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Review Article

Understanding submucosal electrosurgery for the treatment of nasal turbinate enlargement

S E J Farmer, R Eccles

Abstract
The surgical management of inferior turbinate enlargement is controversial. Submucosal electrosurgical techniques for turbinate reduction include conventional diathermy, radiofrequency tissue reduction and coblation. All electrosurgical techniques use radiofrequency electricity to damage turbinate tissue but differ in the control and delivery of energy. This review will examine the history of submucosal electrosurgery and clarify the various techniques. This review will also examine the evidence for the efficacy and safety of electrosurgery for the treatment of nasal turbinate enlargement, and will make a case that no progress will be made in clinical trials on the safety and efficacy unless there is standardisation of equipment and techniques in nasal electrosurgery.

Key words: Turbinates; Electrosurgery; Diathermy

Introduction

Considerable controversy exists regarding the management of inferior turbinate enlargement. Treatment should aim to increase nasal airflow and improve symptoms for as long as possible, whilst preserving normal nasal function and minimising side effects. It is generally agreed that surgery should be reserved for those patients who fail to respond to more conservative measures.[1]

The surgical approach to treating turbinate enlargement essentially involves two main methods; electrosurgery to reduce the size of the turbinate or removal of all or part of the turbinate. However, there is no real consensus of opinion on which form of surgery is the most appropriate. Williams[2] argues that confusion in the literature has confounded the issue and has led many surgeons to use submucosal diathermy as the treatment of choice for turbinate enlargement simply because of its relative lack of complications. This review will examine the use of submucosal electrosurgery for the treatment of turbinate enlargement.

The history of submucosal electrosurgery

The first surgical procedure for the treatment of enlarged inferior turbinates was reported by Heider and Crusel in 1845 when they described surface electrocautery using a galvanic current.[1] The standard technique consisted of coagulating two parallel furrows along the surface of the turbinate. Heat was transferred from the instrument by conduction. Subsequently other types of galvanocaustic instrument were developed and later high frequency surface diathermy or electrosurgery was introduced by Bourgeois and Poyet.[1] In electrosurgery energy is transferred by means of high-frequency electromagnetic radiation and heat is generated within the tissue without the instrument becoming hot.[3]

In 1907 Neres introduced the concept of submucosal surgery for the treatment of turbinate enlargement.[4] Submucosal techniques involve passing the electrode(s) into the turbinate tissue with the intention of avoiding damage to the surface mucosa. Submucosal techniques were developed in response to concerns about the destructive nature of surface electrocautery and recognition of the importance of mucosal conservation for the maintenance of normal nasal function. Neres[4] used a galvanic current and a polished gold needle to pierce the anterior tip of the inferior turbinate. Horn[5] described a technique using a hot wire, and later high frequency submucosal monopolar[6] and bipolar diathermy[7] were used. Submucosal diathermy was popularised by Simpson and Groves in 1958.[8] However, despite its continued widespread use there is very little reported in the literature about submucosal diathermy.

In the last decade several new submucosal techniques have emerged. This has largely been driven by the development of new technology and advances in electronics[9] and has resulted in the introduction of more sophisticated electrosurgical units. However, new techniques have also evolved in an attempt to

From the Common Cold Centre, Cardiff School of Biosciences, Cardiff University, UK.
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address the problems associated with high temperatures and the resulting damage caused to surrounding tissues. These techniques have been termed radiofrequency tissue reduction and coblation.

The term diathermy was first used in 1909 by Nagelschmidt when he discovered that the heating effect of a high frequency current could be used for therapeutic purposes.[10] Although the term is still used today, 'electrosurgery' has a more accurate meaning. The terminology in common use is not standardised and this causes confusion. Conventional submucosal diathermy, radiofrequency tissue reduction and coblation all use high frequency electromagnetic radiation to damage target tissue, and therefore they could all be termed diathermy techniques, or electrosurgical procedures. The term 'radiofrequency surgery' is often incorrectly used to describe radiofrequency tissue reduction, when all of the electrosurgical techniques use electricity within the radio wave spectrum. Radiofrequency tissue reduction has also been termed radiofrequency tissue ablation,[11,12] temperature-controlled radiofrequency ablation,[13] bipolar radiofrequency-induced thermotherapy[14] and radiofrequency volumetric tissue reduction.[15] Coblation is also known as bipolar radiofrequency volumetric tissue reduction,[16] bipolar radiofrequency thermal ablation,[17] subtotal ionised ablation[18] and bipolar radiofrequency plasma-mediated ablation.[19] The key difference between all these three techniques is in the control and delivery of the radiofrequency electricity and the boundaries are artificial.

