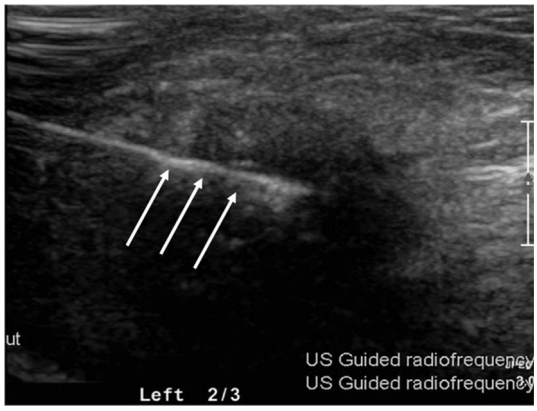

Figure 2 Ultrasound image of a Morton's neuroma with RFA needle within (arrows), introduced in-plane with the ultrasound probe.

treated with RFA under ultrasound guidance. Four neuromas were treated with two RFA treatments; therefore, a total of 26 RFA treatments were performed on 22 neuromas in 18 patients. Thirteen neuromas were treated in the right, nine in the left foot. 11 neuromas were in the second intermetatarsal space and 11 in the third intermetatarsal space. Duration of symptoms pre-procedure ranged from 1–5 years. All patients had conservative treatment with orthotic support and steroid injection in the past. The pre-procedure median VAS score was 8 (7–9 quartile), reduced to 3 (1–4) at 8 weeks, and 1 (0–4) at 6–8 months (Table 1, Fig 4). The VAS score decreased by 5 (3–7) from pre-procedure to 8 weeks, and further by 1 (0–2) from 8 weeks to 8 months. The VAS score at 8 weeks was significantly lower than the pre-procedure VAS score ($p<0.001$, Wilcoxon signed ranks test) and the VAS score at 8 months was significantly lower than the VAS score at 8 weeks ($p=0.008$, Wilcoxon signed ranks test).

RFA of 10 neuromas resulted in near-complete pain relief (>90% reduction in pain scores). RFA of eight neuromas resulted in 30–40% reduction of pain scores, of which two patients are considering a second treatment cycle. Four neuromas were treated with two RFA treatments, of which

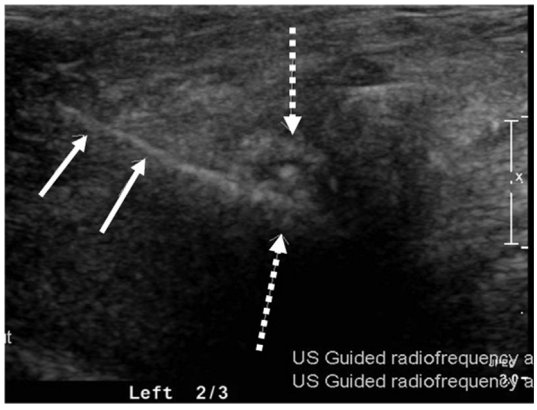

Figure 3 Echogenic ablation zone (dashed arrows) surrounding the radiofrequency cannula (straight arrows) seen following RFA of Morton's neuroma at ultrasound in the same patient.

3 had >75% pain relief. The repeat cycle was offered due to partial treatment response after the first treatment. Eight months follow-up was undertaken in one patient, who is considering a repeat RFA treatment due to incomplete response. Medium-term outcomes are therefore available for 21 neuromas treated with RFA, 15 of these (71.4%) resulted in 50% or greater improvement in VAS pain scores at 8 months review. On telephone follow-up, 10 patients rated the procedure and its outcome as excellent, five said it was good and one said it was satisfactory. One patient was lost to follow-up. Another patient was followed up at 6 months, but was not contactable over the phone at 8 months; this patient had 100% pain relief at 6 months. Overall 89% treated patients had either satisfactory, good, or excellent patient reported outcome. Speedy recovery, lack of need for post-procedure rehabilitation and taking time off work, were considered as significant advantages favouring RFA by all patients. No significant adverse effects were recorded following RFA. One patient had minor bleeding during the procedure, which was controlled with local pressure. There was no delayed bruising or adverse effect on follow-up. Another patient, who had excellent treatment response, experienced new intermittent painless twitching of the second toe, which was self-limiting. This has not been previously described, and the aetiology of this remains uncertain.

