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thesis

THE USE OF RADIOFREQUENCY THERMAL ABLATION FOR THE TREATMENT OF UPPER AIRWAY DISORDERS

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Academic dissertation

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1. ABSTRACT

Soft palate, tonsillar and inferior turbinate interventions are among the most common surgical procedures in medicine, practised mainly by Ear Nose and Throat specialists. This, in spite of the fact that the basic pathophysiological mechanisms causing the disorders to be treated still remain unclear. In addition, the beneficial effects of these upper respiratory tract procedures to the patient have not been documented according to evidence-based rules. Thus, it is clear that when the procedure includes a removal of normal tissue, there should be enough evidence according to good clinical practise guidelines that the procedure is beneficial for the patient, or at least not harmful. Given this background, there is every justification to seek intervention modalities of upper respiratory tract disorders, which are as minimally invasive as possible.

Radiofrequency thermal ablation is a well-known treatment modality, which is characterised by a precise controllable lesion and has demonstrated, in other areas of medicine, acceptable efficacy, safety and reproducibility of treatment results. The purpose of the present study was to evaluate the feasibility of radiofrequency thermal ablation as treatment of pathological conditions of upper airway tissues.

In four prospective non-randomised series with a follow-up period varying from 3 to 12 months the morbidity and efficacy of radiofrequency thermal ablation of the soft palate in habitual snorers, of the inferior turbinates in turbinate hypertrophy and of tonsillar tissue in tonsillar hypertrophy were evaluated. Additionally, in a randomised single-blinded setting, tonsillectomy using radiofrequency scalpels were compared with traditional tonsillectomy.

As soft palate, inferior turbinate and tonsillar hypertrophy procedures the radiofrequency thermal ablation procedure was well tolerated as outpatient procedures. There was a significant improvement of snoring and daytime sleepiness in the treatment of the soft palate in habitual snorers, accompanied by objective radiological changes. The rate of relapses was 6-21 %. The nasal function improved subjectively and objectively after the treatment of inferior turbinates without relapses. Tonsillar radiofrequency procedure induced objectively detectable significant reduction in tonsillar volumes. The results of these procedures are comparable with other conventional treatment modalities.

Radiofrequency thermal ablation tonsillectomy in adult patients did not show any significant advantages compared to the traditional technique and the controversy over which tonsillectomy technique is preferable still exists.

The results of the present investigations are in concordance with previously reported results of this treatment modality and a continual evaluation is warranted.

2. LIST OF ORIGINAL PUBLICATIONS

This thesis is based on the following original publications, which will be referred to in the text with the Roman numerals I to V.

I: L. Bäck, M. Palomäki, A. Piilonen, J. Ylikoski. Sleep-disordered breathing: Radiofrequency thermal ablation is a promising new treatment possibility. *Laryngoscope* 2001; 111: 464-471.

II: L. Bäck, M. Paloheimo, J. Ylikoski. Traditional tonsillectomy compared with bipolar radiofrequency thermal ablation tonsillectomy in adults; a pilot study. *Arch Otolaryngol Head Neck Surg* 2001; 127: 1106-1112.

III: L. Bäck, P. Tervahartiala, A. Piilonen, M. Partinen, J. Ylikoski. Bipolar radiofrequency thermal ablation of the soft palate in habitual snorers without significant desaturations assessed by magnetic resonance imaging. *Am J Respir Crit Care Med* 2002; 166: 865-871.

IV: L. Bäck, M. Hytönen, H. Malmberg, J. Ylikoski. Submucosal bipolar radiofrequency thermal ablation of inferior turbinates: A long-term follow-up with subjective and objective assessment. *Laryngoscope* 2002; 112: 1806-1812.

V: L. Bäck, T. Liukko, P. Tervahartiala, A. Piilonen, J. Ylikoski. Submucosal bipolar radiofrequency thermal tonsillar reduction assessed by magnetic resonance imaging (submitted).

3. ABBREVIATIONS

AHI	= Apnea-Hypopnea Index
AI	= Apnea Index
ARM	= Acoustic Rhinometry
BMI	= Body Mass Index
bRFTA	= Bipolar Radiofrequency Thermal Ablation
CI	= Confidence Interval
CK	= Creatine Kinase
CPAP	= Continuous Positive Airway Pressure
CRP	= C-Reactive Protein
EBM	= Evidence-Based Medicine
EDS	= Excessive Daytime Sleepiness
ENT	= Ear Nose Throat
ESR	= Erythrocyte Sedimentation Rate
ESS	= Epworth Sleepiness Scale
HI	= Hypopnea index
HUCH	= University Central Hospital, Helsinki
J	= Joules
LAUP	= Laser-Assisted Uvuloplasty
Leuc	= Leucocyte count
LUPP	= Laser-Uvulopalatoplasty
MRI	= Magnetic Resonance Imaging
ODI	= Oxygen Desaturation Index
OSAS	= Obstructive Sleep Apnea Syndrome
OTH	= Olfactory Threshold
PAS	= Posterior Airway Space
PNS-P	= Length of the soft palate from the posterior nasal spine to the uvula
PSG	= Polysomnography
PW	= The width of the soft palate (palatal width)
RAUP	= Radiofrequency Assisted Uvuloplasty
RDI	= Respiratory Disturbance Index
RF	= Radiofrequency
RFe	= Radiofrequency energy
RFTA	= Radiofrequency Thermal Ablation
RMM	= Rhinomanometry
SDB	= Sleep-Disordered Breathing
SNB	= Sella – Nasion point B angle
SNRSo	= Snoring Score assessed by the bed partner
SNRSs (=SS)	= Snoring Score assessed by the patient
STT	= Sacharine Transit Time
TE	= Tonsillectomy
TErfta	= Radiofrequency Thermal Ablation Tonsillectomy
TEtrad	= Traditional Tonsillectomy
UARS	= Upper Airway Resistance Syndrome
UPP	= Uvulopalatoplasty
UPPP	= Uvulopalatopharyngoplasty
VAS	= Visual Analogue Scale

4. INTRODUCTION

In the field of medicine, there are many procedures with a long history and still routinely used in the clinic. Removing organs, partly because of lack of knowledge to treat the disorder otherwise, has been the therapy for several disorders. An example of this is tonsillary removal, which was first described as a medical procedure in the first century A.D. (Stevenson et al 1949, Thornval 1969). The comprehension of the function of the tonsillar tissue has varied from being associated with the reproductive function of females to inflammatory tissue that needs to be removed as quickly as possible.

Soft palate, tonsillar and inferior turbinate interventions are commonly practised in Ear Nose Throat (ENT)-clinics, although, many questions about the basic mechanisms in the development of the disorders still remain unanswered. It is clear that when normal organs/tissues or parts of them are removed, there should be enough evidence that the procedure is beneficial for the patient, or at least not harmful.

Evidence-Based Medicine (EBM) has become a hot topic for clinicians. EBM is the use of current best evidence in making decisions about the care of individual patients. The practice of EBM means integrating individual clinical expertise with the best available external clinical evidence from systematic research. Good physicians use both individual clinical expertise and the best available external evidence, and neither alone is enough (Sackett et al. 1996).

In otorhinolaryngology, the Cochrane library (*Cochrane ENT Disorders Group and Airways Group*), consisting of a regularly updated collection of EBM databases, has produced abstracts concerning treatment of tonsillar diseases and sleep-disordered breathing (SDB). In tonsillar surgery there is no evidence-based knowledge or consensus whether to treat chronic or recurrent acute tonsillitis with surgery or with conservative management (Burton et al. 2002), or which technique ought to be used in tonsillectomy (Hollis et al. 2002, Pinder et al. 2002). With the treatment of SDB, the evidence of the effect of conservative treatment e.g. lifestyle modifications and drug treatment is scarce and the conclusion of the reviewers was that there is a need for randomised controlled trials (Shneerson et al. 2002, Smith et al. 2002). The Cochrane ENT Disorders Group is working with several protocols, one of which is dealing with the treatment of snoring.

For the time being, the above-mentioned, commonly practised procedures are lacking evidence-based documentation. Given this background, it is justifiable to seek intervention modalities of minimal invasiveness. The modalities of treatment should be accompanied by as little acute- and long-term morbidity as possible. The cost-effectiveness of the techniques used to achieve the surgical objectives and secure fair reimbursement has to be evaluated.

The purpose of the present study was to evaluate the feasibility of radiofrequency thermal ablation (RFTA), a well-known treatment modality in medicine, in the treatment of pathological conditions of upper airway tissues. The proposed advantages of RFTA over conventional procedures include less pain, faster healing and reduced postoperative care. Furthermore, most procedures can be performed under local anaesthesia in an office setting rather than in the surgical theatre. RFTA is characterised by a precise controllable lesion and has demonstrated, in other fields of medicine, acceptable efficacy, safety and reproducibility of treatment results (Sweet et al. 1974, Calkins et al. 1992, Chapple et al. 1999, Seidenfeld et al. 2002).

5. REVIEW OF THE LITERATURE

A. History and basic principles of electrosurgery

Heating of tissues has been used for thousands of years to treat a variety of conditions or to help stop bleeding from a wound. In the late 19th century a French physicist introduced the concept of an electrical current flowing through the body as a way of producing heat in tissue. The first widely accepted electrosurgical generator was produced through the collaboration of a physicist (William T. Bovie 1882-1958) and a surgeon (Harvey Cushing 1869-1939) (Smith et al. 2001). Harris P. Mosher (1867-1954) used this instrument in the field of otorhinolaryngology to coagulate bleeding vessels in the nose (Hill et al. 1966). Little has changed in the basic principles applied according to Bovie´s invention.

In electrosurgery, a high frequency current, which is used to minimise unwanted tissue stimulation, passes through the tissue for cutting, coagulation and for ablation. The current, which passes through the body between the probe tip and the grounding pad, heats the tissue, not the electrode itself. The electric ions in the tissue close to the probe move through the tissue rapidly due to acceleration by the electric field. They continually collide with other atoms and molecules transferring their excessive kinetic energy. The result is increased random motion of the tissues molecules, and this collective rise in internal energy we refer to as heat.

Electrocautery, however, operates like a soldering iron, in which an ordinary current passes through a heating element that raises its temperature to the desired level. Thus, the heating element conducts heat to an active blade, which is used to cauterise. No electric current is passed through the patient and therefore no dispersive electrode is necessary.

The electrosurgical circuit is similar in both unipolar and bipolar applications. In the bipolar mode, the volume of tissue through which the current is returned, is greatly reduced (Wicker 1992). In the bipolar mode the hand piece contains the active and the dispersive electrode and the current passes between the electrodes in the hand piece generating high current density and heating (Malis 1996). This enables a more precise application of current to tissues.

The different modifications of electrosurgery are electrosection, coagulation, fulguration and needle ablation.

In electrosection the electric current creates enough heat to vaporise tissue ahead of the active probe, thereby separating tissue like a knife. The peak voltage is sufficiently high to produce a constant arching between the electrode and the tissue, which causes tissue heating to the boiling point with cell rupture. In addition, intense local pressure gradients are generated which expedites tissue disruption and ablation.

When the electrode is brought into contact with a severed blood vessel and held in that position, arcing ceases and tissue heating occurs. Coagulation occurs as the local temperature is raised above the range of 45-55 ^{o}C. Electrosurgical units have a spray coagulation (= fulguration) mode, which is used for broad area coagulation in areas of diffuse haemorrhage. In this mode, contact with the tissue is not made. A spray of sparks between the electrode and the tissue is used to provide superficial heating of the tissue and to induce thermal damage with subsequent coagulation. All modern electrosurgical units allow a blend mode of operation in which electrosection can be

accompanied by varying degrees of coagulation. This is the primary advantage of the electrosurgical knife over the scalpel.

In radiofrequency (RF) needle ablation, the generators operate at a much lower frequency, which means that the impedance to current flow is four or five times greater than that associated with the use of conventional electrosurgery generators (Chinpairoj et al. 2001). Equally, the cutting action of needle ablation method is also achieved at lower temperature (65-100 ^{o}C) than with conventional electrosurgery devices (400-600 ^{o}C). The high current density in tissue within a few millimetres of needle electrode causes a rapid local temperature rise of 50 – 90 ^{o}C, within seconds to minutes resulting in thermal injury, coagulation, protein denaturation and irreversible tissue destruction. RF needle ablation uses frictional heating that is caused when ions in the tissue attempt to follow the changing directions of alternating currents. When the 100 ^{o}C threshold is reached, boiling at the electrode-tissue interface results in tissue coagulum adhering to and insulating the electrode and there is an abrupt drop in current density; tissue heating ceases as does lesion formation and tissue damage (Powell et al. 1997). In recent years, electrosurgical devices developed for RF needle ablation have incorporated sensors in the electrode to monitor local tissue temperature and impedance to prevent tissue near the electrode attaining 100 ^{o}C. The sensor automatically shuts off the current and this determines the maximum lesion size. Lesion size depends on current intensity and duration, and on electrode size. Lesions produced by RF needle ablation have a spheroid shape (Organ 1976). Theoretically, the needle ablation method should produce less collateral tissue damage than conventional electrosurgery.

B. Presentation of the interventions investigated in this study

a. Soft palate interventions

Nearly every one of us snores occasionally. Snoring becomes a medical entity when it is habitual and causes social or other disturbances, or when it is associated with symptoms of obstructive sleep apnea syndrome (OSAS). Habitual snoring is a common condition affecting 9-35% of the general adult population and the prevalence is increasing up to the age of 60-65 years, thereafter slightly decreasing (Lugaresi et al. 1980 Figure 1, Partinen et al. 2000).

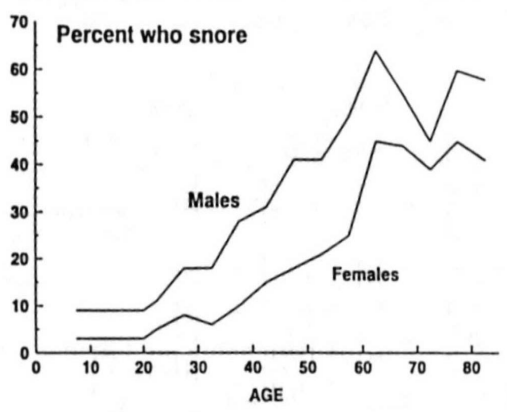

Figure 1: *Snoring in men and women. These data were obtained from 5713 people living in San Marino, Italy (Lugaresi et al. 1980).*

Snoring is a noisy inspiratory sound produced by vibrations and partial obstruction in the oropharynx. Although, in some cases it can be associated with structural abnormalities, the obstruction is mostly the consequence of a functional pharyngeal hypotonia (possibly due to the Bernoulli effect, Sullivan et al. 1980, Ulfberg 1996, Figure 2) in relation to a relatively narrow pharyngeal cross-sectional area (Bradley et al 1986).

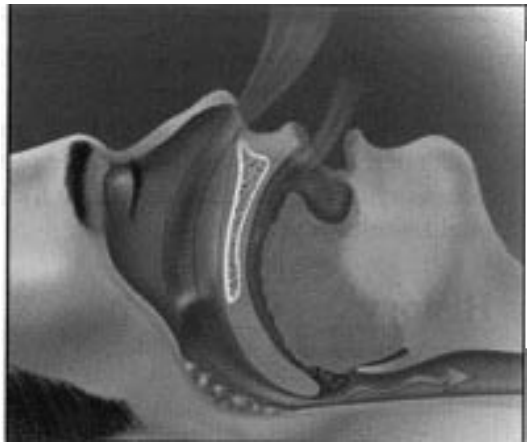

Figure 2: *Snoring is caused when there is narrowing of the normal airway. Because of the Bernoulli effect, air flows faster through a narrowed passage (similar to that when water sprays faster and farther when you put your finger on the tip of a garden hose). This faster flow of air causes high frequency vibrations of the soft tissue of the airway resulting in the characteristic sounds of snoring.*
(Picture modified from the website http://www.drsinha.com/snoring.htm).

Neuromuscular control is a contributory factor to upper airway collapse. It has been suggested that in patients with SDB, chronic snoring vibrations lead to lesions in the afferent and efferent nerves innervating upper airway tissues (Svanborg 2001, Friberg et al. 1998). In a study by Kimoff, snorers and OSAS patients, compared with normal subjects, had impaired sensation in the upper airway, which may predispose to development of apneas of longer duration (Kimoff et al. 2001). Paulsen found structural changes in mucosa of the uvula with scanning electron microscopy and immunohistochemistry of patients with different degrees of SDB indicating increased collapsibility induced by the trauma of snoring (Paulsen et al. 2002). Abnormal neuromuscular control also contributes as reflex activation of the pharyngeal dilatators in response to airway obstruction often fails in patients with SDB.

Anatomic narrowing is an additional factor to upper airway collapse. There is a clear male predisposition in SDB and a model developed by Malhotra et al (2002) demonstrates that the airway is more collapsible in males solely on the basis of anatomic differences.

The surgical interventions of the soft palate share a common goal; reduction, stiffening and stabilisation of the soft palate. In Finland with a population of 5 million about 900 soft palate surgeries were performed in 2001 (Rasilainen et al. 2002). Surgical manipulations in patients with SDB are effective resulting in successful relief of snoring in approximately 80% and improvement of OSAS in 50% of subjects (Larsson 1994). However, surgical procedures are associated with significant morbidity and life-threatening complications have been encountered (Carenfelt et al. 1993, Ylikoski 1995). In addition, the frequency of long-term adverse effects on swallowing, regurgitation, taste, smell and voice have been reported to be up to 40-60% (Hagert et al. 2000).

Therefore, procedures in which a variable amount of normal tissue of the soft palate is removed cannot be regarded as an optimal solution for treatment of habitual snoring. It is clear that in the future far less morbidity causing procedures should replace these surgeries.

b. Tonsillar surgery

Tonsillectomy (TE) is one of the most common surgical procedures performed worldwide. In the early 20th century, TE was the most popular procedure for treating respiratory and systemic disorders (MacBeth 1950, Kornblut 1987). Use of TE began to decline with the advent of antibiotics and critical assessments of the need for it. Although, the first report of the procedure is from the first century A.D. (Stevenson et al 1949, Thornval 1969), the first critical evaluations of beneficial effects of TE are from the 1960s (Mawson et al. 1967). In the 1960s and 1970s 1 to 2 million TEs with or without adenoidectomies was performed annually in the United States. Currently, these operations are performed at half the rate of those 40 years ago (Younis et al. 2002). Still, the procedure is in wide use. In Finland with a population of 5 million about 10 000 TEs were performed in 2001 (Rasilainen et al. 2002).