The effects of submucosal electrosurgery on turbinate tissue

Conventional diathermy produces very high local temperatures due to ohmic heating, resulting in tissue destruction by boiling and coagulation.[20] In turbinate tissue this causes obliteration of the venous sinusoids leading to submucosal fibrosis and scarring[21] which is thought to anchor the mucosa to the periosteum. The heat may also damage terminal cholinergic nerve fibres resulting in reduced glandular activity.[22] Talaat *et al.*[22] reported epithelial, vascular and glandular changes after submucosal diathermy and showed marked diminution of stromal oedema and increased fibrosis one month after surgery.

There is some concern that spread of diathermy currents beyond the therapeutic area causes unnecessary tissue damage.[23] Although it was originally postulated that submucosal treatment would cause little surface damage to the turbinate this has been disputed.[24,25] Woodhead *et al.*[1,25] examined turbinate tissue following submucosal diathermy at a range of settings and showed a lack of histological change at low settings but damage to epithelium at high settings. Scanning electron microscopy studies of the nasal mucosa six weeks after submucosal diathermy have shown a reduction in the density of epithelial ciliated cells.[24]

Radiofrequency tissue reduction works in the same way as submucosal diathermy to cause submucosal fibrosis and scarring. Elwany *et al.*[26] reported intense fibrosis in the stroma of turbinate tissue one year after radiofrequency tissue reduction treatment. Elwany *et al.*[26] also showed intact ciliated epithelium in turbinate tissue one year after radiofrequency tissue reduction suggesting minimal chronic collateral heat damage.

No histological studies examining the effect of coblation on turbinate tissue are reported. Chao *et al.*[19] recognised that coblation effect was dependent on contact time and showed that porcine septal cartilage could be effectively reduced using coblation without causing significant carbonisation or char at 27 combinations of generator setting, probe force and translational velocity.

Chinpairoj *et al.*[27] made equivalent incisions into rat tongue with conventional monopolar diathermy and coblation and showed almost undetectable levels of char following coblation. Coblation resulted in significantly smaller widths of epithelial destruction and areas of collagen denaturation than diathermy.[27] Examination of wound healing showed complete re-epithelialisation of the entire specimen seven days following coblation and 14 days following diathermy.[27] At day seven the mean area of inflammation and granulation tissue was significantly smaller with coblation than with diathermy.[27]

Conventional submucosal diathermy

Equipment and procedure

Conventional submucosal diathermy uses a high frequency (0.25 to 3 MHz) electrical current made to pass through the body between two electrodes. Although power delivery can be set on the electrosurgical unit, the diathermy effect also depends upon the magnitude of the current, the type of current, the impedance of the tissue, electrode factors (such as size and manipulation) and the duration and rate of exposure. Williams *et al.*[2] suggest that accurate calculation of the current applied to the tissues by submucosal diathermy is impossible due to the unpredictable variables involved. Shahinian[28] recognised the need for calibration many years ago in experiments on raw beef. He assessed optimal current density and duration of application by judging maximal coagulation in the absence of charring.