Discussion

Morton's neuralgia is a common cause for foot pain in patients presenting at a foot and ankle clinic. This condition was first described by Civinni in 1835 as a swelling of the common digital nerve at the third intermetatarsal space.[11] In 1876 Thomas Morton published a case series of 15 patients with neuralgia attributed to an injury to the fourth metatarsophalangeal joint.[12] Despite its large prevalence, the aetiopathogenesis and management options for Morton's neuralgia are subject to debate, largely due to limited high-quality evidence on various treatment options. Conservative management options aim to reduce pressure and inflammation of the common digital nerve to reduce pain. Modifications of foot wear can improve symptoms in up to 41% patients in some reported cohorts.[13] In contrast, pronation and supination orthoses have not shown significant therapeutic benefit.[14]

RFA was first described by Finney *et al.* for treatment of Morton's neuroma in 1989.[15] Radiofrequency produces electrocoagulation of tissues due to heating, in an oval shape surrounding the active tip of the radiofrequency probe. Radiofrequency energy has been used for percutaneous treatment of tumours and in cardiac ablation. Gennon *et al.* reported complete symptom relief of 18.4% in a cohort of 37 patients treated with RFA for Morton's neuroma.[16] Fifty-five percent of patients reported a partial response and 26% had no benefit. The procedure was performed without imaging guidance in this cohort. Moore *et al.* reported excellent response to RFA performed under fluoroscopic guidance.[17] This study evaluated outcomes in

Table 1
Treatment outcomes of radiofrequency ablation for Morton's neuroma.

No.	Site	Cross-section diameters (mm)	Cross-section area (square cm)	No. of treatments	Pre procedure VAS (on 10)	VAS 8 weeks (on 10)	VAS 8 months (on 10)
1	Lt 3/4	12×10	1.2	1	6	3	Lost to follow-up
2	Lt 2/3	15×10	1.5	1	6	1	0
3	Rt 2/3	16×13	1.9	1	7	4	4
4	Rt 3/4	14×14	2.1	1	7	4	4
5	Rt 3/4	18×17	2.7	2	10	0	0
6	Rt 2/3	12×9	1.7	2	10	0	0
7	Rt 2/3	18×14	1.3	1	9	1	1
8	Lt 3/4	14×13	1.2	1	5	2	2
9	Rt 3/4	13×13	1.1	1	8	0	0
10	Lt 3/4	19×12	1.9	1	9	4	0
11	Rt 2/3	18×13	1.75	2	8	4	2
12	Lt 2/3	17×14	1.4	1	7	2	0
13	Rt 3/4	10×7	1.1	2	8	8	7
14	Rt 3/4	13×12	1.3	1	8	7	7
15	Lt 2/3	10×13	1	1	8	4	2
16	Rt 2/3	13×8	1.2	1	8	2	0
17	Rt 2/3	18×9	1.3	1	8	8	5
18	Rt 2/3	13×7	0.9	1	8	1	0–1
19	Rt 2/3	13×9	1.3	1	8	2	2
20	Lt 3/4	12×9	1.3	1	9	5	5
21	Lt 3/4	9×6	0.9	1	10	2	1
22	Lt 3/4	12×9	1	1	9	6	-

32 feet followed up to 6 months post-treatment. Steroid injection post-RFA was performed in all patients in this study group, 83% patients reported significant pain relief. One case of cellulitis requiring oral antibiotics was a reported adverse event.

Chuter *et al.* published results of RFA (10 minutes continuous RF) for treatment of Morton's neuroma performed under ultrasound guidance.[18] The authors also administered steroid at the time of RFA in all patients, which could be a confounding factor when assessing outcome. Masala *et al.* have recently published a series of patients treated with a single cycle of RFA for 90 seconds administered in the centre of the neuroma under ultrasound guidance.[19] They reported improved pre-treatment mean VAS pain score of 9.0 to 3.7 at 1 week post-RFA, reducing to 2 at 12 months. At 6 months follow-up, there was symptom improvement in 85% of cases reported by Chuter *et al.* The results of the present study show a comparable high response to a single treatment with ultrasound-guided RFA, 89% patients reported symptom relief at 8 months follow-up, with statistically significant reduction in pain scores at 8 weeks and 8 months.