The indications for TE or the complications associated with the procedure have changed very little. Today, most of the TEs are performed under general anaesthesia. There are two major post-operative morbidity problems; pain and the risk of delayed haemorrhage. Pain does not completely subside until the muscle becomes covered with mucosa 14 to 21 days after surgery. The risk of delayed haemorrhage varies between 2-16 % (Windfuhr et al. 2001, Krishna et al. 2001, Blomgren et al. 2001, Paradise et al. 2002). Any possible improvement of this procedure should decrease operating time, post-operative haemorrhage and particularly the post-operative morbidity. Cost-effectiveness must today be kept in mind when considering the use of one TE technique over another. With the growing interest in day case surgery, quick techniques with rapid recovery are favoured.

c. Inferior turbinate interventions

Nasal obstruction in non-infective chronic hypersensitive rhinitis is frequently caused by mucosal hypertrophy. The basic mechanisms of the development of mucosal disorders in the nasal cavity are partly unknown. Several methods have been used to treat mucosal hypertrophy. The medications proposed, such as intranasal steroids, antihistamines, cromones and symphatomimetics, provide a satisfactory relief of nasal obstruction in only a proportion of patients. Thus, many patients with nasal obstruction caused by non-infective chronic rhinitis may become candidates for surgical turbinate interventions.

Various techniques used for treatment of hypertrophied inferior turbinates are associated with different degrees of nasal crusting, post-operative bleeding and irreversible mucosal complications. Any of the techniques in use ought to achieve optimal volume reduction with preservation of function. It appears so far that there is no method of treatment that could be considered satisfactory for hypertrophied inferior turbinates (Hol et al. 2000). In recent years, accompanying the interest in day case surgery, office based inferior turbinate reduction has regained popularity.

In Finland with a population of 5 million about 150 inferior turbinate surgeries were performed in 2001 (Rasilainen et al. 2002).

C. The development of soft palate surgery for snoring

The first reference referring to sleep disturbances in the modern literature was the classic description of a typical OSAS patient by Charles Dickens´ in *Pickwick Papers* published in 1836. A systematic review of the 19th century literature revealed that patients with obstructive sleep

disorders were vividly described in the second half of the century (Lavie 1984). There were documented observations of the linkage between airway obstructions and noisy snoring.

Palatal stiffening as a treatment of snoring is not a new idea. In a London surgical atlas from 1852 there is a description of palatal stiffening operation, where a central part of the soft palate was removed as a treatment of snoring (Mair et al. 2000). In 1943 Strauss proposed injection of a sclerosing agent (sylnasol) in the soft palate to produce controlled fibrosis for treatment of snoring (Strauss 1943). This procedure was re-introduced recently in a report with 27 patients receiving sodium tetradecyl sulfate (Brietzke et al. 2001). Twenty-five of 27 (92%) patients experienced a decrease in snoring. In Japan, the operation of traditional uvulopalatopharyngoplasty (UPPP) was introduced by Ikematsu (Ikematsu 1964) and by Fujita (Fujita et al. 1981); this is the most established surgical approach to SDB and in widespread use. UPPP is effective and results in successful relief of snoring in approximately 80% (Levin 1994). A laser surgical procedure, laser uvulopalatoplasty (LUPP) to shorten the palate was pioneered in Sweden in the 1980s in a study consisting of 146 patients with a success rate of 90% (Carenfelt 1991). Ellis in Great Britain proposed a new approach in a report of 16 patients (Ellis et al. 1993). Laser palatoplasty, following this model, involves creating a laser burn to the soft palate mucosa to induce scarring. The snoring was greatly reduced in 14/16 (88%) patients. Other methods include laser-assisted uvulopalatoplasty (LAUP) popularised by Krespi in the United States (Krespi et al. 1994) and Kamami in Europe (Kamami 1994). This technique offered the potential advantage of being office procedures and do not always require the use of general anaesthesia. In the report of Kamami, 55 of 63 (87%) patients were successful responders. Other described techniques are uvulectomy alone (Lindholm 1990), uvulectomy with mucosal strip (Powell et al. 1996), cautery of the soft palate (Clarke et al. 1998), submucosal uvulopalatopharyngoplasty (Friedman et al. 2000) and Z-pharyngoplasty (Mukai et al. 2002) with reported success rates varying between 67% - 92%.

D. The development of tonsillar surgery

Over the years, various techniques and instruments have evolved to accomplish TE and have a long history – the first description of tonsillary removal as a medical procedure is from the first century A.D. (Stevenson et al 1949, Thornval 1969). Cornelius Celsus in Rome described blunt removal of inflamed tonsils by using a finger. There is still controversy over the optimal technique of tonsillar surgery. The described techniques include blunt dissection, guillotine excision, cryosurgery, monopolar and bipolar diathermy dissection, suction diathermy dissection, bipolar scissor dissection, microscopic bipolar diathermy dissection, ultrasonic removal and laser dissection (Baily 1997, McGuire 1967, Goycoola et al. 1982, Weingarten 1997, Martinez et al. 1987, Mann et al. 1984, Pang et al. 1994, Saleh et al. 1999, Andrea 1993). Tonsillotomies or intracapsular partial TEs using laser (Hultcrantz et al. 1999) or powered instruments (Koltai et al. 2002) have been reported having a benefit in the post-operative period in children compared with traditional TE. Additionally, a myriad of adjuvant therapies used peri-operatively have been developed to improve outcomes after TE (Steward et al. 2000).

According to a recent report (Zinder 2001) radiofrequency subtotal tonsillectomy was widely performed in the 1920s and 1930s. Kelly and Ward in their book “Electrosurgery”, provide a description of 4 techniques for tonsillar surgery using RF electrosurgical devices (Kelly and Ward 1932). They stated that the bleeding was minimal and the post-operative pain was much less with RF tonsillar shrinkage than when the tonsils were removed by traditional means. For reasons related

to the over-coagulation, i.e. secondary haemorrhage, massive sloughing of tonsillar tissue and severe oedematous reactions, the procedure has fallen out of favour since its advocacy in the 1920s. Other authorities (Nelson et al. 2001) have stated that with the new insertion-coagulation techniques the risk of over-treatment with its associated morbidity is reduced. The modern techniques use low power and temperature-controlled heating on tonsillar stroma providing a precise and predictable lesion formation. A gradual reduction of submucosal tissue volume occurs over time beneath the intact mucosa.

E. The development of inferior turbinate interventions

At least 13 surgical techniques have been used over the past 150 years to treat hypertrophy of the inferior turbinate (Hol et al. 2000). The first method was electrocautery of the turbinates, suggested as early as 1845 by Heider from Vienna and Crusel from St Petersburg (Hol et al. 2000). Surface electrocautery is still one of the most practised methods, even though it is destructive. Intraturbinal thermocoagulation was introduced to diminish the destructive mucosal complications. The amount of deep tissue reduction is, however, difficult to predict (Wengraf et al. 1986). Secondly, the effect of intraturbinal thermocoagulation is often limited or temporary (Meredith 1988). The use of chemical coagulation (trichloric acid or chromic acid) to reduce turbinate volume also came into use during the last decades of the 19th century. The procedure had to be repeated and it led to mucosal damage. Reduction by surgical resection of the turbinates dates also from the last decades of the 19th century. The first description of partial resection of the turbinates is from 1882 and total turbinectomy from 1895. Thereafter, several varieties of surgical interventions have been introduced being more conservative and aiming for preservation of turbinate function, such as lateralization (1904), lateropexia (1967), submucous resection of turbinate bone (1906), crushing and trimming and partial resection (1930), turbinoplasty (1982) and the use of powered instruments (1994) (Hol et al. 2000). Injection of corticosteroids (Semenov 1952) and sclerosing agents (Shainian 1953) have also been used for reducing a hypertrophied turbinate. However, due to unpredictable results and serious complications, the methods never became widely used. A different approach to the problem was introduced 1961, the cutting of the parasympathetic fibers in the Vidian canal to decrease the parasympathetic tone in the nose, Vidian neurectomy (Golding-Wood 1961). Hypersecretion was diminished but not the blockage and the technique has been abandoned. In the 1970s, cryosurgery was introduced. Here the inferior turbinate was frozen with a cryoprobe using nitrous oxide or liquid nitrogen as a cooling agent (Ozenberger 1970). The reaction of the mucosa was found to be different than with electrocautery and it was assumed that new respiratory epithelium would replace the frozen tissue. The overall short-term results were satisfactory, but the benefit was usually not sustained, and cryosurgery was gradually abandoned. The use of laser technology to treat hypertrophied turbinates was first reported in 1977 by using Argon-laser (Lenz et al. 1977). In later years, several other types of laser were applied, i.e. CO_2, KTP, Neodinum-Yag and Holmium-Yag laser. Microscopic studies of laser-treated mucosa have shown that the epithelium regenerates only to a limited degree and part of the seromucinous glands and blood spaces are decreased permanently (Kubota 1995). Laser surgery seems not meet the requirement of preservation of function and should not be used to threat a hypertrophied inferior turbinate.

F. Radiofrequency thermal ablation

a. Applications in Medicine

The use of radiofrequency energy (RFe) in medicine to ablate soft tissue is not new. The first study of the therapeutic value of RFe was reported in 1974 for the treatment of trigeminal neuralgia (Sweet et al. 1974). A precise controllable lesion is a characteristic of the RFTA -method. Following wound healing the delivered RF current leads to scar formation and retraction of tissue, resulting in volume reduction (Powell et al. 1997, Courvey et al. 1999). It has demonstrable efficacy, safety and reproducibility of treatment results. More recent applications include destruction of aberrant conduction pathways in the heart (Calkins et al. 1992) and volumetric reduction of benign prostate hypertrophy (Chapple et al. 1999), and indications are still expanding covering a large scale of disorders in medicine such as cardiology (Vital et al. 2002), vascular surgery (Harris 2002), orthopaedics (Hecht et al. 1999, Torriani et al. 2002), gastroenterology (DiBaise et al. 2002) and surgical oncology (Seidenfeld et al. 2002, Solbiati et al. 2001, Dupuy et al. 1998, Zuboy 2000, Jeffrey et al. 1999, Navarro et al. 2002, Hoffman et al. 1995, Wood et al. 2001, Dupuy et al. 2001, Putnam 2002).

b. Applications in Otorhinolaryngology – Head & Neck Surgery

Powell first reported the use of RFe in the volumetric reduction of pharyngeal tissue (Powell et al. 1997). This study established the relative safety of RFe ablation and looked at both the gross and histologic effects on porcine tongue tissue. It was found that the lesion size created was proportional to the amount of RFe administered and that the tissue treated demonstrated a very localised response of initial oedema, subsequent formation of scar tissue and a resultant reduction in the volume.

Current literature on this topic includes the use of RFe ablation in human subjects and the first was reported by Powell (Powell et al. 1998). In this study, 22 patients with SDB were treated on an outpatient basis with RFe delivered to the submucosa of the soft palate. Powell demonstrated improvement of snoring (with snoring scores) and daytime sleepiness (with the Epworth Sleepiness Scale (ESS) questionnaire) after RF ablation of the soft palate with minimal morbidity. Additionally, there was a significant reduction in the distance from the nasal spine to the tip of the uvula (PNS-P) assessed with cephalometric radiographs indicating shrinkage of the free edge of the soft palate in the midline after treatment of that region. Thereafter, several studies have been performed in treating habitual snorers with similar conclusions (Coleman et al. 2000, Emery et al. 2000, Boudewyns et al. 2000, Ferguson et al. 2001, Sher et al. 2001, Johnson et al. 2002). It appears that the result of RF treatment of the soft palate decreases with time as with other surgical procedures of the soft palate (Li et al. 2000, Trotter et al. 2002). Scar tissue matures and softens over 12-18 months, which might explain the relapses (Courey et al. 1999). However, the relapses after RF treatments can be improved with additional treatments (Li et al. 2000). The minimal invasiveness of this treatment modality provides a high acceptance of re-treatment.

In the management of mild to moderate obstructive sleep apnea syndrome (OSAS), the results of RF tissue ablation of the soft palate are controversial. In the study groups of Powell and Brown (Powell et al. 1998, Brown et al 2001) there were no clinically significant differences in sleep parameters of the polysomnographies (PSG). However, in the report by Blumen (Blumen et al. 2002 a) there was a significant decrease in the respiratory disturbance index (RDI) post-operatively.

As a soft palate procedure, RFTA seem to produce less post-operative pain compared to LAUP and UPPP due to reduced coagulation temperature and the insulation of the mucosa from tissue injury (Troell et al. 2000 a, Blumen et al. 2002 b). The earliest equipment for RF delivery includes monitoring equipment measuring the tissue temperature and impedance during the application, which adds significantly to the cost of the procedure. Additionally, the hand pieces are of single use only. In a study by Taliafero (Taliafero 2001) concomitant monitoring of tissue impedance and temperature during the volumetric reduction of the soft palate was not necessary for the safe and effective application in the treatment of snoring.

Reports on complications associated with RF ablation of the soft palate have shown that the incidence of mucosal injuries is high, although, many of which were only visualised endoscopically. The injuries present themselves rapidly and are self-limiting. The occurrence of mucosal ulcers is usually associated with only a minor increase in post-operative pain (Terris et al. 2001, Pazos 2001). In a report by Haraldsson (Haraldsson et al. 2002), where they assessed subjectively and objectively the voice quality of patients treated, the RF ablation of the soft palate did not cause adverse effects on nasopharyngeal function.

Radiofrequency-assisted uvulopalatoplasty is a modification of LAUP in using similar surgical technique as described for laser surgery, but with different equipment. The procedure is done with a radiofrequency knife with comparable results and, according to the report, less morbidity and costs than with the equipment used for LAUP (Wedman et al. 2002).

Li was the first to report the use of RF volumetric tissue reduction for treatment of inferior turbinate hypertrophy (Li et al 1998). They treated 22 consecutive patients with hypertrophy of the inferior turbinate refractory to medical treatment with RF ablation in an outpatient setting. The patient was discharged approximately 5 min after the treatment without restrictions on normal daily activities. The results were assessed subjectively with visual analogue scales (VAS). The procedure was associated with minor adverse effects, such as mild discomfort or heat during the application and mild oedema during the first post-operative days. The nasal breathing improved in 21 of 22 patients. Thereafter, the promising treatment results have been repeated including objective assessments with rhinomanometry (RMM) and acoustic rhinometry (ARM) in short-term follow-up (Elwany et al. 1999, Fisher et al. 2000, Coste et al. 2001, Rhee et al. 2001). In several studies there are assessments of the preservation of normal turbinate function after RF ablation. Electron microscopic examination of the nasal mucosa at the end of the follow-up period in Elwanys report revealed intact healthy epithelium as well as intense fibrosis of the underlying stroma (Elwany et al. 1999). The saccharine transit time (STT) (Coste et al. 2001, Rhee et al. 2001), ciliary beat frequency (Coste et al. 2001, Rhee et al. 2001) and olfactory thresholds (OTH) (Rhee et al. 2001) have not been adversely affected by the treatments. In subjects using continuous positive airway pressure (CPAP) with turbinate hypertrophy, the RF treatment appears to improve nasal breathing and CPAP-treatment for SDB, a conclusion drawn by Powell in a randomised, double-blind, placebo-controlled study with subjective assessment using VAS (Powell et al. 2001).

Radiofrequency tonsillar volume reduction was reported by Nelson (Nelson 2000). He treated 9 patients with tonsillar hypertrophy with submucosal RF ablation into each tonsil in an outpatient setting. The author himself assessed the change in the tonsillar volume by measuring the oropharyngeal airway between the tonsils with photographs. The evaluation of the change in symptoms were not statistically analysed. The procedure, however, avoids the post-procedure morbidity and discomfort of more invasive and currently practised treatments of this condition (Nelson 2000). In the same report, there were no visible damages to underlying muscular or

vascular structures in the tonsil fossa. In the extended follow-up study the achieved reduction was still present one year after the procedure (Nelson 2001).

Powell reported a pilot study on RF tongue base reduction in SDB (Powell et al. 1999). The treatment group consisted of 18 patients with a broad distribution of OSAS severity with a RDI of 39.5 (0.7-110) in PSG before the treatment. At minimum, palatopharyngoplasty had failed in all. The treatments were done in an outpatient setting and the patients were allowed to leave in 5 min after the completion of the session. The assessment was done with questionnaires (morbidity, quality of life, ESS), radiologically (cephalograms and magnetic resonance imaging, MRI) and PSGs. The mean number of treatment sessions per patient was 5.5 (range 2-9) with a treatment interval of 3-4 weeks. Sedative pre-medication was not given. In PSGs, there was a significant decrease in RDI and nadir oxygen saturation accompanied with questionnaire results indicating less snoring and daytime sleepiness. The posterior airways space (PAS) and the tongue volume decreased significantly. The morbidity was acceptable, although, they reported three adverse events (ulceration, pain on swallowing and a tongue infection). The results were promising along with the lack of hospitalisation and few concerns regarding post-operative morbidity accompanying midline glossectomy, lingualplasty and maxillofacial approaches with or without hyoid suspension. The results of this treatment modality were confirmed by a multi-institutional study (n=57) by Woodson (Woodson et al. 2001), where he used non-randomly concurrently enrolled CPAP users (n=99) as a cohort group. Four base of tongue infections were recorded. Stuck claims to have achieved a similar cure rate with only a slight increase in post-operative complications by increasing the amount of energy per treatment session and reducing the number of treatment sessions (Stuck et al. 2000, 2002 a). However, the changes in the PSGs were not statistically significant. He recommended the prophylactic use of antibiotics for this patient group. Complications associated with RF ablation of the tongue base, such as tongue base abscesses and floor of the mouth oedema with ensuing airway compromise, seem to be more severe, delayed and life threatening (Pazos et al. 2001). In a study by Li (Li et al. 2002), where the study population of the pilot study by Powell (Powell et al. 1999) was re-evaluated, they concluded that the success of temperature-controlled RF tongue base reduction for SDB might decrease with time. They demonstrated in PSGs that long-term relapse is primarily reflected in the hypopnea index (HI) without significant detrimental effects on the patient's quality of life (questionnaire) and sleepiness (ESS).

The technique of tissue coblation TE is a method, in which RF energy with a special hand piece is used to removal the tonsil down to but not through the lateral portion of the tonsillar capsule, which essentially constitutes a subtotal supracapsular tonsillectomy. In paediatric patients this technique seem to offer significant advantages in the post-operative period, with a rapid return to a normal diet and a drastic reduction in analgesic requirements following the surgery (Temple et al. 2002), although opposite results have been reported (Shah et al. 2002). The favourable morbidity outcome of coblation TE was also reported in an adult patient group (Timms et al. 2002).