Bipolar submucosal diathermy involves the use of twin electrodes, with current passed between them, and has the advantage of greater precision and predictability of effect. It is also inherently safer as the patient does not form part of the electrical circuit and it uses a lower power output.[29] Shahinian[28] reported that his bipolar technique using a modified double-needle instrument has the advantage of obtaining a 'ribbon-like reaction. . .between the two needles and parallel to the mucosal surface and turbinate bone, with minimum possibility of damage to either'. Typically a monopolar technique is now practised for submucosal diathermy, and this has been documented previously[30] and is illustrated in Figure 1. Simpson and Groves[8] argue that although monopolar diathermy only produces a line

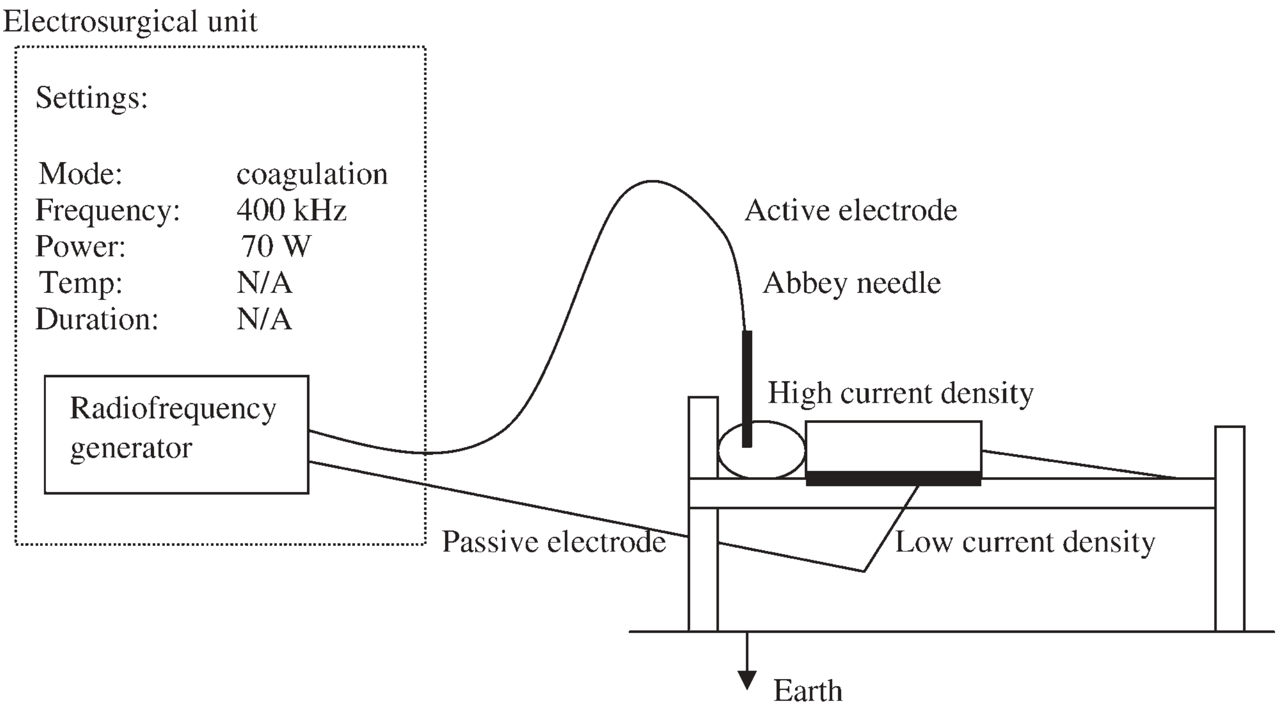

FIG. 1

Set-up for monopolar submucosal diathermy according Jones *et al.*[30]

or cylinder of coagulation, several runs can be made and a single needle is easier to control and position.

Efficacy and safety

It is difficult to assess the literature with regards to the safety and efficacy of submucosal diathermy, as there are very few studies with useful outcome measures. The studies often involve small numbers of patients, lack randomised controls and report only short-term follow up. Furthermore, the absence of a standardised technique for performing submucosal procedures makes it difficult to assess and compare the evidence. Woodhead *et al.*[25] argue that many trials of submucosal diathermy fail to report the method by which the operation was performed. Some authors state that submucosal diathermy was performed 'in a standard way'.[31] However, Table I illustrates that there is no standard method for performing submucosal diathermy.