In the present study, 3–10 minute continuous radiofrequency cycles were applied to the neuroma, until an ablation zone involving most of the neuroma could be seen at real-time imaging. Increased echogenicity, liquefaction, and bubbling surrounding the needle tip within the neuroma, at real-time ultrasound during RFA were

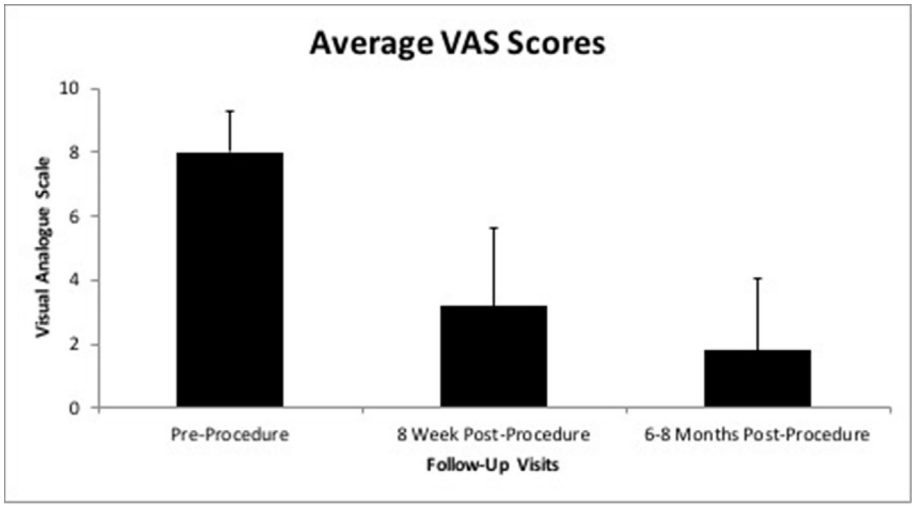

Figure 4 Treatment outcomes of ultrasound-guided RFA of Morton's neuroma.

demonstrable as an "ablation zone"; this has not been described previously. Corticosteroid was not injected during RFA in the present cohort. Future randomised studies will be needed to prospectively compare the reported variation of duration of continuous radiofrequency for Morton's neuroma ablation (10 minutes, 90 seconds, 3–10 minutes demonstrating adequate ablation zone), to identify the optimal treatment parameters for optimising outcomes. Unlike alcohol ablation, which typically can require four visits for injections, a single treatment consisting of up to 10 minutes of continuous RF at 80°C sufficed in most patients.

The response rates for ultrasound-guided RFA are greater than for other non-operative interventions for Morton's neuroma treatment, and compare favourably to that of surgery, without the need for rehabilitation. A small sample size and follow-up of 8 months post-procedure are limitations of the present study. The treated group was not compared with other conservative and operative treatment methods, as this is an initial pilot study. No significant complications were noted.

Steroid injections are widely used as an initial management option for treatment of Morton's neuroma. Two level 1 randomised control trials with a 6 month and 1 year follow-up, indicated the results of steroid injection were not superior to the control group.[20,21] The injections in these studies were performed without ultrasound guidance. Makki *et al.* found that the relief of symptoms following steroid injection was short term.[22] There have been reports of alcohol and phenol injections, with improvement noted with alcohol ablation.[23] The regime consisted of four injections, 2 weeks apart. Espinosa *et al.* reported a lower response to alcohol injection (20% improved).[24]

In conclusion, ultrasound-guided RFA is safe, with excellent results in the treatment of symptomatic Morton's neuroma of the foot. Further studies on optimal ultrasound-guided RFA technique, long-term outcomes, and comparison to other management options will be required to establish its role in the management of symptomatic Morton's neuroma.