Additionally, there are reports of RFe ablation as palliative treatment of head and neck tumours (Owen et al. 2002), as treatment of adenoid cystic carcinoma of the head and neck (Bui et al. 2002) and as a treatment alternative for microcystic lymphangiomatous macroglossia (Cable et al. 2001).

6. AIMS OF THE STUDY

The general aim of this study was to investigate the role of radiofrequency thermal ablation in some common surgical procedures in otorhinolaryngology .

Our hypothesis was that radiofrequency ablation is an effective treatment modality associated with acceptable morbidity.

The specific goals were to analyse the morbidity and efficacy of:

I monopolar and bipolar radiofrequency thermal ablation of the soft palate in subjects with habitual snoring.

II bipolar radiofrequency thermal ablation tonsillectomy and compare it with the traditional tonsillectomy in adults.

III bipolar radiofrequency thermal ablation of inferior turbinates in patients with nasal obstruction caused by turbinate hypertrophy due to non-infective chronic rhinitis.

IV bipolar radiofrequency thermal ablation tonsillar reduction in patients with symptomatic obstructive tonsillar hypertrophy.

7. MATERIALS AND METHODS

The study protocol was reviewed and approved by the Research Ethical Committee of the of Department of Otorhinolaryngology - Head & Neck Surgery, University Central Hospital, Helsinki (HUCH), Finland. Informed consent was obtained from all patients.

A. Patients (I-V)

The patients had been referred to the Department of Otorhinolaryngology - Head & Neck Surgery, HUCH. The patients in studies I and III had visited the ENT-clinic because of habitual snoring associated with excessive daytime sleepiness (EDS) and they were scheduled for palatal surgery. In study II the patients were admitted for elective TE and the indications were recurrent infections, chronic infection, airway obstruction or history of quinsy. In study V only patients with symptomatic obstructive tonsillar hypertrophy were included. In study IV the patients were suffering from nasal obstruction due to non-infective chronic rhinitis and hypertrophied inferior turbinates despite varying treatments. Study characteristics, inclusion and exclusion criteria are presented in tables I and II.

Table I: Clinical study characteristics according to the protocol.

Study	Patients	Design	Object of the study
I	20	Prospective, non-randomised	Effects on habitual snoring (monopolar)
II	40	Prospective, randomised, single-blinded	Comparison of two tonsillectomy techniques (traditional and radiofrequency)
III	20	Prospective, non-randomised	Effects on habitual snoring (bipolar)
IV	20	Prospective, non-randomised	Effects on hypertrophied inferior turbinates
V	10	Prospective, non-randomised	Effects on hypertrophied tonsillar tissue

Table II: Inclusion and exclusion criteria for the studies.

Study	I	II	III	IV	V
INCLUSION					
Age (years)	18-60	18-65	18-65	> 18	18-65
PAS (mm)	$\geq$ 8		$\geq$ 8		
SNB (^{o})	$\geq$ 74		$\geq$ 74		
ODI 4%	$\leq$ 15		$\leq$ 5		
ODI 10%	< 1		< 1		
BMI (kg/m^2)	< 33		< 35		
EXCLUSION					
Local anaesthetics/allergy	+		+	+	+
Bleeding disorders	+	+	+	+	+
Any illness interfering the recovery		+			+
Psychiatric disorder	+	+	+	+	+
Neurologic disorder	+	+	+	+	+
Pacemakers	+	+	+	+	+
Previous palatal surgery	+		+		
Speech/swallowing disorders	+		+		
Intensive gag reflex	+		+		+
Rhinitis medicamentosa				+	
Nasal cancer				+	
Other major nasal disease				+	
Radiation therapy	+	+	+	+	+
Oral steroid use				+	
Anosmia				+	

Abbreviations: PAS = posterior airway space, SNB = Sella-Nasion point B angle, ODI = oxygen desaturation index, BMI = body mass index

B. Radiofrequency thermal ablation procedure (I-V)

In study I, RFe was delivered at 460 $\pm$ 1 kHz using a RF generator with needle electrodes (VidaMed® generator, model nr. 7200), initially designed for use in the prostate (Chapple et al. 1999). In all other studies the procedures were done with the bipolar ENTec Coblator Plasma Surgery System^{TM} with a voltage range of 96 – 312 voltage root-mean-square value at 100 kHz. The safety and effectiveness of Coblation^{TM} have been proven through its extensive use in arthroscopic surgery (Tasto et al. 1999). Bipolar RFTA (bRFTA) has been adapted to operate in dry field environments and the first clinical applications have been in cosmetic surgery (Burns et al. 1999). The equipment and the treatment modalities are summarised in table III.

Table III: The equipment and treatment modalities of the RF procedures.

study	equipment	hand piece	J / Vrms	sessions	insertions
I	VidaMed® generator model nr 7200	Tuna 3 model no 6193	600 J and 300 J	2	1
II	ENTec Coblator Plasma Surgery System™	Plasma scalpel™	192-260 Vrms		
III	ENTec Coblator Plasma Surgery System™	ReFlex™ 55	216-234 Vrms	2	3
IV	ENTec Coblator Plasma Surgery System™	Hummingbird™	168-182 Vrms	1	6
V	ENTec Coblator Plasma Surgery System™	ReFlex™ 55	216-234 Vrms	1	6

Abbreviations: J = Joule, Vrms = voltage root-mean-square-value, session = treatment sessions, insertion = insertion points per session into the treated tissue.

Studies I, III-V

No premedication was given. The patients had no restrictions in diet prior to surgery. The treatments were delivered on an outpatient basis using lidocaine 10 mg/dose spray (Xylocain®, AstraZeneca, Sweden) as a topical anaesthetic. A needle was used to locally inject lidocaine hydrochloride 10 mg/ml cum epinephrine (Lidocain®, Orion, Finland) into the treatment region (Figure 3). The patients were allowed to leave within a few minutes after completion of treatment and were advised to sleep the first night in a half sitting position and reduce pain / swelling with ice cubes (I, III and V). No medications were prescribed, but the patients were advised to use ibuprofen or ketoprofen if needed.

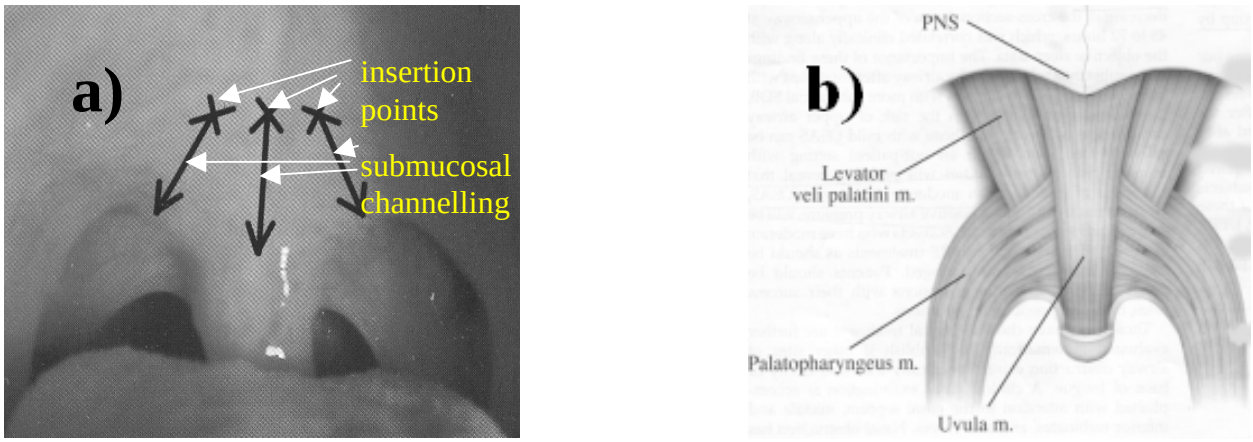

Figure 3: *Picture of oropharynx with the insertion points of the hand piece in treating the soft palate (a) and the muscular anatomy of the soft palate viewed without the mucosa (b) (Troell et al. 2000 b). Abbreviation: PNS = posterior nasal spine.*

Study II

A standardised anaesthetic technique was used in all patients. The patients were prepared in accordance of our standardised guidelines for TE in both groups. Each patient was randomly

assigned to either traditional tonsillectomy (TEtrad) or bipolar radiofrequency thermal ablation tonsillectomy (TErfta) by the surgeon picking a card from a pack of cards. In the TEtrad group, TE was initiated by an incision overlaying the superior pole of the tonsil and dissection proceeded along the tonsillar fossa in the peritonsillar plane. Haemostasis was achieved by pressure with packs and bipolar diathermy coagulation of vessels. In the TErfta group, TE was done with the bipolar RF equipment and a special device. The wand is composed of five active electrodes located at the distal end of the tip and an exposed portion of the shaft acting as the return electrode just proximal to the active electrodes. Cooled saline was connected to the wand and a different suction line was used. The TE proceeded slowly along the capsular plane. If there was more bleeding or if the wand did not seal the vessel within five seconds, point diathermy coagulation was used.

C. Evaluation of morbidity (I-V)

VAS was used for evaluation of the morbidity of the procedures. Patients were asked to grade their symptoms by drawing a vertical line crossing a 100 mm line, where 0 was anchored as no symptoms and 100 represented intensive symptoms. The symptoms evaluated in studies I-III and V was pain, swelling sensation of the oropharynx, difficulty in drinking, difficulty in eating, difficulty in opening the mouth, and in difficulty in speaking. In study IV each patient used VAS to grade post-operative nasal symptoms for a week (pain, nasal discharge, itching, sneezing, crusting, frequency of nasal obstruction and degree of nasal obstruction). Additionally, the patients graded the development of long-term symptoms using VAS before the treatments and at 3, 6, and 12 months post-operatively (nasal discharge, itching, sneezing, crusting, frequency of nasal obstruction, degree of nasal obstruction and patient satisfaction).

In study II, different recovery indicators were used to assess the morbidity of TE. We calculated the time spent and medications used in the recovery room. Additionally, the general condition and status of the uvula the first post-operative day was evaluated. Furthermore, the use of corticosteroids in the surgical ward, the time the patients returned to work and the use of antibiotics for the following two weeks was assessed.

The post-operative use of pain medication was registered using a different questionnaire. In the analysis of the used amount of pain medications in studies I - III and V, the milligrams were converted into dosages related to the maximal amount of the medication that are recommended per day (ketoprofen 300 mg/d => 1 dosage is 100 mg, ibuprofen 3200 mg/d => 1 dosage is 800 mg, asetosalicylic acid 3000 mg/d => 1 dosage is 1000 mg, paracetamol 3000 mg/day => 1 dosage is 1000 mg, combination of paracetamol 500 mg and codeinphosphate 30 mg 8 tbl/d => 1 dosage 1 tbl, tramadolhydrochloride 8 tbl/d => 1 dosage is 1 tbl). The total dosages of group A) ketoprofen/ ibuprofen/ asetosalicylic acid/ paracetamol and group B) paracetamol-codeinphosphate/ tramadolhydrochloride were calculated either during the 2 weeks following (I, III and V) or in three different periods; during three days, seven days and two weeks (II).
Finally, we asked for the patients' re-treatment acceptance.

D. Laboratory blood tests (I, II, V)

We measured C-reactive protein (CRP), leucocyte counts (Leuc), creatine kinase (CK) (I) and erythrocyte sedimentation rate (ESR) (II and V) levels before the procedure and post-operatively in

the following two days and one week after the last treatment (I), one day and two weeks after surgery (II), and one and two days after treatment (V) in order to evaluate the inflammatory host response induced by the procedure.

E. Evaluation of efficacy

a. Questionnaires (I, III, IV)

Studies I and II
In studies I and III, snoring was assessed by the patient using a 10-point grade rating scale SNRSs (Table IV, abbreviation SS was used in study I). An additional snoring score (SNRSo) (Lim et al. 1999) in study III was given to the bed partner for completion (Table V). EDS was evaluated with ESS questionnaire presented by Johns (Johns 1991, 1993) (Table VI).

Table IV: Snoring Score, SNRSs, assessed by the patients in study I and III.

No snoring	0 p
Soft snoring, which does not interrupt the bed partners' sleep	1-3 p
Loud snoring, enough to be bothersome to bed partner	4-6 p
Very intense, snoring is annoying to anyone nearby	7-9 p
Bed partner leaves the room	10 p

Score: _____

Table V: Snoring score, SNRSo, assessed by the bed partner in study III.

Please pick the answer in each of the three questions below that describes your partners snoring

1. How often does your partner snore?	
Every night	3 p
Snores on most of the nights	2 p
Snores on some nights	1 p
Snores on very rare occasions or never snore	0 p
2. How much does your partner snore?	
Snores all time throughout the night	3 p
Snores most of the time throughout the night	2 p
Snores occasionally throughout the night	1 p
Hardly snores or no snoring	0 p
3. How loud is the snore?	
Snoring can be heard throughout the flat or louder with the bedroom door closed	3 p
Snoring can be heard in the next room with the bedroom door closed	2 p
Snoring can only be heard in the bedroom	1 p
There is no snoring noise	0 p

Total score: ____

Table VI: Epworth Sleepiness Scale (ESS) used in study I and III.
How likely are you to doze off or fall asleep in the following situations, in contrast to feeling just tired? Use the following scale to choose the most appropriate number for each situation.

0 = would never doze 1 = slight change of dozing
2 = moderate change of dozing 3 = high change of dozing

Situations	chance of dozing
Sitting and reading	
Watching TV	
Sitting inactive in a public place (e.g. a theatre or a meeting)	
As a passenger in a car for an hour without break	
Lying down to rest in the afternoon when circumstances permit	
Sitting and talking to someone	
Sitting quietly after lunch without alcohol	
In a car, while stopped for a few minutes in the traffic	

Total score: ____

Study IV
The efficacy of the RF ablation of the inferior turbinates in study IV was assessed with VAS scores of subjective complaints (nasal discharge, itching, sneezing, crusting) and evaluation of the effectiveness (frequency of nasal obstruction, degree of nasal obstruction, patient satisfaction) in 12 months follow-up.

b. Imaging studies (I, III, V)

The upper airway anatomy examination using cephalometric radiographs in studies I and III were done to evaluate the level of obstruction. A lateral radiographic cephalometric head film was taken prior to (I and III) and three months (I) after the RFTA-treatments. The two radiologists together measured the traditional bony and soft tissue measurements before (I and III) and after (I) the treatments. This was done for inclusion and exclusion purposes and, in study I, to evaluate changes in the soft palate length and width (PW) induced by treatment. All radiographs were taken in the same anatomic head position that was assured by the use of a standardised, ridged, cephalometric head holder.

In studies III and V, MRI was done before and 3-4 months after treatment in order to evaluate the changes in the dimensions of the soft palate (III) and in the tonsillar volume (V). The MRI was performed with a 1.5 T imager (TR 500-725 msec, TE 14 msec, slice thickness 3 mm, matrix 512, Siemens Magnetom Vision, Siemens AG, Erlangen, Germany). In study III, high-resolution transaxial and sagittal images of the oropharynx were obtained by using a head coil and a T1-weighted spin-echo sequence. In study V, T1-weighted sagittal and T2-weighted transaxial images were obtained from the oropharynx by using a head coil.

In study III, the radiologists measured the different dimensions of the pharynx in one session to ensure the use of exactly the same measurement points in the MRIs before and after treatment. The length of the soft palate and also the curved, corrected length of the soft palate was measured. The width of the soft palate was evaluated at the thickest part and at one cm from the junction of the hard palate. The post uvular space was measured from the posterior margin of the uvula to the posterior pharyngeal wall and to the anterior surface of the longitudinal ligaments of the cervical

vertebras I and II. The distance between the tip of the uvula and the bottom of the sella was calculated to assess the retraction of the soft palate. In the transaxial images, the cross-sectional dimensions of the narrowest point in oropharynx were documented. The area of the soft palate was measured from three adjacent images in order to get an evaluation of the volume of the soft palate. The T1-signal intensity of the soft palate was evaluated before the treatments by using an arbitrary scale (mild – moderate – major). The change in the T1-signal intensity initiated by the RF treatments was analysed by comparing the pre- and post-treatment MRIs. The signal alteration was assessed with an arbitrary scale (mild – moderate – major) by two radiologists and a consensus value agreed in the changes in the T1-signal intensity.

In study V, two radiologists measured the tonsillar volumes independently and the volumes are the mean value of two measurements. The volumes were processed by the soft ware of the equipment. The tonsillar areas in the transaxial images were defined and multiplied by the slice thickness (3 mm) including the interslice gap (0.3 mm). In order to assess the reliability of our measurement method, the earlier MRIs of habitual snorers that were treated with RFe of the soft palate, but not of the tonsils, were used as a control group.

The assessors were blinded to the condition of the subjects. However, they knew whether the cephalograms or the MRIs were done before or after the procedures.

c. Tests of nasal function (IV)

Rhinomanometry and acoustic rhinometry

ARM (A 1 / 2 Acoustic Rhinometer GM Instruments Ltd., Glasgow, UK), and NR6-2 computerised RMM (GM Instruments Ltd., Glasgow, UK) were performed in study IV at the evaluation visit pre-operatively and in the morning before the procedure in order to assess the day-to-day variation and to create an internal control. The measurements were repeated 3, 6 and 12 months after the procedure. We did the measurements at the same time during the day in a sitting position at the same room temperature and the background noise was minimised. The patients were acclimatised for 15-30 min before in order to minimise the vasoconstrictive effect of physical exercise (Sipilä 1991).

The nasal resistance and cavity volumes were measured with and without vasoconstrictors. A 0.5% xylometazoline hydrochloride solution was sprayed (Nasolin®, Orion, Finland) in both nasal cavities 15 min before the measurements to vasoconstrict the nasal mucosa. In RMM the nasal resistance was measured from each side using a Broms 200 units circle and the total resistance was calculated. In ARM the sum of both nasal cavity volumes were measured from the nostril opening to a depth of 5 cm. The response to the vasoconstrictor agent was evaluated by calculating the differences between the total nasal resistance / volume before and after the vasoconstrictor.