Guidelines exist for the use of electrical energy for defibrillation[32] and for endometrial radiofrequency ablation,[33] and this review proposes that similar standard algorithms should be devised for the use of radiofrequency energy in turbinate surgery.

Early reviews on submucosal diathermy claimed 'relief from nasal obstruction in practically every case' with only a few patients requiring repeated treatment.[6] Shahinian[28] reported on the outcome of 412 patients treated with submucosal diathermy who had relief for between two and 10 years. Impaired nasal breathing was most consistently responsive to treatment but the subjective annoyance of excess nasal secretions was frequently reduced in varying degrees, and headaches, sneezing and pruritus were sometimes ameliorated.[28] Subsequent studies report that subjective improvements in nasal airflow occur in between 76 per cent and 95 per cent of patients, one to three months after surgery.[22,30,35,37] However, Cook *et al.*[38] argue that there is no significant change in subjective nasal airflow after submucosal diathermy and suggest that the subjective sensation of airflow six weeks post-operatively is actually worse. It would appear that the subjective sensation of nasal obstruction does worsen in the immediate post-operative period for between one and 10 days.[8,22,28] Simpson and Groves[8] suggest that turbinate shrinkage begins three to five days after submucosal diathermy and continues for between three and four weeks. Several studies have examined the long-term outcome of submucosal diathermy. Cook *et al.*[38] suggested that there was no significant improvement in the subjective sensation of nasal airflow one year after submucosal diathermy, despite showing significant improvements in patients treated with laser reduction. Fradis *et al.*[37] found that 95 per cent of patients questioned one year after submucosal diathermy reported to be either symptom free or have better nasal breathing. The study with the longest follow-up period reports that a significant number of patients (39 per cent) have improved nasal symptoms 15 months after submucosal diathermy.[31]

The success of submucosal diathermy almost inevitably depends upon patient selection for surgery. Thus the reported requirements for further surgery after submucosal diathermy vary widely from 1.5 per cent[28] to 22 per cent.[37] Patient satisfaction following submucosal diathermy has been reported to be 70 per cent.[35] Submucosal diathermy has been shown to

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TABLE I

REPORTING OF THE SUBMUCOSAL DIATHERMY METHOD IN THE LITERATURE

Author, year	Electro-surgical unit	Type	Mode	Electrode	Setting description	Technique description
Jones, 1989[30]	not stated	not stated	coagulation	Abbey needle	70 W, 400 kHz	5 secs, up to 3 passes
Quine, 1999[34]	not stated	not stated	not stated	not stated	70 W	not stated
Jones, 1987[31]	not stated	not stated	not stated	not stated	not stated	not stated
Woodhead, 1989[25]	not stated	not stated	not stated	Abbey needle	not stated	10 secs
Fradis, 2000[35]	not stated	not stated	not stated	not stated	not stated	10 secs, 2 passes
Wengraf, 1986[24]	not stated	not stated	not stated	not stated	not stated	3 secs, 3 passes
Simpson, 1958[8]	not stated	monopolar	coagulation	Matburn electrode	0.4–0.5 amps, 100 Kc./sec.	10–20 secs, several passes
Talaat, 1987[22]	not stated	not stated	not stated	not stated	not stated	not stated
McCombe, 1992[23]	not stated	not stated	not stated	not stated	not stated	not stated
Cook, 1993[36]	not stated	not stated	not stated	not stated	not stated	not stated
Jones, 1985[21]	not stated	not stated	not stated	not stated	not stated	not stated
Beck, 1930[6]	not stated	monopolar	not stated	based on Hagedorn needle	not stated	up to 4 passes

have a less predictable effect on the subjective assessment of other nasal symptoms. McCombe *et al.*[23] reported that there was no significant effect on rhinorrhoea and sneezing. Although other studies report improvements in nasal discharge, hyposmia, sneezing and headache after submucosal diathermy.[8,22,35]