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References

1. Thomson CE, Gibson JN, Martin D. Interventions for the treatment of Morton's neuroma. *Cochrane Database Syst Rev* 2004;(3). CD003118.
2. Nissen KI. Plantar digital neuritis (Morton's metatarsalgia). *J Bone Joint Surg Br* 1948;**30-B**:84.
3. Bossley CJ, Cairney PC. The intermetatarsophalangeal bursa: its significance in Morton's metatarsalgia. *J Bone Joint Surg Br* 1980;**62-B**:184–7.
4. Gauthier G. Thomas Morton's disease: a nerve entrapment syndrome. A new surgical technique. *Clin Orthop* 1979;**142**:90–2.
5. Boswell MV, Colson JD, Sehgal N, *et al.* A systematic review of therapeutic facet joint interventions in chronic spinal pain. *Pain Physician* 2007;**10**:229–53.
6. Goel RK, Kaouk JH. Probe ablative treatment for small renal masses: cryoablation vs. radio frequency ablation. *Curr Opin Urol* 2008;**18**:467–73.
7. Lubitz SA, Fischer A, Fuster V. Catheter ablation for atrial fibrillation. *BMJ* 2008;**336**:819–26.
8. Ni Y, Mulier S, Miao Y, *et al.* A review of the general aspects of radiofrequency ablation. *Abdom Imaging* 2005;**30**:381–400.
9. Organ LW. Electrophysiologic principles of radiofrequency lesion making. *Appl Neurophysiol* 1976–1977;**39**:69–76.
10. NICE. Radiofrequency ablation for symptomatic interdigital (Morton's) neuroma. *Interv Proced Guidance [IPG539]* December 2015. Available at: www.nice.org.uk.
11. Civinni F. Su di un gangliare rigonfiamento Della piñata Del piede. *Mem Chir Arcispedale di Pistoia* 1835.
12. Morton TG. A peculiar and painful affection of the fourth metatarsophalangeal articulation. *Am J Med Sci* 1876;**71**:37–9.
13. Bennett GL, Graham CE, Mauldin DM. Morton's interdigital neuroma: a comprehensive treatment protocol. *Foot Ankle Int* 1995;**16**:760–3.
14. Kilmartin TE, Wallace WA. Effect of pronation and supination orthosis on Morton's neuroma and lower extremity function. *Foot Ankle Int* 1994;**15**:256–62.
15. Finney W, Wiener SN, Catanzariti F. Treatment of Morton's neuroma using percutaneous electrocoagulation. *J Am Podiatry Med Assoc* 1989;**79**:615–8.
16. Genon MP, Chin TY, Bedi HS, *et al.* Radio-frequency ablation for the treatment of Morton's neuroma. *ANZ J Surg* 2010;**80**:583–5.
17. Moore JL, Rosen R, Cohen J, *et al.* Radiofrequency thermoneurolysis for the treatment of Morton's neuroma. *J Foot Ankle Surg* 2012;**51**:20–2.
18. Chuter GSJ, Chua YP, Connell DA, *et al.* Ultrasound-guided radiofrequency ablation in the management of interdigital (Morton's) neuroma. *Skeletal Radiol* 2013;**42**:107–11.
19. Masala S, Cuzzolino A, Morini M, *et al.* Ultrasound-guided percutaneous radiofrequency for the treatment of Morton's neuroma. *Cardiovasc Intervent Radiol* 2018;**41**:137–44.
20. Thomson CE, Beggs I, Martin DJ, *et al.* Methylprednisolone injections for the treatment of Morton neuroma: a patient-blinded randomized trial. *J Bone Joint Surg Am.* 2013;**95**(9):790–8. S791.
21. Lizano-Diez X, Gines-Cespedosa A, Alentorn-Geli E, *et al.* Corticosteroid injection for the treatment of Morton's neuroma:a prospective, double-blinded, randomized, placebo-controlled trial. *Foot Ankle Int* 2017;**38**(9):944–51.
22. Makki D, Haddad BZ, Mahmood Z, *et al.* Efficacy of corticosteroid injection versus size of plantar interdigital neuroma. *Foot Ankle Int* 2012;**33**(9):722–6.
23. Musson RE, Sawhney JS, Lamb L, *et al.* Ultrasound guided alcohol ablation of Morton's Neuroma. *Foot Ankle Int* 2012;**33**(3):196–201.
24. Espinosa N, Seybold JD, Jankauskas L, *et al.* Alcohol sclerosing therapy is not effective treatment for interdigital neuroma. *Foot Ankle Int* 2011;**32**:576–80.