Olfactory thresholds and Saccharine transit time

OTH was conducted in an odourless room under standard conditions using a commercially available smell test kit (OlfactoLabs, Berkley, California, USA). The method has been described elsewhere in details (Amoore et al. 1983, 1986). The threshold was expressed in arbitrary logarithmic units, designated as decismels (dS). The concentrations used were –25, -15, -5, 5, 15, 25, 35, 45 and 55 arbitrary logarithmic units. In the statistical analyses the value of 65 dS was used for those who could not identify even the strongest concentration.

Nasal epithelial function was evaluated before and 3, 6 and 12 months after the procedure by measuring the STT by placing a saccharine particle on the anterior portion of the inferior turbinate. The time until the patient felt sweetness was measured up to 30 min.

Table VII: Summary of the evaluations of morbidity and efficacy in studies I-V.

Study	Assessment methods
I	VAS, questionnaires (SS, ESS), re-treatment acceptance, pain medication, cephalograms, laboratory parameters
II	Operating time, intra-operative bleeding, need of anaesthetics, different recovery indicators in the recovery room (time, medications), in the surgical ward (medications, use of corticosteroids, general condition and status of the uvula the first post -operative day) and the two weeks following (VAS, pain medication, time the patients returned to work, use of antibiotics, re-treatment acceptance), complications and laboratory parameters
III	VAS, questionnaires (SNRSs, SNRSo, ESS), re-treatment acceptance, pain medication MRI
IV	VAS, re-treatment acceptance, OTH, STT, RMM and ARM
V	VAS, pain medication, re-treatment acceptance, laboratory parameters, MRI

F. STATISTICAL METHODS

Paired Wilcoxon ranked signs test was used to determine whether changes from the baseline to the final measurements were significant (I, III, V). Friedman's repeated measures analysis of variance on ranks was used to determine whether changes from the baseline to the final measurements in the laboratory parameters (II, V), questionnaires (III, IV) and RMM, ARM, STT and OTH (IV), were significant. A pairwise multiple comparison procedures with Dunnett's method were done if the change was significant. Certain correlation's between different recovery rates were measured by non-parametric Sperman´s two-tailed correlation test (I-III, V). Non-repeated, non-parametric data was compared using a Mann Whitney test (II, V).

In study II, we chose a clinically significant difference of 20 mm on the VAS, which would be considered reasonable in medical research. A sample size of 15 patients per group was calculated to reveal a clinically significant difference in 20 mm on the VAS with a probability of 80 % in our power calculations. For the VAS scores, areas under curve values were calculated from the time point 1. to 14. post-operative day in order to evaluate to total discomfort of the 14 post-operative days. Day-by-day calculations were done with the Mann Whitney test. A learning curve of the new TErfta method was done in order to evaluate the influence of experience on operating time and intra-operative blood loss.

In study III, linear regression analyses were used to study relationships between dependent and independent variables.

Results were expressed as medians and range and they were generated using computerised statistical packages (SPSS, version 9.0 and Sigma Stat, version 3.0 SPSS science, Chicago, Illinois, USA, Medstat 2.01 Thomson-Medstat Corporation, Ann Arbor, Michigan, USA). A P-value below 0.05 was considered statistically significant.

8. RESULTS

A. The patients enrolled (I-V)

Twenty-one patients were enrolled in study I. The post-treatment results of one patient are lacking and another one was living alone and he could not evaluate his SS. There were only 17 patients in which the post-treatment PW could be measured. In our questionnaires at 12 months after the treatment, we did not manage to contact one patient and those 3 patients that needed an uvulectomy after 3 months are not included.

In study II, 40 patients entered the study. The indication for TE was chronic and/or recurrent tonsillitis in 14 cases in both groups and history of quinsy in 5 cases of the traditional and in 4 cases the RF group. Two patients were subsequently excluded from the study. The first one suffered from a severe post-operative pneumonia, which influenced her recovery rates significantly and the second one excluded had only the right tonsil removed, because the left one had been removed previously due to quinsy. Additionally, one patient cancelled the operation. Therefore, 37 patients were available for the analysis. No inter-group difference was noted in age, gender, weight and indications for TE ($P > 0.05$).

Twenty patients entered study III. One patient did not answer his questionnaires and one did not submit his bed partners' questionnaire results. Their MRI results and VAS are included.

Twenty patients entered study IV, 16 patients with non-infective, non-allergic rhinitis and 4 with non-infective, allergic rhinitis. Six patients had had cryosurgery previously with dissatisfying results. One patient did not attend the follow-up visits. In 14 patients inferior turbinates were treated bilaterally, in 5 unilaterally. One patient did not perform his ARM and RMM, but his subjective assessments are included. Two patients were not satisfied with the results 6 months after the treatment and a turbinoplasty was performed, their evaluation at 12 months is not included.

Ten patients entered study V. One patient did not complete his VAS and analgesic consumption questionnaires, but his laboratory parameters and MRI is included. Two patients received only 2 RF ablations on one of their tonsils, because of treatment-associated discomfort.

Demographic and clinical characteristics of study population are summarised in table VIII.

Table VIII: Demographic and clinical characteristics of the study population presented as median and range.

Study	I	II	III	IV	V
Age (years)	44 (35-55)	30 (19-63)	43 (35-63)	52 (23-77)	24.5 (19-55)
n (m/f)	21 (21/0)	37 (15/22)	20 (19/1)	20 (10/10)	10 (6/4)
BMI (kg/m^2)	26.9 (22.7- 32.3)		25.7 (22.6-34.6)		
Mass (kg)		71 (52-116)			
ODI 4%	0.8 (0-7.3)		0.1 (0-3.8)		
PNS-P (mm)	46.5 (39-54)		45 (34-58)		
PW (mm)	11 (7-14)				
PAS (mm)	13 (8-18)		11 (8-18)		
Drop-outs/Excluded		3		1	
Follow-up	12 m	3 w	9.5 (9-11.5) m	12 m	41 (35-43) w

Abbreviations: BMI = body mass index, ODI = oxygen desaturation index, PNS-P = length of the soft palate from the posterior nasal spine to the uvula, PAS = posterior airways space, PW = palatal width, m = months, w = weeks.

B. Morbidity of the procedures

a. Visual analogue scale and different recovery rate indicators (I-V)

Studies I, III

All the patients tolerated the procedure well. The most common complaint was swelling of the soft palate, which gradually decreased during the two-weeks follow-up time. Pain scores (Figure 4,5) were the highest the day after the first treatment session and then gradually decreased during the two-week period. One patient, in study III, was given corticosteroids because of the swelling. In study III, 4 patients received antibiotics because of development of a small abscess in the insertion point of the electrode. Minor transient changes in speech and swallowing difficulties were encountered (Figure 4,5).

Fourteen patients in study I and 6 patients in study III developed a mucosal blanching. The post-operative morbidity showed significant correlation with the occurrence of blanchings after the treatments. The patients with blanchings reported higher VAS scores in pain, swelling sensation and dysphagia, but not in speech. In study I, these blanchings did not correlate with the use of pain medications ($r = 0.220$, $P = 0.492$). However, in study III, the blanchings correlated with the use of pain medications ($r = 0.882$, $P = 0.036$) but not with the use of antibiotics ($r = 0.357$, $P = 0.882$), although, in a linear regression model the occurrence of blanchings did not increase significantly the use of pain medications ($R^2 = 0.030$, $F = 0.553$, $P = 0.467$) or the need for antibiotics ($R^2 = 0.128$, $F = 2.633$, $P = 0.122$). There was no signs left of these blanchings at the follow up visit.

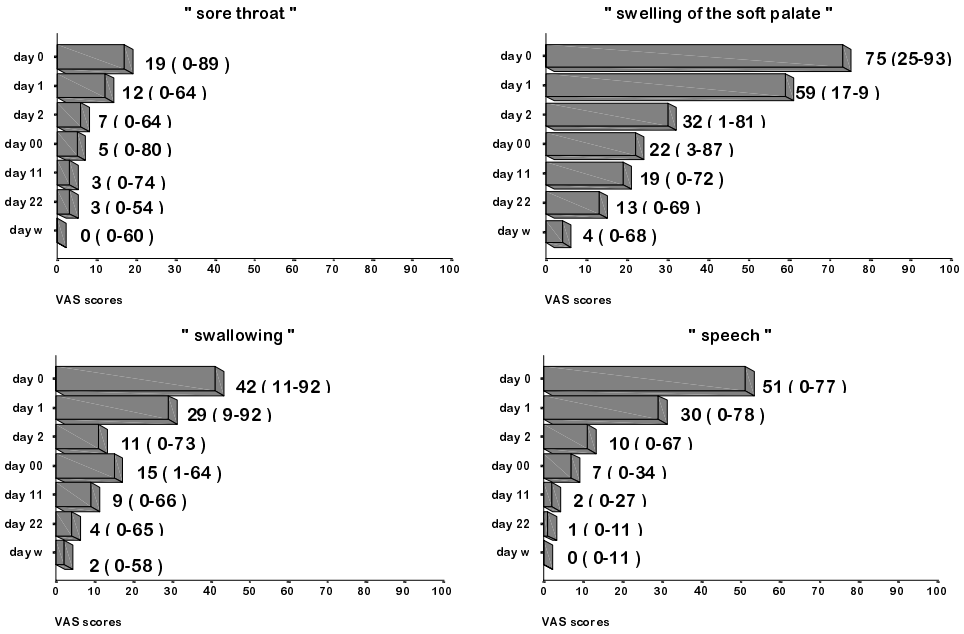

Figure 4: *Visual analogue scale scores (median and range) of different symptoms related to the monopolar radiofrequency thermal treatments of the soft palate in study I. Abbreviations: VAS = visual analogue scale, Day 0 = the first treatment day, day 1 = the day after the first treatment, day 2 = two days after the first treatment, day 00 = the second treatment day (one week after the first treatment day), day 11 = the day after the second treatment, day 22 = two days after the second treatment, day w = one week after the second treatment.*

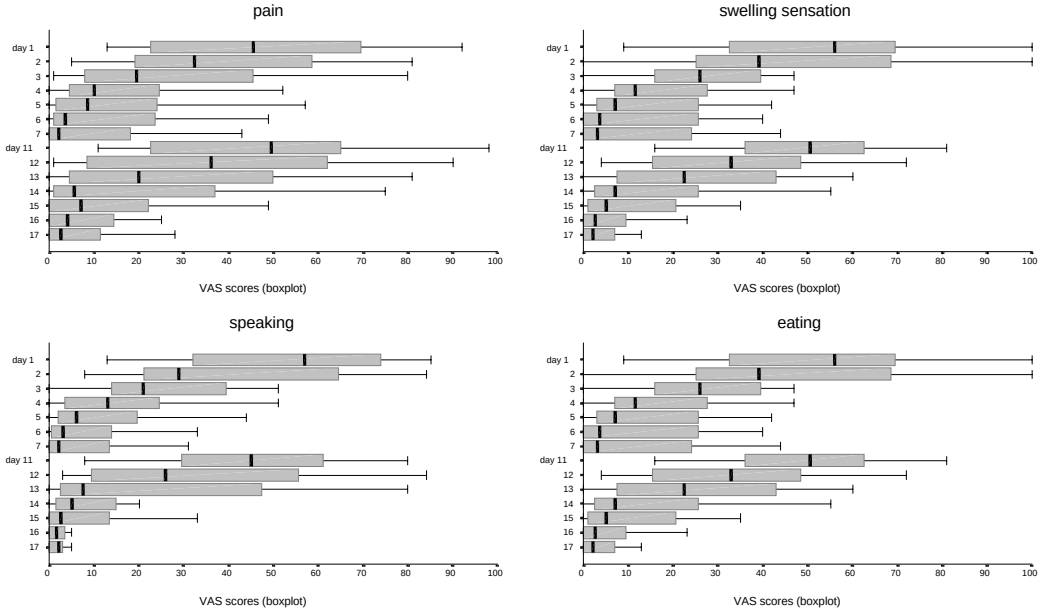

Figure 5: *Visual analogue scale scores (boxplot) of different symptoms related to the bipolar radiofrequency thermal ablations in study III. Abbreviations: VAS = visual analogue scale, Day 1 = the first treatment day, 2/ 3/ 4/ 5/ 6/ 7 = the days following the first treatment, day 11= the second treatment day (one week after the first treatment day), 12/ 13/ 14/ 15/ 16/ 17 = the days following the second treatment.*

Study II and V

In study II, the VAS questionnaires on the different symptoms showed no significant differences in neither the day-by-day analysis ($P > 0.05$) nor in the whole post-operative period analysis ($P > 0.05$) (Figure 6). There was a significant difference in operating time and intra-operative blood loss in favour of the TEtrad group ($P < 0.01$ and $P < 0.001$ respectively). There were no significant differences between the groups in their requirement of intra-operative additional fentanyl or post-operative need of oxycodone doses, the time spent in the recovery room, the occurrence and the management of primary and secondary bleeding, the need for corticosteroids, the general condition and the swelling of the uvula the following morning after surgery, the use of antibiotics or the time the patients returned to work. The variations on the learning curves in the RF group on operating time and intra-operative blood loss diminished, but they showed no significant correlation with the number of procedures done (number vs. operating time $r = 0.185$, $P = 0.461$, number vs. intra-operative bleeding $r = -0.099$, $P = 0.695$).

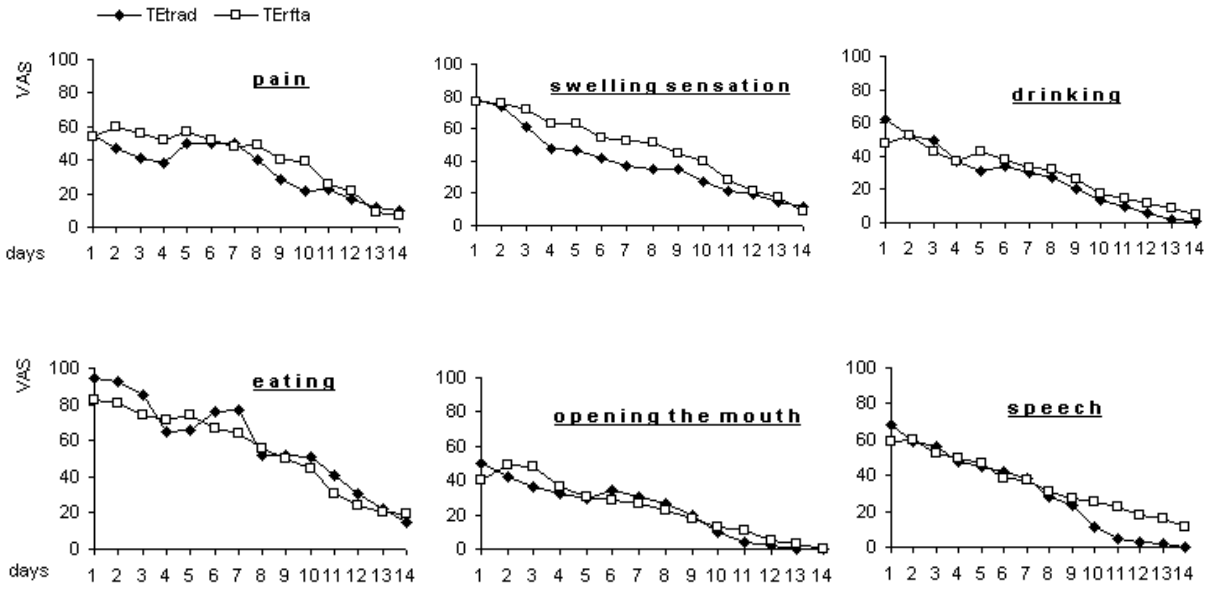

Figure 6: *Visual analogue scale scores obtained daily for two weeks on different symptoms following elective tonsillectomy with the TEtrad and TErfta techniques in study II. The data points represent the median of the group on each day. Abbreviations: VAS = visual analogue scale, TEtrad = traditional tonsillectomy, TErfta = radiofrequency thermal ablation tonsillectomy.*

In study V, the majority of the patients tolerated the RF ablation procedure well. Mucosal sloughing Bleeding related to the procedure did not occur. Four patients developed an infection after the treatment and were prescribed penicillin. The most common complaint was a swelling sensation, as in studies I and III, which gradually decreased during the one-week follow-up time (Figure 7). However, no patient received corticosteroids. Pain scores were the highest on the night after the treatment. The VAS scores of every symptom were significantly lower in the tonsillar reduction group in study V than in the two TE groups in study II after the 4th post-operative day.

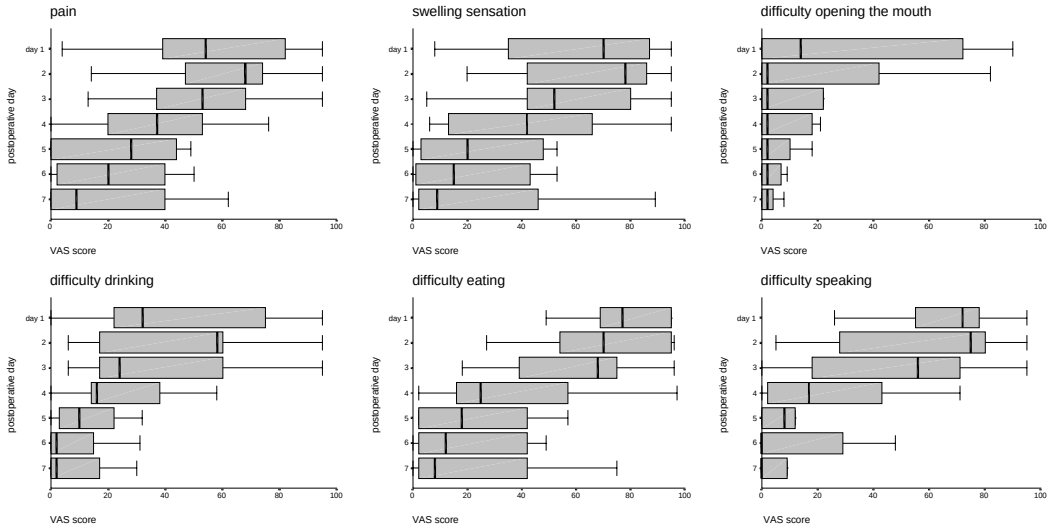

Figure 7: Visual analogue scale scores (boxplot) of different symptoms related to submucosal bipolar radiofrequency thermal tonsillar reduction in study V. Abbreviations: VAS = visual analogue scale, Day 1 = the first treatment day, 2/ 3/ 4/ 5/ 6/ 7 = the days following the treatment day.