The few studies that examine objective measures of nasal obstruction use a variety of techniques, including anterior and posterior rhinomanometry, the Gertner-Podoshin plate and peak nasal inspiratory airflow. Jones and Lancer[31] were one of the first investigators to show an objective improvement in nasal airway resistance after submucosal diathermy. Quine *et al.*[34] used standardised posterior rhinomanometry to measure nasal airflow in 27 patients and showed that 89 per cent had an improved nasal airflow post-operatively. Fradis *et al.*[35,37] have shown significant improvements in nasal breathing using the Gertner-Podoshin plate. Studies using peak nasal inspiratory airflow have consistently failed to show a significant improvement in nasal obstruction after submucosal diathermy.[23,38] The few studies that have examined the long-term outcome of submucosal diathermy objectively present conflicting information. Fradis *et al.*[37] reported that 89.3 per cent of patients had good nasal breathing one year after submucosal diathermy. However, Jones and Lancer[31] failed to show a significant difference in mean nasal airway resistance when comparing pre-operative measurements with repeated measurements 15 months after surgery.

Submucosal diathermy is typically reported to be easy to perform with few complications compared with alternative techniques.[1] The most common complications reported are haemorrhage, crusting and infection.[22,28,35] Severe bleeding after submucosal diathermy is rare.[35,39] Nasal crusting has been reported to occur in up to 6 per cent of patients[35] and may rarely occur in association with avascular necrosis of the turbinate bone.[2] Infection has been reported to occur in up to 4 per cent of patients after submucosal diathermy[35] and is almost invariably treated conservatively.[28] The formation of adhesions between the diathermy entry site and the septum[22] and occulomotor nerve palsy[40] have also been reported after submucosal diathermy.

Radiofrequency tissue reduction

Equipment and procedure

Radiofrequency tissue reduction is a bipolar single needle technique that uses very high frequency radio waves to achieve rapid and selective tissue heating. There is no standard terminology to define radiofrequency tissue reduction. The National Institute for Clinical Excellence refer to radiofrequency tissue reduction as 'an out-patient procedure in which a submucosal scar is created by the use of a needle electrode inserted into soft tissue'.[41] Typically radiofrequency tissue reduction uses an electrosurgical unit which allows the surgeon to set parameters other than power delivery and current type, such as maximal temperature and duration. In the literature, various models of the Somnus Medical Technology instrument (Sunnyvale, CA USA) are most frequently described.

The Somnus Medical Technology instrument can be set to specify the maximum temperature of the surrounding tissue, the energy or time required for the procedure, and the maximum power to be applied at any time,[43] as illustrated in Figure 2. An automated algorithm modulates power delivery while maintaining automated settings. Thermocouples within the electrode can also provide the surgeon with real-time information regarding energy delivery, temperature, impedance and time.[11] Cavaliere *et al.*[44] report a target tissue temperature of less than 90°C and a low power level with radiofrequency tissue reduction. Radiofrequency tissue reduction may be more precise than submucosal diathermy because it allows more accurate control over energy delivery so that it can be optimised to give a predicable result. However, different electrosurgical units appear to permit varying levels of control over different parameters

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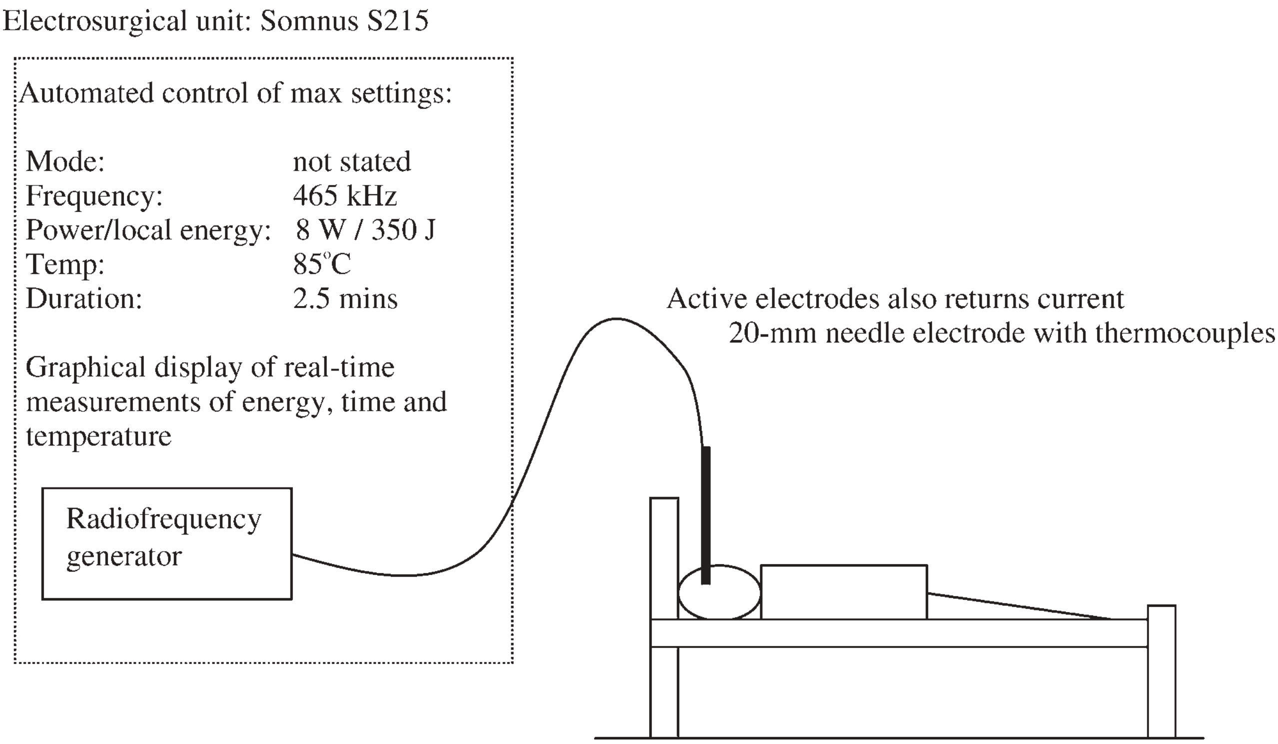

FIG. 2
Set-up for radiofrequency tissue reduction according to Coste *et al.*[42]

and it is unclear how basic units differ from standard bipolar diathermy, other than that a single needle or probe is used.

Efficacy and safety

The same lack of standardisation exists with radiofrequency tissue reduction as with conventional submucosal diathermy, although the equipment allows for easier reporting. There is a lack of standardisation regarding the energy level, temperature, number of passes and duration of application.

There are many studies that report subjective improvement in nasal obstruction after radiofrequency volumetric turbinate reduction.[12–15,42,44–50] Li *et al.*[46] found that 95 per cent of patients reported improvement in nasal breathing eight weeks after radiofrequency turbinate surgery. Subjective improvements in nasal obstruction have been found to persist for two years after radiofrequency tissue reduction.[49]

There is conflicting evidence regarding the objective changes in nasal obstruction after radiofrequency tissue reduction. Fischer *et al.*[15] measured nasal airflow using anterior rhinomanometry and found no significant increase following radiofrequency tissue reduction. They also used acoustic rhinometry and showed a 68.2 per cent increase in the average cross-sectional area of both sides of the nasal cavity after surgery.[15] Other studies have used anterior rhinomanometry and reported significant improvements in total nasal airway resistance[12,13,50] and nasal airflow.[14,44] Seeger *et al.*[14] reviewed patients 20 months after radiofrequency tissue reduction and showed a 30 per cent increase in mean nasal airflow. In 1689 patients, Barbieri *et al.*[50] reported that radiofrequency tissue reduction caused a significant reduction in mean total airway resistance one month and 12 months after surgery. There was no change in mucociliary transport time after radiofrequency tissue reduction.[50] Repeat surgery was necessary in 5 per cent of patients at 12 month follow-up.[50]