Study IV

The majority of the patients tolerated the RF ablation of the inferior turbinates procedure well. No patients had mucosal erosion, bleeding or adherent crust formation. The most common complaint was pain and nasal discharge immediately after treatment, which gradually decreased after two days. Minor transient changes in crusting and sneezing were recorded (Figure 8). Although the treatment induces mild to moderate oedema it did not adversely affect the scores or degree of frequency of nasal obstruction immediately after treatment (Figure 8).

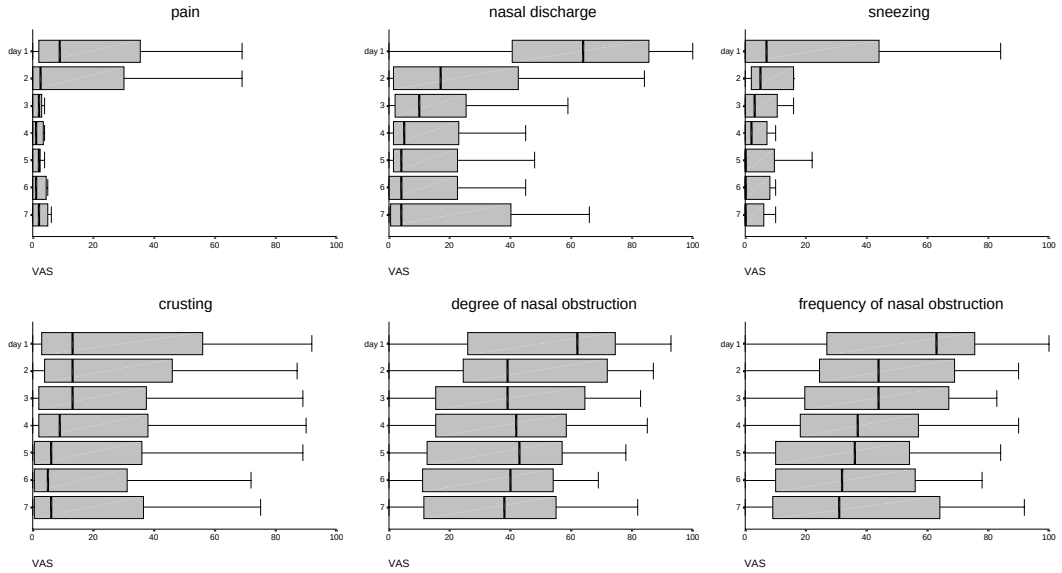

Figure 8: *Visual analogue scale scores (boxplot) of immediate post-operative nasal symptoms related to the submucosal bipolar radiofrequency thermal ablations of the inferior turbinates in study IV. Abbreviations: VAS =visual analogue scale, Day 1 = the treatment day, 2/ 3/ 4/ 5/ 6/ 7 = the days following the treatment day.*

b. The use of pain medication (I-V)

The use of pain medication in studies I and III was low with a median of 1 (0-9)(I) and 2 (0-27)(III) dosages during the two-week period. There were no significant differences between the groups (P = 0.072), although, the tendency was clearly in favour of study I.

In study II, the use of pain medications in the surgical ward, during three days, seven days and two weeks time post-operatively did not show significant differences between the groups (P > 0.05). However, the use of pain medications during the post-treatment week was significantly lower in the tonsillar reduction group in study V than in the two TE groups in study II group (P = < 0.001 respectively).

c. Re-treatment acceptance (I-V)

All the patients treated with RF energy of the soft palate (I, III) were willing to undergo additional treatment if necessary. There were no significant differences between the groups according to their re-treatment acceptance in study II (yes 15/15 no 5/4, P > 0.05). Two of the patients with their inferior turbinates treated (IV) and one in the tonsillar reduction group (V) refused additional sessions due to treatment-associated discomfort.

d. Inflammatory response (I-II, V)

The monopolar RF energy on the soft palate (I) did not induce notable changes related to the procedure in any of the laboratory parameters. The two different TE techniques (II) and bipolar RF energy ablation into tonsillar tissue (V) resulted in a significant change from the baseline to the final measurements suggesting that an inflammatory host response is induced by the procedure (P = < 0.001). In study II, the change in the ESR was significant on the first postoperative day and two weeks after the operation with both the techniques. This change was also noticed the first post-operative day in CRP in both the techniques, but only in the study group two weeks after the operation. Thus, the only difference between the groups was a significant CRP value change in the TErfta group but not in the TEtrad group. In study V, the changes of the values were significant compared to the preoperative one.

C. Efficacy according to the questionnaires, imaging results and tests of nasal function

a. Questionnaires (I, III, IV)

Study I and III
The analyses of the questionnaires in studies I and III of all the patients showed a significant change indicating decreased snoring and daytime sleepiness. Fourteen patients out of 20 (70%) in study I was satisfied after two treatments. A 3rd treatment was given to 3 patients. The success rate was 17 / 20 (85%). Three (15 %) needed an uvulectomy despite the RFTA-treatments. In study III, the changes in the questionnaires SNRSs and SNRSo from before to 3 months and 9.5 (9-11.5) months after the procedures correlated significantly (r = 0.792, P = < 0.001and r = 0.529, P = 0.029, Figure 9,10). In the regression analyses the changes in the SNRSs and SNRSo questionnaires from before to 3 months and 9.5 (9-11.5) months after the procedures were of the same kind indicating similar improvement in the symptoms determined by the patient and the bed partner. SNRSs explained

70.2% of the variance of the SNRSo at 3 months (R^2 = 0.702, F = 15.561, P = 0.001) and 54.5% of the variance at 9.5 (9-11.5) months (R^2 = 0.545, F = 17.988, P = 0.001).

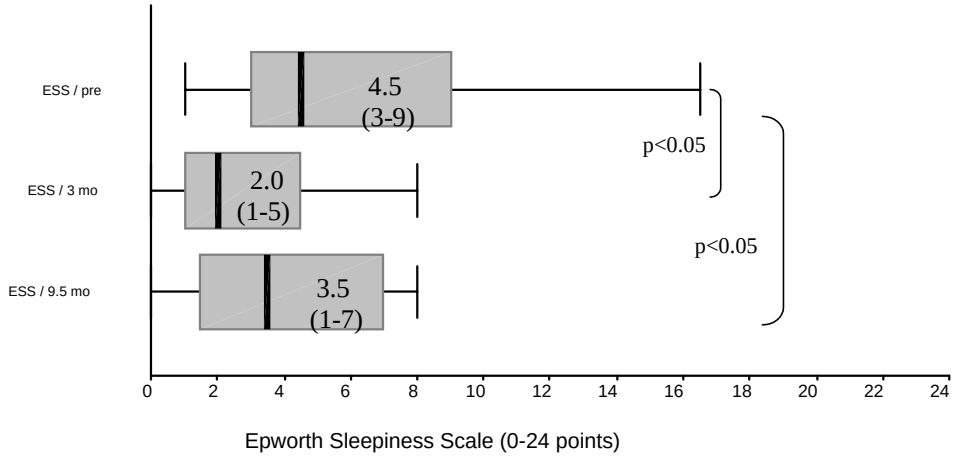

Figure 9: *Epworth sleepiness scale scores (boxplot, median with 95% Cl) pre- and post-operatively in study III. Abbreviations: ESS = Epworth sleepiness scale, pre = pre-operatively, 3 mo = 3 months after the treatments, 9.5 mo = 9.5 (9-11.5) months after the treatments, CI = confidence interval.*

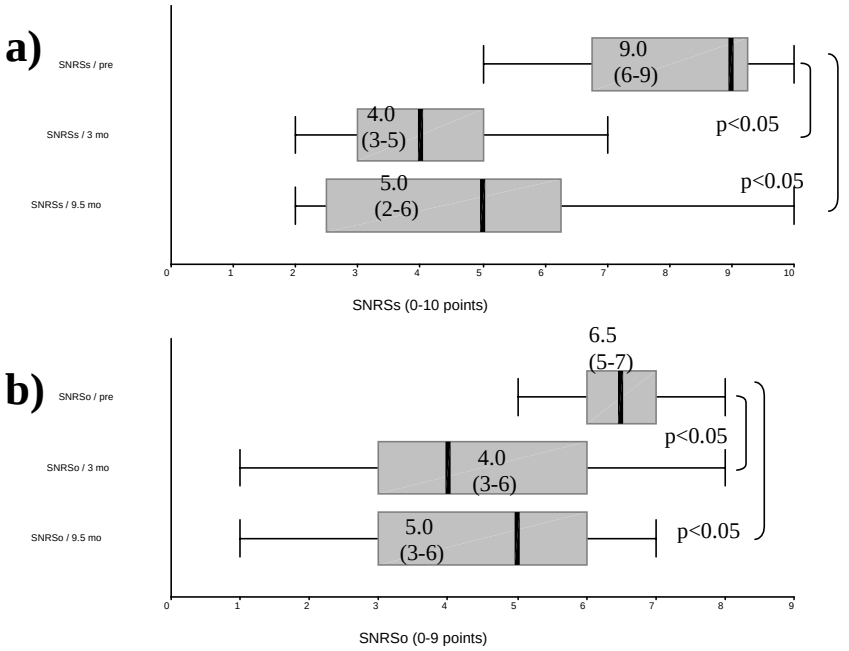

Figure 10: *The snoring scores (boxplot, median with 95% Cl) assessed by the patient (a) and the bed partner (b) pre- and post-operatively in study III. Abbreviations: SNRSs = snoring score assessed by the patient, SNRSo = snoring score assessed by the bed partner, pre = pre-operatively, 3 mo = 3 months after the treatments, 9.5 mo = 9.5 (9-11.5) months after the treatments, CI = confidence interval.*

We defined a relapse in the treatments as changes of more than two points in the questionnaires in study I and, accordingly, there were four relapses in our follow up study (I) (Figures 11,12).

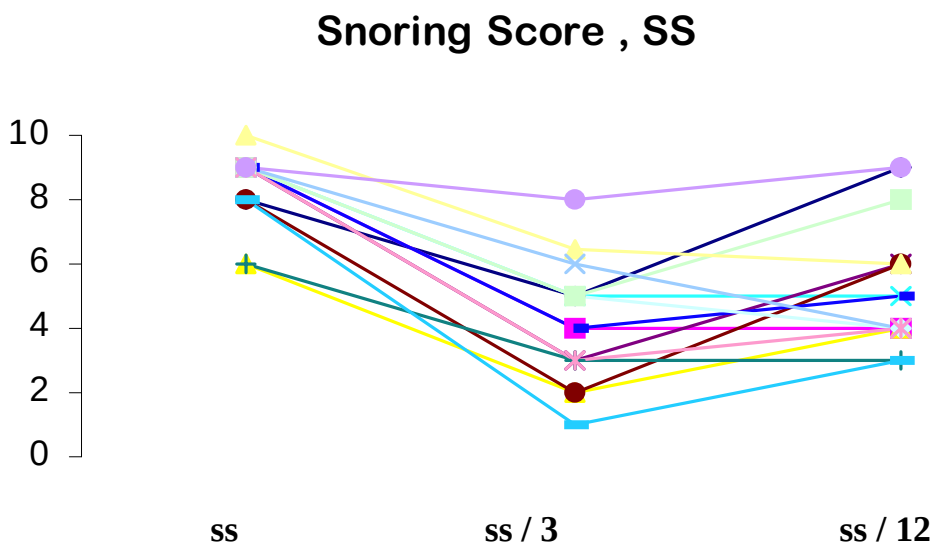

Figure 11: *Snoring scores results pre- and post-operatively shown case by case in study I. SS/ 3 and SS/ 12 are the results obtained three and twelve months after the treatments. There were four significant relapses. Abbreviations: SS = snoring score assessed by the patient (= SNRSs).*

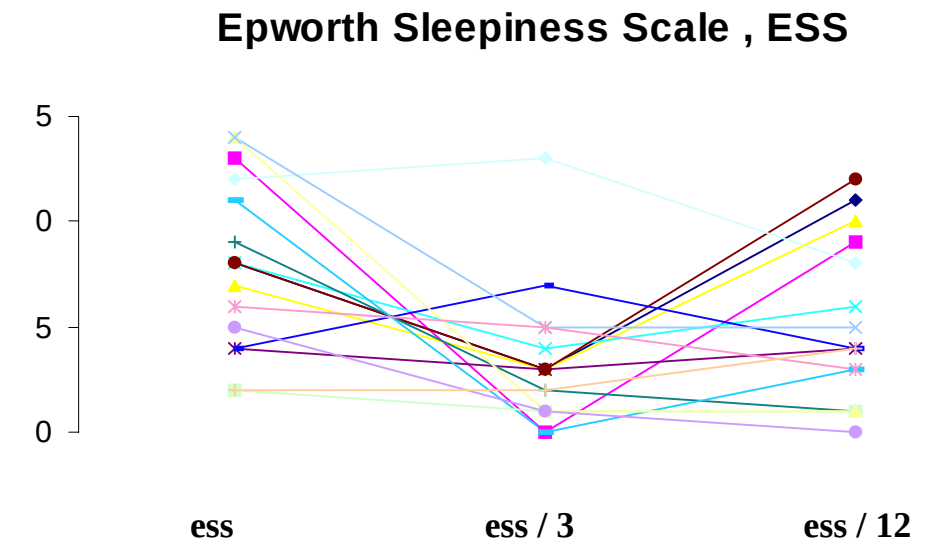

Figure 12: *Epworth sleepiness scale results pre- and post-operatively shown case by case in study I. ESS/ 3 and ESS/ 12 are the results obtained three and twelve months after the treatments. There were four significant relapses. Abbreviation: ESS = Epworth sleepiness scale.*

Significant improvements, successful outcomes and relapses according to our criteria in study III are shown in Table IX.

Table IX: Evaluation of the efficacy and relapses of two bipolar radiofrequency thermal ablations of the soft palate according to the SNRSs (n=19) and SNRSo (n=18) questionnaires in primary habitual snorers in study III.

	Significant improvement	Successful outcome	Relapses
SNRSs / 3 mo	11/19 (58%)	6/19 (32%)	
SNRSs / 9.5 mo	12/19 (63%)	7/19 (37%)	4/19 (21%)
SNRSo / 3 mo	7/18 (39%)	6/18 (33%)	
SNRSo / 9.5 mo	6/18 (33%)	5/18 (28%)	1/18 (6%)

A successful treatment outcome was defined as a reduction of SNRSs from at least 7 to 0-3 points and a reduction of SNRSo from at least 6 to 0-3 points. An improvement in the SNRSs and SNRSo of 3 points was considered significant. The relapse in treatment was defined as a change of more than two points in the SNRSs and SNRSo questionnaires between 3 and 9.5 (9-11.5) months after treatment. Abbreviations: SNRSs = snoring score answered by the patient, SNRSo = snoring score answered by the bed partner, mo = months.

Study IV

After the RF ablation of the inferior turbinates (IV), the VAS scores of subjective complaints in the 12 months follow-up decreased significantly (Figure 13). Evaluation of the effectiveness of the treatment showed significant changes without significant relapses (Figure 14).

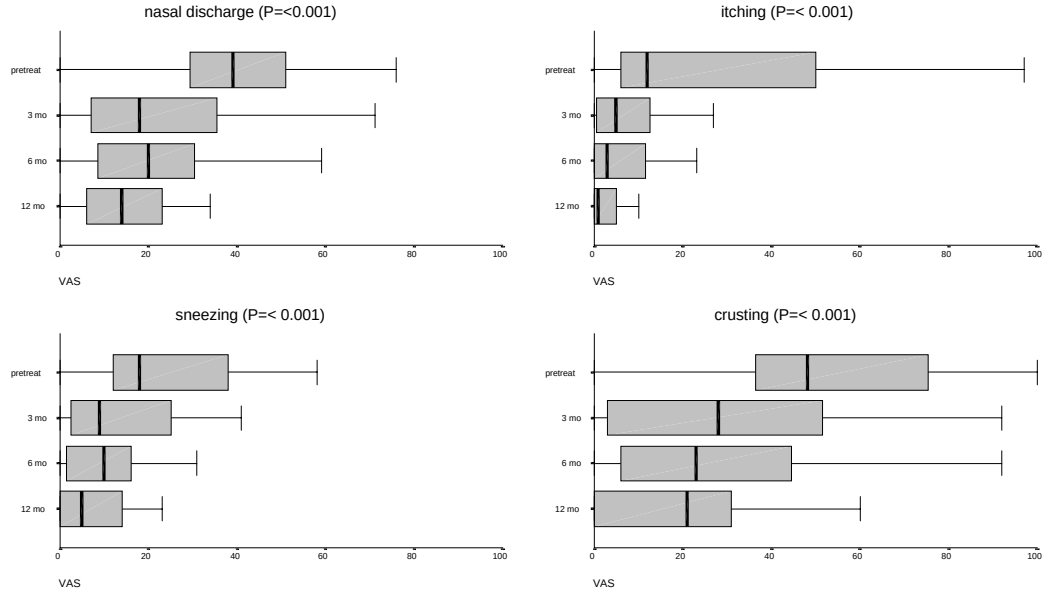

Figure 13: *Visual analogue scale scores (boxplot) of long-term symptoms (nasal discharge, itching, sneezing, crusting) related to the submucosal bipolar radiofrequency thermal ablations of the inferior turbinates in study IV. Abbreviations: VAS = visual analogue scale, pretreat = before the treatments, 3 mo / 6 mo /12 mo = 3 / 6 / 12 months after the treatments post-operatively.*

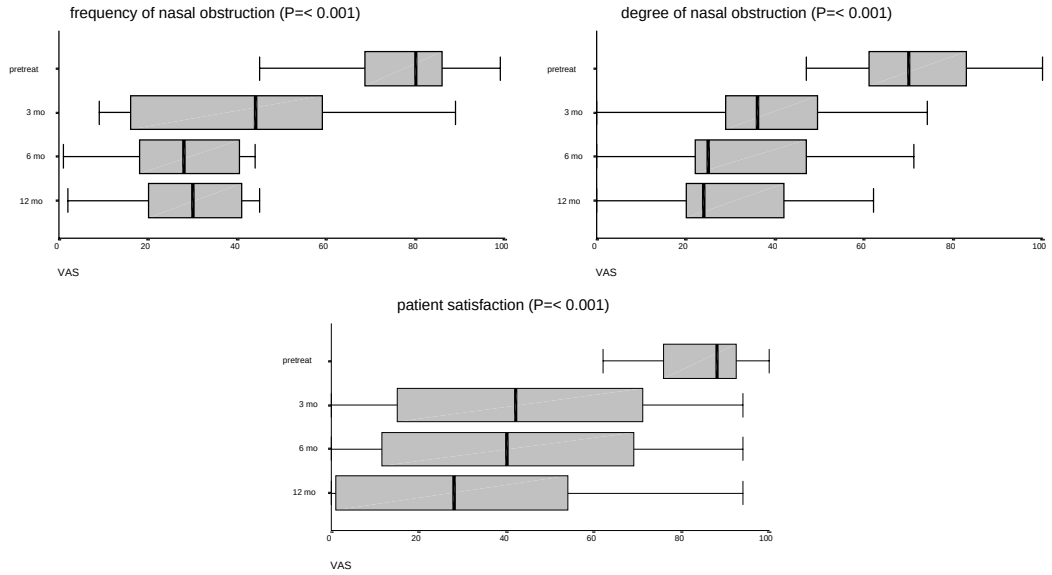

Figure 14: *The evaluation of the long-term effectiveness (frequency of nasal obstruction, degree of nasal obstruction and patient satisfaction) of the submucosal bipolar radiofrequency thermal ablations of the inferior turbinates using visual analogue scale scores (boxplot) in study IV. Abbreviations: VAS = visual analogue scale, pretreat = before the treatments, 3 mo / 6 mo / 12 mo = 3 / 6 / 12 months after the treatments post-operatively.*

b. Imaging results (I, III, V)

With monopolar RFe treatment of the soft palate (I), the reduction of the soft palate length was significant ($P < 0.01$) indicating volume reduction of the soft palate. The changes in the PNS-P did not correlate with the changes in the questionnaires (SS-PNS-P r = 0.098, P = 0.691, ESS-PNS-P r = -0.014, P = 0.952). The changes in PW, which was measured in 17 cases, were not significant (P = 0.13).