Although minor bleeding at the site of needle insertion may be reported in up to 50 per cent of cases,[13] the incidence of significant post-operative epistaxis after radiofrequency tissue reduction is reported to be approximately 5 per cent.[50] One of the most common complaints is of discomfort/numbness during the procedure, which is reported in 19–37.5 per cent of patients.[13,42,46–48] Up to 80 per cent of patients may experience short-lived crusting in the immediate post-operative period[44] and 37 per cent of patients in one study[14] reported blood-stained nasal discharge for an average of four days after surgery. Synechias are observed in 5 per cent of patients one year after radiofrequency tissue reduction.[50]

Coblation

Equipment and procedures

Coblation technology was developed by ArthroCare Corporation and patented in 1997. Originally developed for cartilage ablation in arthroscopic knee surgery,[51] it now has many applications and in the last four years coblation has also been used to treat turbinate enlargement.[17,52] Coblation uses a bipolar

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probe and an electrically conductive fluid in the gap between the electrode and the tissue, as illustrated in Figure 3. When radiofrequency current is applied to this field, ArthroCare claim that a precisely focused plasma is created.[53] 'The plasma's particles have sufficient energy to break molecular bonds within tissue, causing tissue to dissolve at relatively low temperatures (typically 40°C to 70°C).'[53] However, industrial experiments suggest that plasma is unlikely to be generated outside of a vacuum.[20] Zinder[20] suggests that coblation works by controlled application of radiofrequency electricity through fluid, and that a vapour layer acts to restrict current density with the fluid having a cooling effect that minimises collateral tissue damage.

Efficacy and safety

To date there have only been three published articles reporting the use of coblation surgery for the treatment of turbinate enlargement.[16,17,52] Back *et al.*[17] treated 20 patients using a standard technique at a coblation setting of level four with three passes of 15 seconds duration. Two patients were not satisfied with the result at six months and went on to have turbinoplasty surgery, the remainder were followed up for 12 months post-operatively. Eighty-nine per cent of patients stated that they would be prepared to have the procedure performed again. The most common complaints were pain and nasal discharge immediately after treatment. Visual analogue scores (VAS) for nasal obstruction and patient satisfaction showed statistically significant changes without relapse for up to 12 months after surgery.[17] VAS for other nasal complaints, such as nasal discharge, crusting, sneezing and itching, also decreased significantly in the 12 month follow-up period.[17] However, anterior rhinomanometry showed no significant changes in total inspiratory resistance after coblation.[17] Acoustic rhinometry showed that the nasal cavity volumes from the nostril to 5 cm were significantly larger six and 12 months after treatment.[17] There were no adverse effects on nasal epithelial function or olfactory function.[17]

Bhattacharyya *et al.*[52] assessed the outcome of coblation using the Rhinosinusitis Symptom Inventory and a nasal symptom questionnaire. Six months after treatment a statistically significant reductions in all Rhinosinusitis Symptom Inventory domains was found. Significant improvements in the severity and frequency of nasal obstruction were also demonstrated up to six months after surgery. Furthermore, patients tolerated the procedure well and the majority did not require post-operative analgesia. Epistaxis was reported by 8.3 per cent of patients in the post-operative period, although only one patient required admission for anterior nasal packing. Crusting was noted in 16.7 per cent of patients, but was confined only to the two week clinic visit.

Atef *et al.*[16] used subjective and objective measures of nasal obstruction to determine the number of coblation treatments patients received. They found that 88.3 per cent of patients had complete relief of nasal obstruction, but the majority of patients required two or three treatments to achieve this. However, at one year follow up patients who had received only one or two sessions showed significantly worse VAS, nasal fossa volumes and turbinate volumes than those who had received more treatments.

Although there is insufficient evidence to support the use of coblation for treating nasal turbinate enlargement, there is evidence to support the use of

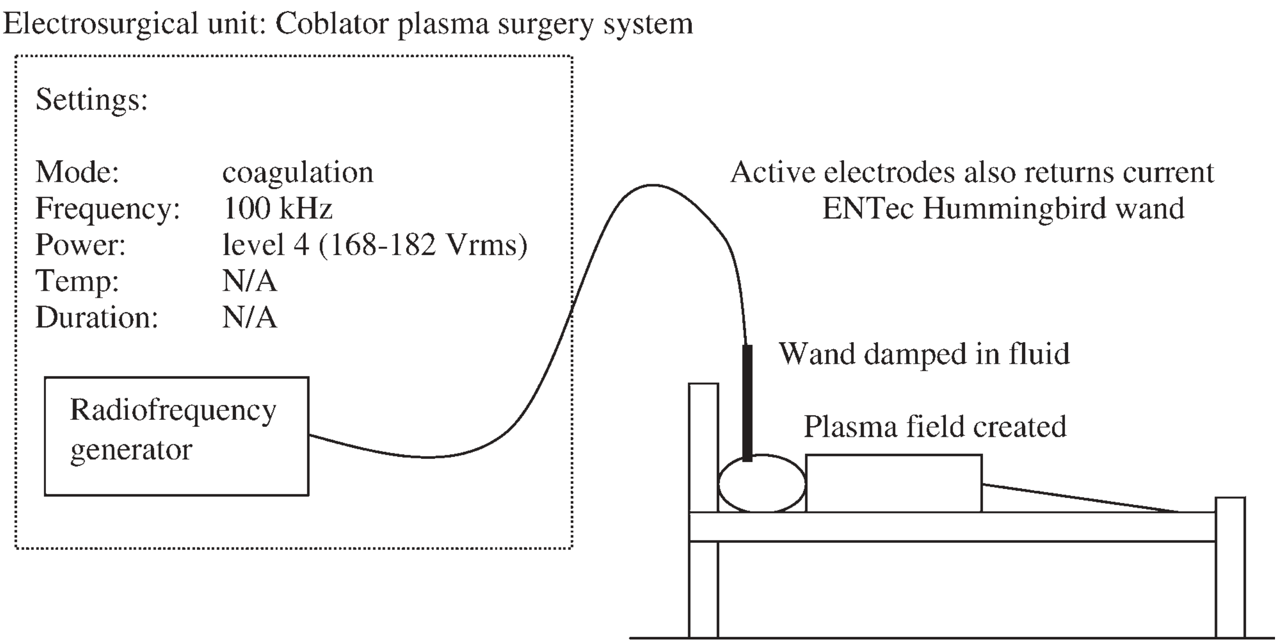

FIG. 3
Set-up for coblation according to Back *et al.*[17] Vrms = voltage root-mean-squared

coblation for tonsillectomy. The National Institute for Clinical Excellence has concluded that coblation probably reduces post-operative pain and speeds functional recovery, compared with standard bipolar diathermy.[54] Coblation tonsillectomy appears to offers no additional adverse effects, but might increase operation time[54] and can result in higher rates of haemorrhage than other techniques.[55]

Conclusions

Electrosurgery describes a group of surgical procedures that use high frequency electromagnetic radiation to damage target tissue. The differences between techniques are not always clear but usually involve the control and delivery of radiofrequency energy. Review of the evidence for the efficacy and safety of submucosal electrosurgery is difficult because there is no standard terminology or standard methods described in the literature. Traditional submucosal diathermy probably results in both subjective and objective improvements in nasal airflow, although these may be short-lived. There appear to be few serious side effects.

Radiofrequency tissue reduction and coblation appear to offer the advantage of permitting more precise delivery of energy with potentially less collateral tissue damage whilst still producing fibrosis and shrinkage of the turbinate tissue. It seems likely that patients will also benefit objectively from these techniques, although there is little evidence to support this at present. There is a great need to standardise electrosurgical techniques to permit valid comparisons of safety and efficacy and this will only be achieved through properly documented clinical trials. Standardisation is also important to guide further patient management and enable appropriate audit. General guidelines need to be issued which take into account the variables involved in energy delivery during electrosurgery.

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Address for correspondence:
Professor R Eccles,
Common Cold Centre,
Cardiff School of Biosciences,
Cardiff University,
Museum Avenue,
Cardiff CF10 3US, UK.

Fax: 029 20 874093
E-mail: eccles@cardiff.ac.uk

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