In study III with bipolar RF energy treatment of the soft palate, the second MRI was performed in 13 weeks after the first treatment. There was a significant change in the distance between the tip of the uvula and the bottom of sella, indicating a retraction of the uvula (P = 0.005). However, the length of the soft palate was not significantly shortened (P = 0.849 and P = 0.983). The change in the T1-signal intensity, reflecting fibroid scar formation of the soft palate, showed major changes in 9 cases, moderate in 4 cases and no/mild changes in 6 cases. These changes did not correlate significantly with the changes in the questionnaires before and three months after the treatment (r = -0.196, P = 0.421, r = -0.156, P = 0.536 and r = 0.064, P = 0.795 respectively). In a linear regression analysis SNRSs-change explained only 2.3% of the variance of the T1-signal change. There was no relationship between questionnaires and T1-signal change (R^2 = 0.023, F = 0.404, P = 0.534 // R^2 = 0.005, F = 0.083, P = 0.777 // R^2 = 0.011, F = 2.633, P = 0.699 respectively). Neither was the T1-signal intensity before the treatments a prognostic factor for a successful treatment outcome (R^2 = 0.116, F = 2.222, P = 0.154 // R^2 = 0.007, F = 0.111, P = 0.793 // R^2 = 0.072, F = 1.241, P = 0.282 // R^2 = 0.000, F = 0.007, P = 0.933). There were no significant changes in the other dimensions of the soft palate.

The MRI after the tonsillar reduction (V) was done 19 (18-28) weeks after the treatment. Reliability of the measurement evaluated by comparing the two radiologists measurements of the

treatment group and the control group was good, the volumes did not differ significantly (treatment group P = 0.48 – 0.68, control group P = 0.53 - 0.80). The volume of both tonsils in the treatment group reduced significantly (P < 0.01). The tonsillar volumes in the control group did not change (right tonsil volume P = 0.14, left tonsil volume P = 0.33). The decrease in the tonsil volume did not correlate with the need of TE after the reduction (r = - 0.098, P = 0.79 and r = - 0.312, P = 0.38 respectively).

c. Tests of nasal function (IV)

Rhinomanometry and acoustic rhinometry

In RMM the total nasal resistance and response to the vasoconstrictor agent diminished after the procedures during the follow-up period, but the changes were not significant (Figure 15). However, in ARM the change in the sum of both nasal cavity volumes from nostril to 5 cm were significant 6 and 12 months after the treatments (Figure 16). The difference between the pre- and post-operative vasoconstrictive effect in ARM diminished up to 6 months after the treatment. However, the high variation of the values at 12 months made the overall statistical change not significant (Figure 16).

Olfactory threshold and saccharine transit time

According to the OTH and STT determinations, there were no adverse effects on nasal epithelial clearance time and olfactory functions. In fact, the values were better 6 months after than before the treatments (Figure 17).

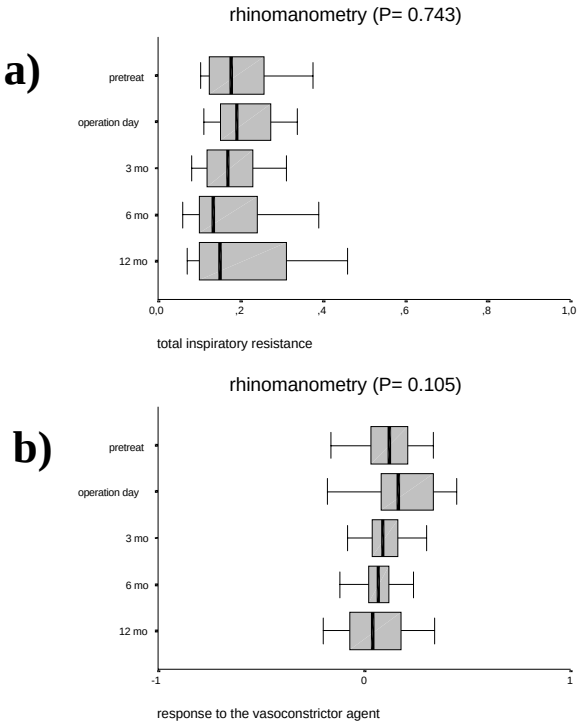

Figure 15: *The total nasal resistance (a) and the response to the vasoconstrictor agent (b) evaluated with rhinomanomerty related to the submucosal bipolar radiofrequency thermal ablations of the inferior turbinates (boxplot) in study IV. Abbreviations: pretreat = evaluation visit pre-operatively, operation day = the morning before the procedure, 3 mo / 6 mo / 12 mo = 3 / 6 / 12 months after the treatments post-operatively.*

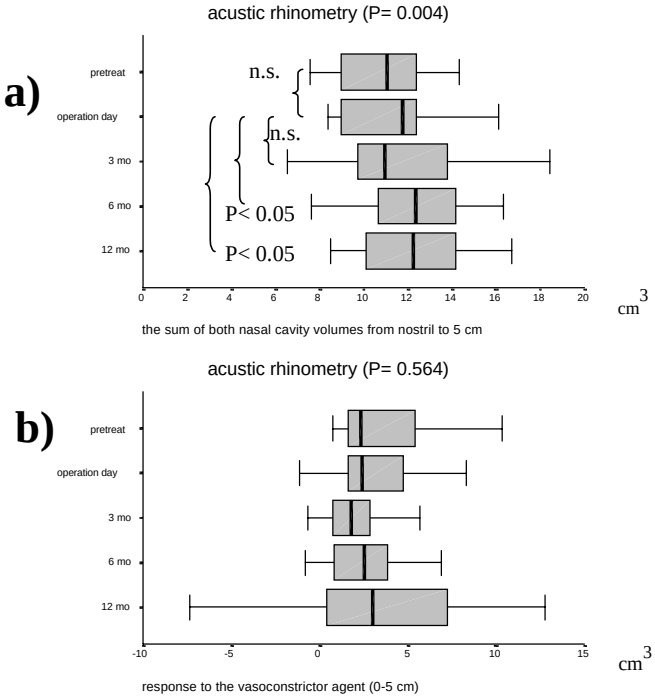

Figure 16: *The sum of both nasal cavity volumes from nostril to 5 cm (a) and the response to the vasoconstrictor agent (b) evaluated with acoustic rhinometry related to the submucosal bipolar radiofrequency thermal ablations of the inferior turbinates (boxplot) in study IV. Abbreviations: pretreat = evaluation visit pre-operatively, operation day = the morning before the procedure, 3 mo / 6 mo / 12 mo = 3 / 6 / 12 months after the treatments post-operatively, n.s. = non significant.*

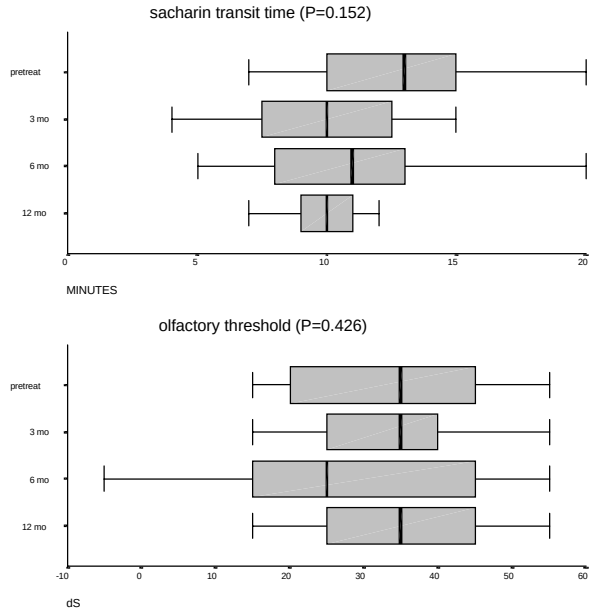

Figure 17: *Olfactory threshold and saccharine transit time determination (boxplot) related to the submucosal bipolar radiofrequency thermal ablations of the inferior turbinates in study IV. Abbreviations: pretreat = before the treatments, 3 mo / 6 mo / 12 mo = 3 / 6 / 12 months after the treatments post-operatively, dS = decismels.*

9. DISCUSSION

A. General discussion

The studies show that RFTA of the soft palate, tonsils and inferior turbinates are well tolerated by patients because of minimal discomfort. All these RFTA procedures seem also to have at least a fairly good efficacy as compared to any conventional surgical procedures. The RFTA procedures are easy to perform and have as minimally invasive outpatient procedures a high re-treatment acceptance. The efficacy of RFTA is based on the assumption that it leads to necrosis and fibrosis with contracture of target tissue without actual removal (Powell et al. 1997), although, the ideal RFTA-treatment modality for snoring, obstructive hypertrophied turbinates and hypertrophied tonsils is unclear. The number of treatment sites, optimal energy per treatment site and value of repeated treatment sessions while maintaining satisfactory tolerance needs to be evaluated. In all, it seems that the efficacy of RFTA of the soft palate, inferior turbinates and tonsils has been proven in a similar manner as with the previous treatment modalities (Carenfelt 1991, Kamami 1994, Lenz et al 1977).

The reduction of post-TE morbidity is important, not only for patient comfort, but also because reducing pain improves oral intake, which reduces risk of dehydration, infection and post-TE haemorrhage. Electrosurgical instruments and lasers all achieve cutting and simultaneous haemostasis by sealing the blood vessel lumina by virtue of tissue heating. Earlier studies support the hypothesis that the extent of diathermy used in TE has a direct influence on the delayed post-operative morbidity and healing of the mucosal wounds (Choy et al. 1992). The degree of pain must be related to the degree of soft tissue damage. Apparently, the TErfta technique does not affect positively on the factors causing the post-operative pain. However, the RF tonsillar reduction seems to be a promising alternative in treating obstructive tonsillar disease.

Questionnaires were used extensively in current investigations in order to gather data on the subjective variables. VAS has been firmly suggested as a reliable method for reporting of pain and other symptoms (Price et al. 1983). The RFTA induced objectively detectable changes in radiological images and assessments of nasal patency in studies I, III, IV and V. However, all of these changes did not correlate with the clinical outcome or the subjective assessments.

In all the studies, the normality tests of the patient groups failed. Thus, the only way of performing statistical analyses was to use non-parametric tests in every study.

Studies I, III-V are prospective case series and the results are partly based on subjective outcomes. The promising results of radiofrequency ablation need to be confirmed in a placebo-controlled randomised study with a larger sample size and a long-term follow-up. There are some studies now being reported that attempt to address this objective. The preliminary results published by Terris (Terris et al. 2002) from a prospective, randomised trials of two palatal operations (RFTA and LAUP) for SDB reveal that prospective, randomised trials of surgery for snoring are possible. There was a slight advantage of LAUP over RFTA in snoring reduction, but with a greater degree of discomfort post-operatively. In subjects using CPAP with turbinate hypertrophy, the RF treatment appears to improve nasal breathing and CPAP-treatment for SDB, a conclusion drawn by Powell (Powell et al. 2001) in a randomised, double-blinded, placebo-controlled study with subjective assessment using VAS.

B. Morbidity

Study I and III
Pain is moderate or intense after surgical procedures of the palate and mesopharynx requiring pain medication for up to two weeks. RFTA of the soft palate leaves the mucosa intact contrary to LUPP, LAUP and UPPP. Almost all the patients in our studies (I, III) reported restless sleep on the first post-treatment night because of mild discomfort and feeling of swelling of the soft palate. Speech and swallowing difficulties are well-known complications after palatal surgery (Fairbanks 1990). Only mild or moderate speech or swallowing problems were reported with the RFTA-treatment and they resolved within two days. The overall post-operative discomfort was low even though there were a few blanchings in the soft palate. The occurrence of blanchings did not increase the post-operative discomfort, which is in accordance with the studies by Pazos (Pazos et al. 2001) and Terris (Terris et al. 2001).

There is a clear-cut advantage of RFTA-treatment over UPPP, LUPP or LAUP with respect to post-operative morbidity. This may be due to avoidance of mucosal transection in using a protective sheat (I Tuna 3, III ReFlex^{TM} 55) in both the wands. RFTA treatment with the hand piece (ReFlex ^{TM} 55 (III)), caused more blanchings than we experienced with the usage of monopolar Vidamed® (I) and have been reported with the usages of monopolar Somnoplasty® (Powell et al. 1998, Coleman et al. 2000). Additionally, four patients needed antibiotics during their recovery because of development of a small abscess in the insertion points of the soft palate. This complication has not been reported previously. The ReFlex^{TM} 55 hand piece is of greater size than that of the Vidamed® or Somnoplasty®, but the treatment time was only 15 s per site, which the patients accepted easily. The ongoing acute and chronic inflammatory response, due to our treatment regimen, may contribute to an increased risk of infection. The effect of these blanchings and the need for antibiotics on post-operative morbidity cannot be evaluated in the present study.

Study II and V
Pain is intense after TE requiring pain medication for up to two weeks, independent of the technique or equipment employed. Our aim was to evaluate several different post-operative symptoms in our VAS questionnaires and we thought that it would be difficult to evaluate differences between right and left sides. Therefore we chose to randomise the patients in the two groups.

Our study did not show a significant difference in post-operative morbidity between the two techniques, the TEtrad and TErfta. Differences in intra-operative blood loss and operating time were statistically significant, but clinically insignificant in otherwise healthy adults. Although, there were no significant differences between the groups in the occurrence of primary and secondary bleedings, the frequencies (haemostasis was done in the operating room in 5 % of the cases and in 19% the bleeding was managed locally) were higher than usually seen in our practice. This might be due to the study setting (i.e. the patients were advised to contact the ENT ward immediately when signs of bleeding occured) or by chance.

During the operation, the need of diathermy was common in the TErfta group to achieve haemostasis and therefore there might be deeper thermal damage to the surrounding tissue. Thus, both groups sustained the same thermal injury at least in portions of the tonsillar beds and the possible beneficial value of bipolar RFTA tonsillectomy was eliminated by the usage of diathermy. This can also affect the post-operative morbidity in a significant manner. During the time of learning a new technique, these matters may be corrected. However, this was not shown in this pilot

study with small groups. Apparently, the TErfta technique does not decrease the post-operative pain after TE.

The morbidity of the outpatient procedure of RF tonsillar reduction in study V can be considered acceptable compared with two different TE techniques, namely the traditional and the RFTA technique. The difference was significant after the 4th post-operative day, although, the patients were not totally free of symptoms thereafter. However, the return to their pre-treatment activity was prompt in the tonsillar reduction group. Four patients were prescribed antibiotics post-operatively and there were significant changes in the inflammatory laboratory parameters as well as in the TE groups. In the future, we recommend the use of prophylactic antibiotics in tonsillar reduction, which partly differs from the guidelines of antibiotic use in Finland (Rautakorpi et al . 1999).

Study IV
Our results of RFTA of the inferior turbinates are based on long-term subjective and objective assessment, which has not been reported before. The procedure seems to be effective, it can be repeated if necessary and there were no significant relapses. Our results indicate that in treating this patient group a follow-up of six months is needed before you know whether the intervention is effective. Laser-, cryo- or electrocautery reductions are not well tolerated by patients under local anaesthesia and can cause prolonged rhinorrhea and worsening of nasal obstruction secondary to oedema and crusting. This is probably due to the depth of tissue injury, which is unpredictable with laser-, cryo- or electrocautery, in contrast with RF energy. Additionally, RF equipment avoids potential laser hazards. In our study VAS scores of subjective long-term nasal complaints at follow-up decreased significantly indicating the procedure having a symptom-controlling effect.

The application of RF energy to the anterior part of inferior turbinates was used to minimise any potential adverse effect to the physiologic function of the turbinate. Additionally, the anterior end of the inferior turbinate was selected as the treatment site because the swelling of the erectile tissue in this location significantly increases nasal resistance leading to nasal airway obstruction (Haigtht et al. 1983). A previous turbinate procedure was not an exclusion criterion, because the patients were still unsatisfied with the present situation.

C. Efficacy according to the questionnaires, imaging results and tests of nasal function

a. Questionnaires (I, III)

Snoring is first and foremost a subjective perception by a listener. Several methods of treatment for snoring have been developed, but there is no general agreement on how snoring should be assessed. Objective measurements are usually made in unnatural environment. Neither is there any standard measurement of snoring in the sleep laboratory. Other qualities of snoring than the loudness of snoring, such as its frequency content, may contribute to the annoyance caused by snoring (Smithson et al. 1995). Therefore, in most studies reliance is placed on subjective assessment.

Assessment of snoring by self-report is limited because persons naturally are unaware of their behaviour during sleep. During the clinical interview the spouse may verify the patients' symptoms and many recommend that spouses should be routinely queried concerning the sleep-related symptoms of their mates. Clinicians have recognised that patient- and spouse-derived histories of snoring often differ. However, the overall agreement between self- and spouse related symptoms have been found to be generally high. Furthermore, patients who report that they snore habitually

do seem to snore objectively (Koskenvuo et al. 1987). Even though, the results of the questionnaires may be misleading in part, which can affect estimates of treatment effects (Wiggins et al. 1990). Additionally, the assessment tools based on self-report can be influenced by the placebo effects.

The subjective outcome (snoring and daytime somnolence) of mono- and bipolar RFTA of the soft palate in habitual snorers was satisfactory. Our results are in agreement with the other reports on RFe (Powell et al. 1998, Coleman et al. 2000, Emery et al. 2000, Boudewyns et al. 2000, Ferguson et al. 2001, Sher et al. 2001). The short-term results of the present study are compatible with those of UPPP (Levin et al. 1994), LUPP (Carenfelt 1991) and LAUP (Kamami 1994). It appears that the efficacy of RFTA treatment diminishes with time similar to other surgical procedures of the palate. However, the relapses after RFTA can be treated with additional RFTA-treatments (Li et al. 2000). The minimal invasiveness of the RFTA-treatment provides a high acceptance of re-treatment also shown in these studies.

b. Imaging results (I, III and V)

Cephalometric analysis in study I with monopolar RFTA of the soft palate showed a significant shrinkage of the PNS-P, but not in the PW. Cephalometric analysis cannot give us information about the changes in the volume or increased stability of the soft palate. Although, there was some shrinkage of the soft palate, we presume that the advantageous outcome regarding snoring and daytime somnolence was mainly due to increased rigidity of the palate caused by the tissue scarring. This speculation is supported by the fact that the shrinkage of the PNS-P did not correlate with the subjective outcome measures. The measurement of the palate length may not be a good parameter in determining the outcome in future studies.

The soft tissue resolution capability is superior with MRI compared with other radiological methods available; it avoids radiation exposure and yields both transverse and sagittal sections of the upper airways. Our hypothesis was that MRI would be the only radiological way to find possible objective changes caused by RF energy. To our knowledge, there is no previous report on treatment evaluation of habitual snorers and obstructive tonsillar volumes with MRI. In evaluation of the upper airways in patients with SDB, MRI has been shown to be a useful research tool in two review articles (Douglas 1990, Shepard et al. 1991) and an effort to develop a standardised protocol for MRI measurements of the upper airway has been published by Stuck (Stuck 2002 b).

MRI provides indirect information about the changes in the stability of the soft palate. In study III the RFe induced objectively detectable changes in certain dimensions and in the T1-signal intensity of the soft palate. Simultaneously, there was an advantageous outcome regarding snoring and daytime somnolence. However, there was no statistical relationship between the results of the questionnaires and the MRI-analyses. The degree of the T1-signal intensity 3 months after treatment reflects most probably scar tissue formation supporting the theoretical background of RFTA treatment. We presume that the increased rigidity of the palate caused by tissue scarring is the basis of the relief of symptoms and improved sleep quality. Thus, RFTA seems more reasonable compared to removing the noise-causing vibrating portion of the snorers soft palate.

In study V, the RFTA induced objectively detectable changes in tonsillar volume. Simultaneously, there was an advantageous outcome regarding the need of TE in patients with symptomatic obstructive tonsillar disease. The clinical outcome of the treatment was evaluated after the first treatment session because our primary aim was to assess the radiological outcome. There were a decrease in the tonsillar volume induced by the RFTA procedure in the treatment group, whereas there where no change in the tonsillar volume of the control group. The reliability of our assessment

method was evaluated with the pre-treatment MRIs and the MRIs from the control group. We achieved an acceptable clinical outcome of 7/10 with this setting and it is probable that it would increase with repeated treatment sessions. However, this cannot be evaluated in this study.

c. Tests of nasal function (IV)

In RMM the coefficient of nasal resistance was chosen because it has the best validity, calculability and reproducibility (Sipilä 1991). In ARM the 0-5 cm range was chosen since it includes the functional nasal valve and most of the septal and lateral erectile tissue (Hilberg et al. 1995). Also the accuracy of nasal volume measurement decreases with increasing distance from the nares (Hilberg et al. 2000). Nasal cycle, which is the spontaneous variation in patency of the nasal halves, is present in 70-80% of the patients (Sipilä 1991). It is unilateral so that the total nasal resistance/volume, which was used in our calculations, remains roughly unchanged.

When the RMM and ARM measurements before and after RFTA are compared in the same patient, whose obstruction is caused by mucosal disorders, they provide an objective measurement of the nasal mucosal change (McCaffrey et al. 1979). The reproducibility of both methods of nasal patency assessment, if performed by an experienced operator under controlled circumstances, compared favourably with many widely accepted clinical tests (Silkoff et al. 1999, Nurminen et al. 2000). However, ARM and RMM results are sometimes inconsistent with the patient's subjective assessment of nasal obstruction (Kim et al. 1988). VAS has been used in previous studies as an effective method to quantify the condition of the subject. Ultimate success in treating patients with nasal obstruction should include each patient's perception of nasal obstruction, highlighting the significance of patient-assessment data such as VAS (Feinstein 1977).

One indication for a successful soft-tissue reduction in chronic hypertrophied turbinates is a decreased response to the vasoconstrictor agent post-operatively. The induced fibrosis fixes the epithelium to the underlying tissues, resulting in decreased congestion of the turbinate in response to noxious and other stimuli (Elwany et al. 1999). The effect of topical vasoconstrictors in this study did not change significantly, even though the tendency was clear. A repeated treatment at 6 months after the first procedure in patients with partial response need to be further investigated.

Our results are in accordance with previous reports on RFTA of inferior turbinates and are based on long-term subjective and objective assessment, which has not been reported before. The procedure is effective, it can be repeated if necessary and there were no significant relapses.

10. CONCLUSION

- The mono- and bipolar ablation of radiofrequency energy of the soft palate as an outpatient procedure results in a decrease in snoring and daytime somnolence with acceptable morbidity. It appears that the treatment results diminish with time.

- Radiofrequency thermal ablation tonsillectomy in adult patients did not show any significant advantages compared to the traditional technique. The controversy over which tonsillectomy technique is preferable whit the lowest morbidity rates still exists.

- Radiofrequency energy is capable of reducing turbinate volume without altering the nasal mucosa and causing only minimal discomfort for the patient. There were no relapses. The long-term radiofrequency results are comparable with other surgical treatment modalities.

- Submucosal bipolar radiofrequency thermal tonsillar reduction is a safe procedure associated with low morbidity in patients with obstructive tonsillary hypertrophy. It seems to reduce tonsillar volume considerably even with only one treatment session.

- Continual evaluation of RF treatment modality is warranted.

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12. REFERENCES

Amoore JE, Ollman BG. Practical test kits for quantitatively evaluating the sense of smell. *Rhinology* 1983; 21: 49-54.

Amoore JE, O´Neill RS. Clinical olfactometry: improved convenience in squeeze-bottle kits; and a portable olfactometer. *Chem Senses* 1986; 11: 576-577.

Andrea M. Microsurgical bipolar cautery tonsillectomy. *Laryngoscope* 1993: 193; 1177-1178.

Baily BJ. Tonsils and adenoids: Snapshots from the Laryngoscope scrapbook. *Laryngoscope* 1997; 107: 301-306.

Blomgren K, Qvarnberg YH, Valtonen HJ. A prospective study on pros and cons of electrodissection tonsillectomy. *Laryngoscope* 2001; 111: 478-482.

(a) Blumen MB, Dahan S, Fleury B, Hausser-Hauw C, Chabolle F. Radiofrequency ablation for the treatment of mild to moderate obstructive sleep apnea. *Laryngoscope* 2002; 112: 2086-2092.

(b) Blumen MB, Dahan S, Wagner I, De Dieuleveult T, Chabolle F. Radiofrequency versus LAUP for the treatment of snoring. *Otolaryngol Head Neck Surg* 2002; 126: 67-73.

Boudewyns A, Van De Heyning P. Temperature-controlled radiofrequency tissue volume reduction of the soft palate (Somnoplasty®) in the treatment of habitual snoring: Results of a European multicenter trial. *Acta Otolaryngol* 2000; 120: 981-985.

Bradley TD, Brown IG, Grossman RF, Zamel N, Martinez D, Phillipson EA, Hoffstein V. Pharyngeal size in snorers, non-snorers and patients with obstructive sleep apnea. *N Engl J Med* 1986; 315: 1327-1331.

Brietzke SE, Mair EA. Injection snoreplasty: How to treat snoring without all the pain and expense. *Otolaryngol Head Neck Surg* 2001; 124: 503-510.

Brown DJ, Kerr P, Kryger M. Radiofrequency tissue reduction of the palate in patients with moderate sleep-disordered breathing. *J Otolaryngol* 2001 ; 30: 193-198**.**

Bui QT, Dupuy DE. Percutaneous CT-guided radiofrequency ablation of an adenoid cystic carcinoma of the head and neck. *AJR Am J Roentgenol* 2002 ; 179: 1333-1335.

Burns RL, Carruthers A, Langtry JA, Trotter MJ. Electrosurgical skin resurfacing: A new bipolar instrument. *Dermatol Surg* 1999 ; 25: 582-586.

Burton MJ, Towler B, Glasziou P Tonsillectomy versus non-surgical treatment for chronic/recurrent acute tonsillitis (Cochrane Review) *The Cochrane Library,* Issue 3, 2002. Oxford: Update Software.

Cable BB, Mair EA. Radiofrequency ablation of lymphangiomatous macroglossia. *Laryngoscope* 2001; 111: 1859-1961.

Calkins H, Langberg J, Sousa J, El-Atassi, Leon A, Kou W, Kalbfleisch S, Morady F. Radioferquency catheter ablation of accessory atrioventricular connections in 250 patients. Abbreviated therapeutic approach to Wolff-Parkinson-White syndrome. *Circulation* 1992; 85: 1337-1346.

Carenfelt C. Laser uvulopalatoplasty in treatment of habitual snoring. *Ann Otol Rhinol Laryngol* 1991 ; 100: 451-454.

Carenfelt C, Haraldsson PO. Frequency of complications after uvulopalatopharyngoplasty. *Lancet* 1993; 341: 437.

Chapple CR, Issa MM, Woo H. Transurethral needle ablation (TUNA ™). *Eur Urol* 1999; 35: 119-128.

Choy ATK, Su AP. Bipolar diathermy or ligation for haemostasis? A prospective study on postoperative pain. *J Laryngol Otol* 1992; 106: 21-22.

Chinpairoj S, Feldman MD, Saunders JC, Thaler ER. A comparison of monopolar electrosurgery to a new multipolar electrosurgical system in a rat model. *Laryngoscope* 2001; 111: 213-217.

Clarke RW, Yardley MP, Davies CM, Panarese A, Clegg RT, Parker AJ. Palatoplasty for snoring: A randomized controlled trial of three surgical methods. *Otolaryngol Head Neck Surg* 1998; 119: 288-292.

Coleman SC, Smith TL. Midline radiofrequency tissue reduction of the palate for bothersome snoring and sleep-disordered breathing: A clinical trial. *Otolaryngol Head Neck Surg* 2000; 122: 387-394.

Coste A, Yona L, Blumen M, Louis B, Zerah F, Rugina M, Peynegre R, Harf A, Escudier E. Radiofrequency is a safe and effective treatment of turbinate hypertrophy. *Laryngoscope* 2001; 111: 894-899.

Courvey MS, Fomin D, Smith T, Huang S, Sanders D, Reinisch L. Histologic and physiologic effects of electrocautery, CO_2 laser and radiofrequency injury in the porcine soft palate. *Laryngoscope* 1999; 109: 1316-1319.

DiBaise JK, Brand RE, Quigley EM. Endoluminal delivery of radiofrequency energy to the gastroesophageal junction in uncomplicated GERD: Efficacy and potential mechanism of action. *Am J Gastroenterol* 2002; 97: 833-842.

Douglas NJ. Upper airway imaging. *Clin Phys Physiol Meas* 1990; 11 Suppl A: 117-119.

Dupuy DE, Monchik JM, Decrea C, Pisharodi L. Radiofrequency ablation of regional recurrence from well-differentiated thyroid malignancy. *Surgery* 2001; 130: 971-977.

Dupuy DE, Safran H, Mayo-Smith WW, Goldberg SN. Radiofrequency ablation of painful osseous metastases. *Radiology* 1998; 80: 815-821.

Ellis PD, Williams JE, Shneerson JM. Surgical relief of snoring due to palatal flutter: a preliminary report. *Ann R Coll Surg Engl* 1993; 75: 286-290.

Elwany S, Gaimaee R, Fattah HA. Radiofrequency bipolar submucosal diathermy of the inferior turbinates. *Am J Rhinol* 1999; 13: 145-149.

Emery BE, Flexon PB. Radiofrequency volumetric tissue reduction of the soft palate: A new treatment for snoring. *Laryngoscope* 2000; 110: 1092-1098.

Fairbanks DNF. Uvulopalatopharyngoplasty; complications and avoidance strategies. *Otolaryngol Head Neck Surg* 1990; 102: 239-245.

Feinstein AR. Clinical biostatistics. XV: hard science, soft data and the challenges of choosing clinical variables in research. *Clin Pharmacol Ther* 1977; 22: 485-491.

Ferguson M, Smith TL, Zanation AM, Yarbrough WG. Radiofrequency tissue volume reduction: Multi-lesion vs. single-lesion treatments for snoring. *Arch Otolaryngol Head Neck Surg* 2001; 127: 1113-1118.

Fischer Y, Gosepath J, Amedee RG, Mann WJ. Radiofrequency volumetric tissue reduction (RFVTR) of inferior turbinates: A new method in the treatment of chronic nasal obstruction. *Am J Rhinol* 2000; 14: 355-360.

Friberg D, Ansved T, Borg K, Carlsson-Nordlander B, Larsson H, Svanborg E. Histological indications of a progressive snorers disease in an upper airway muscle. *Am J Respir Crit Care Med* 1998 ; 157: 586-593.

Friedman M, Landsberg R, Tanyeri H. Submucosal uvulopalatopharyngoplasty. *Operative Techniques Otolaryngol Head Neck Surgery* 2000; 11: 26-29.

Fujita S, Conway W, Zorick F, Roth T. Surgical correction of anatomic abnormalities in obstructive sleep apnea syndrome: Uvulopalatopahryngoplasty. *Otolaryngol Head Neck Surg* 1981; 89: 923-934.

Golding-Wood PH. Observations on petrosal and vidian neurectomy in chronic vasomotor rhinitis. *J Laryngol Otol* 1961; 75: 232.

Goycoola MV, Cubillod PM, Martinez GC. Tonsillectomy with a suction coagulator. *Laryngoscope* 1982; 92: 818-819.

Haigtht SJ, Cole PH. The site and function of the nasal valve. *Laryngoscope* 1983; 93: 49-55.

Hagert B, Wikblad K, Odkvist L, Wahren LK. Side effects after surgical treatment of snoring. *ORL J Otorhinolaryngol Relat Spec* 2000; 62: 76-80.

Haraldsson PO, Karling J, Lysdahl M, Svanborg E. Voice quality after radiofrequency volumetric tissue reduction of the soft palate in habitual snorers. *Laryngoscope* 2002; 112: 1260-1263.

Harris EJ. Radiofrequency ablation of the long saphenous vein without high ligation versus high ligation and stripping for primary varicose veins: Pros and cons. *Semin Vasc Surg* 2002; 15: 34-38.

Hecht P, Hayashi K, Fantons GS, Thabit G, Vanderby Jr R, Markel MD. Monopolar radiofrequency energy effects on joint capsular tissue: Potential treatment for joint instability. *Am J Sports Med* 1999; 27: 761-771.

Hilberg O, Grymer LF, Pedersen OF. Spontaneous variations in congestion of the nasal mucosa. *Ann Allergy Asthma Immunol* 1995; 74: 516-521.

Hilberg O, Pedersen OF. Acoustic rhinometry: recommendations for technical specifications and standard operating procedures. *Rhinology* 2000; Suppl 16: 3-17.

Hill FT. Harris Peyton Mosher. Historical vignette. *Arch Otolaryngol* 1966; 47: 751-784.

Hoffman JP, Weese JL, Solin LJ, Engstrom P, Agarwal P, Barber LW, Guttmann MC, Litwin S, Salazar H, Eisenberg BL. A pilot study of pre-operative chemoradiation for patients with localized adenocarcinoma of the pancreas. *Am J Surg* 1995; 169: 71-77, discussion 77-78.

Hol MK, Huizing EH. Treatment of inferior turbinate pathology: a review and critical evaluation of the different techniques. *Rhinology* 2000; 38: 157-166.

Hollis LJ, Burton MJ, Millar JM. Peri-operative local anaesthesia for reducing pain following tonsillectomy (Cochrane Review). In: *The Cochrane Library*, Issue 3, 2002. Oxford: Update Software.

Hultcrantz E, Linder A, Markstrom A. Tonsillectomy or tonsillotomy?--A randomised study comparing post-operative pain and long-term effects. *Int J Pediatr Otorhinolaryngol* 1999 Dec 15; 51(3): 171-176.

Ikematsu T. Study of snoring, 4th report: Therapy. *J Japan Oto-Rhino-Laryngol* 1964; 64: 434-435.

Jeffrey SS, Birdwell RL, Ikeda DM, Daniel BL, Nowels KW, Dirbas FM, Griffey SM. Radiofrequency ablation of breast cancer: First report of an emerging technology. *Arch Surg* 1999; 134: 1064-1068.

Johns MW. A new method for measuring daytime sleepiness: The Epworth sleepiness scale. *Sleep* 1991; 14: 540-545.

Johns MW. Daytime sleepiness, snoring and obstructive sleep apnoea. The Epworth sleepiness scale. *Chest* 1993; 103: 30-36.

Johnson JT, Pollack GL, Wagner RL. Transoral radiofrequency treatment of snoring. *Otolaryngol Head Neck Surg* 2002; 127: 235-237.

Kamami YV. Outpatient treatment of snoring with CO2 laser: laser-assisted UPPP. *J Otolaryngol* 1994 ; 23: 391-394.

Kelly HA, Ward GE. Otolaryngology. In: *Electrosurgery*. Philadelphia, Pa: WB Saunders Co; 1932: 114-127.

Kim SC, Moon BK, Jung DH, Min YG. Correlation between nasal obstruction symptoms and objective parameters of acoustic rhinometry and rhinomanometry. *Auris Nasus Larynx* 1988; 25: 45-48.

Kimoff RJ, Sforza E, Champagne V, Ofiara L, Gendron D. Upper airway sensation in snoring and obstructive sleep apnea. *Am J Respir Crit Care Med* 2001; 164: 250-255.

Koltai PJ**,** Solares CA, Mascha EJ, Xu M. Intracapsular partial tonsillectomy for tonsillar hypertrophy in children. *Laryngoscope* 2002; 112: 17-19.

Kornblut AD. A traditional approach to surgery of the tonsils and adenoids. *Otolaryngol Clin North Am* 1987; 20: 349-363.

Koskenvuo M, Kaprio J, Heikkilä K, Sarna S, Telakivi T, Partinen M. Snoring as a risk factor for ischaemic heart disease and stroke in men. *Br Med J* 1987; 294: 16-19.

Krespi YP, Pearlman SJ, Keidar A. Laser-assisted uvulo-palatoplasty for snoring. *J Otolaryngol* 1994; 23: 328-334.

Krishna P, Lee D. Post-tonsillectomy bleeding: a meta-analysis. *Laryngoscope* 2001; 111: 1358-1361.

Kubota I. Nasal function following carbon dioxide laser turbinate surgery for allergy. *Am J Rhinology* 1995; 9: 155-161.

Larsson LH, Carlsson-Nordlander B, Svanborg E. Four-year follow up after uvulopalatopharyngoplasty in 50 unselected patients with obstructive sleep apnoea syndrome. *Laryngoscope* 1994; 104: 1362-1368.

Lavie P. Nothing under the moon. Historical accounts of sleep apnea syndrome. *Arch Intern Med* 1984; 144: 2025-2028.

Lenz H, Eichler J, Schafer G, Salk J. Parameters for argon laser of the lower human turbinates. *Acta Otolaryngol* (Stockholm) 1977; 83: 360.

72) Levin BC, Becker GD. Uvulopalatopharyngoplasty for snoring: Long-term results. *Laryngoscope* 1994; 104: 1150-1152.

Li KK, Powell NB, Riley RW, Guilleminault C. Temperature-controlled radiofrequency tongue base reduction for sleep-disordered breathing: Long-term outcomes. *Otolaryngol Head Neck Surg* 2002 Sep; 127: 230-234.

Li KK, Powell NB, Riley RW, Troell RJ, Guilleminault C. Radiofrequency volumetric reduction of the palate: An extended follow-up study. *Otolaryngol Head Neck Surg* 2000; 122: 410-414.

Li KK, Powell NB, Riley RW, Troell RJ, Guilleminault C. Radiofrequency volumetric tissue reduction for treatment of turbinate hypertrophy: A pilot study. *Otolaryngol Head Neck Surg* 1998; 119: 569-573.

Lim PVH, Eng FRSC, Curry AR. A new method for evaluating and reporting the severity of snoring. *J Laryngol Otol* 1999; 113: 336-340.

Lindholm RN, Lowry LD. An office treatment for snoring. *Ear Nose Throat J* 1990; 69: 98, 101.

Lugaresi E, Cirignotta F, Coccagna G, Piana C. Some epidemiological data on snoring and cardiocirculatory disturbances. *Sleep* 1980; 3: 221-224.

MacBeth RG. The tonsil problem. *J Laryngol* 1950; 64: 591-598.

Mair EA, Day RH. Cautery-assisted palatal stiffening operation. *Otolaryngol Head Neck Surg* 2000; 122: 547-556.

Malhotra A, Huang Y, Fogel RG, Pillar G, Edwards JK, Kikinis R, Loring SH, White DP. The male predisposition to pharyngeal collapse. Importance of airway length. *Am J Respir Crit Care Med* 2002; 166: 1388-1395.

Malis LI. Electrosurgery. Technical note. *J Neurosurg* 1996; 85: 970-975.

Mann DG, St George C, Granoff D. Tonsillectomy: some like it hot. *Laryngoscope* 1984; 94: 677-679.

Martinez SA, Akin DP. Laser tonsillectomy and adenoidectomy. *Otolaryngol Clin North Am* 1987; 20: 371-376.

Mawson SR, Adlington P, Evans M. A controlled study evaluation of adeno-tonsillectomy in children. *J Laryngol Otol* 1967; 81: 777-790.

McCaffrey TV, Kern EB. Clinical evaluation of nasal obstruction: A study of 1.000 patients. *Arch Otolaryngol Head Neck Surg* 1979; 105: 542-545.

McGuire NJ. A method of guillotine tonsillectomy with an historical review. *J Laryngol Otol* 1967; 81: 187-195.

Meredith GM. Surgical reduction of hypertrophied inferior turbinates: A comparison of electrofulguration and partial resection. *Plast Reconstr Surg* 1988; 81; 891-899.

Mukai S, Nitta M. Z-pharyngoplasty for sleep disorders and ronchopathy. *Acta Otolaryngol* 2002; 122: 524-530.

Navarro G, Jiao LR, Nicholls JP, Jensen SL, Habib NA. A novel approach to gallbladder cancer in a Jehovah's Witness. *Surg Endosc* 2002; 16: 1109-1110.

Nelson LM. Radiofrequency treatment for obstructive tonsillar hypertrophy. *Arch Otolaryngol Head Neck Surg* 2000; 126: 736-740.

Nelson LM. Temperature-controlled radiofrequency tonsil reduction: extended follow-up. *Otolaryngol Head Neck Surg* 2001; 125: 456-461.

Nelson LM, Boytim ML. Letters to the Editor: Radiofrequency tonsil reduction. *Arch Otolaryngol Head Neck Surg* 2001; 10: 1286-1287.

Nurminen M, Hytönen M, Sala E. Modelling the reproducibility of acoustic rhinometry. *Statist Med* 2000; 19: 1179-1189.

Organ LW. Electrophysiologic principles of radiofrequency lesion making. *Appl Neurophysiol* 1976; 39: 69-79.

Owen RP, Ravikumar TS, Silver CE, Beitler J, Wadler S, Bello J. Radiofrequency ablation of head and neck tumors: dramatic results from application of a new technology. *Head Neck* 2002; 24: 754-758.

Ozenberger I. Cryosurgery in chronic rhintis. *Laryngoscope* 1970; 80: 723-734.

Pang YT, El-Hakim H, Rothera MP. Bipolar diathermy tonsillectomy. *Clin Otolaryngol* 1994; 19: 355-357.

Paradise JL, Bluestone CD, Colborn DK, Bernard BS, Rockette HE, Kurs-Lasky M. Tonsillectomy and adenotonsillectomy for recurrent throat infection in moderately affected children. *Pediatrics* 2002; 110: 7-15.

Partinen M, Hublin C. Epidemiology of sleep disorders. In: Kryger M, Roth T, Dement WC, eds. *Principles and Practice of Sleep Medicine*. New York, Saunders, third edition; 2000: 558-579.

Paulsen FP, Steven P, Tsokos M, Jungmann K, Muller A, Verse T, Pirsig W. Upper airway epithelial structural changes in obstructive sleep-disordered breathing. *Am J Respir Crit Care Med* 2002; 166: 501-509.

Pazos G, Mair EA. Complications of radiofrequency ablation in the treatment of sleep-disordered breathing. *Otolaryngol Head Neck Surg* 2001; 125: 462-467.

Pinder D, Hilton M. Dissection versus diathermy for tonsillectomy (Cochrane Review). In: *The Cochrane Library*, Issue 3, 2002. Oxford: Update Software.

Powell NB, Riley RW, Guilleminault C. Radiofrequency tongue base reduction in sleep-disordered breathing: A pilot study. *Otolaryngol Head Neck Surg* 1999; 120: 656-664.

Powell N, Riley R, Guilleminault C, Troell R. A reversible uvulopalatal flap for snoring and sleep apnea syndrome. *Sleep* 1996; 19: 593-599.

Powell NB, Riley RW, Troell RJ, Blumen MB, Guilleminault C. Radiofrequency volumetric reduction of the tongue. A porcine pilot study for the treatment of obstructive sleep apnea syndrome. *Chest* 1997; 111: 1348-1355.

Powell NB, Riley RW, Troell RJ, Li K, Blumen MB, Guilleminault C. Radiofrequency volumetric tissue reduction of the palate in subjects with sleep-disordered breathing. *Chest* 1998; 113: 1163-1174.

Powell NB, Zonato AI, Weaver EM, Li K, Troell R, Riley RW, Guilleminault C. Radiofrequency treatment of turbinate hypertrophy in subjects using continuous positive airway pressure: a randomised, double-blind, placebo-controlled clinical pilot trial. *Laryngoscope* 2001; 111: 1783-1790.

Putnam JB Jr. New and evolving treatment methods for pulmonary metastases. *Semin Thorac Cardiovasc Surg* 2002; 14: 49-56.

Price DD, McGrath PA, Rafii A, Buckingham B. The validation of visual analogue scales as ratio scales measures for chronic and experimental pain. *Pain* 1983; 17: 45-56.

Rasilainen J, Rintanen H, Gissler M. Toimenpiteelliset hoitojaksot vuonna 2001. National Research ands Development Centre for Welfare and Health (Stakes, www.stakes.fi). Stakes Annual Statistical Report 17/2002.

Rautakorpi UM, Lumio J, Huovinen P, Klaukka T. Indication-based use of antimicrobials in Finnish primary health care. Description of a method for data collection and results of its application. *Scand J Prim Health Care* 1999; 17: 93-99.

Rhee C-S, Kim D-Y, Won T-B, Lee H-J, Park S-W, Kwon T-Y, Lee CH, Min Y-G. Changes of nasal function after temperature-controlled radiofrequency tissue volume reduction for the turbinate. *Laryngoscope* 2001; 111: 153-158.

Sackett DL, Rosenberg WM, Gray JA, Haynes RB, Richardson WS. Evidence based medicine: what it is and what it isn't. *BMJ* 1996 13; 312: 71-72.

Saleh HA, Cain AJ, Mountain RE. Bipolar scissor tonsillectomy. *Clin Otolaryngol* 1999; 24: 9-12.

Sipilä J. Modern computerized rhinomanometry in clinical practice. Thesis Annales Universitatis Turkuentis, Turku, Finland 1991.

Seidenfeld J, Korn A, Aronson N. Radiofrequency ablation of unresectable primary liver cancer. *J Am Coll Surg* 2002; 194: 813-828.

Semenov H. The pathology of the nose and paranasal sinuses in relation to allergy. *Trans Amer Acad Opth Otol* 1952; 56: 121-170.

Shah UK, Galinkin J, Chiavacci R, Briggs M. Tonsillectomy by means of plasma-mediated ablation. *Arch Otolaryngol Head Neck Surg* 2002; 128: 672-676.

Shahinian L. Chronic vasomotor rhinitis, treatment by submucous diathermic coagulation. *Arch Otolaryngol* 1955; 57: 475-489.

Shepard JW Jr, Gefter WB, Guilleminault C, Hoffman EA, Hoffstein V, Hudgel DW, Suratt PM, White DP. Evaluation of the upper airway in patients with obstructive sleep apnea. *Sleep* 1991; 14: 361-371.

Sher AE, Flexon PB, Hillman D, Emery B, Swieca J, Smith TL, Cartwright R, Dierks E, Nelson L. Temperature-controlled radiofrequency tissue volume reduction in the human soft palate. *Otolaryngol Head Neck Surg* 2001; 125: 312-318.

Shneerson J, Wright J. Lifestyle modification for obstructive sleep apnoea (Cochrane Review). In: *The Cochrane Library*, Issue 3, 2002. Oxford: Update Software.

Silkoff PE, Chakravorty SC, Chapnik J, Cole P, Zamel N. Reproducibility of acoustic rhinometry and rhinomanometry in normal subject. *Am J Rhinol* 1999; 13: 131-135.

Smith I, Lasserson T, Wright J. Drug treatments for obstructive sleep apnoea (Cochrane Review). In: *The Cochrane Library*, Issue 3, 2002. Oxford: Update Software.

Smith T, Smith J. Electrosurgery in otolaryngology-head and neck surgery: Principles, advances and complications. *Laryngoscope* 2001; 111: 769-780.

Smithson AJ, White JES, Griffiths CJ, Prichard AJN, Close PR, Drinnan MJ, Marshall HF, Gibson GJ. Comparison of methods for assessing snoring. *Clin Otolaryngol* 1995: 20; 443-447.

Solbiati L, Livraghi T, Goldberg SN, Ierace T, Meloni F, Dellanoce M, Cova L, Halpern EF, Gazelle GS. Percutaneous radio-frequency ablation of hepatic metastases from colorectal cancer: Long-term results in 117 patients. *Radiology* 2001; 221: 159-166.

Stevenson RC, Guthrie D. A history of oto-laryngology. Edinburgh, E.&S. Livingstone, Ltd, 1949.

Steward DL, Chung SJ. The role of adjuvant therapies and techniques in tonsillectomy. *Curr Opin Otolaryngol Head Neck Surg* 2000; 8: 186-192.

Strauss JF. A new approach to the treatment of snoring. A preliminary report. *Arch Otolaryngol* 1943; 38: 225-229.

Stuck BA, Maurer JT, Hörmann K. Tongue base reduction with radiofrequency tissue ablation: preliminary results after two treatment sessions. *Sleep Breath* 2000; 4: 155-162.

(a) Stuck BA, Maurer JT, Verse T, Hörmann K. Tongue base reduction with temperature-controlled radiofrequency volumetric tissue reduction for treatment of obstructive sleep apnea syndrome. *Acta Otolaryngol* 2002; 122: 531-536.

(b) Stuck BA, Kopke J, Maurer JT, Verse T, Kuciak G, Duber C, Hörmann K. Evaluating the upper airway with standardized magnetic resonance imaging. *Laryngoscope* 2002; 112: 552-558.

Sullivan CE, Issa FG. Pathophysiological mechanisms in obstructive sleep apnea. *Sleep* 1980; 3: 235-246.

Svanborg E. Upper airway nerve lesions in obstructive sleep apnea. *Am J Respir Crit Care Med* 2001; 164: 187-188.

Sweet WH, Wepsic JG. Controlled thermocoagulation of trigeminal ganglion and rootlets for differential destruction of pain fibers. 1. Trigeminal neuralgia. *J Neurosurg* 1974; 40: 143-156.

Taliaferro C. Submucosal radiosurgical uvulopalatoplasty for the treatment of snoring: Is the monitoring of tissue impedance and temperature necessary? *Otolaryngol Head Neck Surg* 2001; 124: 46-50.

Tasto JP, Ash SA. Current use of radiofrequency in arthroscopic knee surgery. *Am J Knee Surg* 1999; 12: 186-191.

Temple RH, Timms MS. Paediatric coblation tonsillectomy. *Int J Pediatr Otorhinolaryngol* 2001; 61: 195-198.

Terris DJ, Chen V. Occult mucosal injuries with radiofrequency ablation of the palate. *Otolaryngol Head Neck Surg* 2001; 125: 468-472.

Terris DJ, Coker JF, Thomas AJ, Chavoya M. Preliminary findings from a prospective, randomised trial of two palatal operations for sleep-disordered breathing. *Otolaryngol Head Neck Surg* 2002; 127: 315-23.

Thornval A. Wilhelm Meyer and the adenoids. *Arch Otolaryngol* 1969; 90: 383-386.

Timms MS, Temple RH. Coblation tonsillectomy: a double blind randomised controlled study. *J Laryngol Otol* 2002; 116: 450-452.

Torriani M, Rosenthal DI. Percutaneous radiofrequency treatment of osteoid osteoma. *Pediatr Radiol* 2002; 32: 615-618.

(a) Troell RJ, Powell NB, Riley RW, Kasey KL, Guilleminault C. Comparison of post-operative pain between laser-assisted uvulopalatoplasty, uvulopalatopharyngoplasty and radiofrequency volumetric tissue reduction of the palate. *Otolaryngol Head Neck Surg* 2000; 122: 402-409.

(b) Troell RJ, Li KK, Powell NB, Riley RW. Radiofrequency of the soft palate in snoring and sleep-disordered breathing. *Operative Techniques Otolaryngol Head Neck Surg* 2000; 11: 21-23.

Trotter MI, D'Souza AR, Morgan DW. Medium-term outcome of palatal surgery for snoring using the Somnus™ unit. *J Laryngol Otol* 2002; 116: 116-118.

Ulfberg J. Bernoulli`s law is of current interest during snoring. Mechanisms make the air flow easier. *Läkartidningen* 1996; 93: 3780-3782.

Vital OA, Teerlink JR, Gaxiola E, Wallace AW, Najar S, Camacho DH, Gutierrez A, Herrera G, Zuniga G, Mercado-Rios F, Ratcliffe MB. Left ventricular volume reduction by radiofrequency heating of chronic myocardial infarction in patients with congestive heart failure. *Circulation* 2002; 105: 1317-1322.

Wedman J, Miljeteig H. Treatment of simple snoring using radio waves for ablation of uvula and soft palate: a day-case surgery procedure. *Laryngoscope* 2002; 112: 1256-1259.

Weingarten C. Ultrasonic tonsillectomy: rationale and technique. *Otolaryngol Head Neck Surg* 1997; 116: 193-196.

Wengraf CL, Gleeson MJ, Siodlak MZ. The stuffy nose: a comparative study of two common methods of treatment. *Clin Otolaryngol* 1986; 11: 61-68.

Wicker P. Making sense of electrosurgery. *Can J Surg* 1992; 88: 31-33.

Wiggins CL, Schmidt-Nowara WW, Coultas DB, Samet JM. Comparison of self- and spouse reports on snoring and other symptoms associated with sleep apnea syndrome. *Sleep* 1990: 13; 245-252.

Windfuhr JP, Ulbrich T. Post-tonsillectomy haemorrhage: results of a 3-month follow-up. *Ear Nose Throat J* 2001; 80: 790, 795-798, 800.

Wood BJ, Bates S. Radiofrequency thermal ablation of a splenic metastasis. *J Vasc Interv Radiol* 2001; 12: 261-263.

Woodson BT, Nelson L, Mickelson S, Huntley T, Sher A. A multi-institutional study of radiofrequency volumetric tissue reduction for OSAS. *Otolaryngol Head Neck Surg* 2001; 125: 303-311.

Ylikoski J. Is snoring a healthrisk? *Duodecim* 1995; 111: 1129-1130.

Younis RT, Lazar RH. History and current practice of tonsillectomy. *Laryngoscope* 2002; 112: 3-5.

Zinder DJ. Letters to the Editor: The tumble of medical advancement: A call for knowledge management. *Arch Otolaryngol Head Neck Surg* 2001; 2: 228.

Zuboy J. Radiofrequency ablation used to treat select renal and adrenal tumors. *Curr Treat Options Oncol* 2000; 1: 93-94.