

**EXPERIMENTAL AND CLINICAL EXPERIENCES GAINED WITH
RADIOFREQUENCY INTERVENTIONS IN
OTORHINOLARYNGOLOGY**

PhD Thesis

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1. Introduction

1.1. Mechanism of radiofrequency

Radiofrequency (RF) surgery is a type of electrosurgery. We talk about a *radiofrequency surgical intervention*, if the frequency of the high-frequency generator is set between 3-5 MHz. During the procedure, tissues heat up to 50-90 °C as a result of high-frequency waves surrounding the electrode, causing thermal damage and consequent irreversible tissue damage.

1.2. The use of radiofrequency interventions in clinical practice

Radiofrequency in Otorhinolaryngology

In the field of otorhinolaryngology, radiofrequency (RF) can be applied in nearly all areas. The most common areas include the treatment of rhynophima, the inferior turbinate, palatal tonsils, laryngeal and hypopharyngeal laesions and surgeries to treat snoring. Consequently, our clinical investigations encompassed the above areas.

2. Aims

The use of radiofrequency methods in medicine has been increasing considerably in several areas, including otorhinolaryngology. The aims of my investigations are summarised below:

1. To summarise experiences gained through otorhinolaryngological interventions carried out using radiofrequency, to analyse the results in the light of related findings in international and national literature.
2. Our study has been the first to emphasise and support the relevance of the use of radiofrequency tonsillotomy in Hungary in the light of international publications.

3. We have been the first in Hungary to introduce the use of microlaryngeal radiofrequency on an adult patient population with reference to international literature.
4. Our study has been the first in Hungary to analyse snoring and speech sounds of patients having undergone radiofrequency uvulopalatoplasty.
5. On two animal models, we investigated the effects of laser versus radiofrequency volume reduction on the inferior turbinate by histology and electron microscopy.

3. Examinations (Patients, method, results)

All radiofrequency interventions were performed using **Surgitron® 4.0 MHz Dual Frequency RF™ (Ellman® International, Oceanside, NY, USA)** applying the power settings specified in the user's manual and using the specific electrodes for the particular areas treated.

3.1. Clinical investigations

3.1.1. Radiofrequency excision of rhinophyma

Nine patients (1 female, 8 male; average age 58 ± 11.2 , range 41–70) participated in a preoperative clinical assessment and detailed rhinoplasty planning, including standardized multiplanar photography, airway assessment, and discussion of esthetic goals. General anesthesia was administered, together with local anesthetic infiltration (1% novocaine with tonogen). Radiosurgery was applied as an atraumatic process to cut or coagulate the unsightly, bulbous overgrowth of the nasal skin. The radiofrequency instrument was set to the recommended 28W and “cut-coag” position. In all of the cases, a 10-mm-diameter wire loop electrode was applied as a “radiofrequency shaver,” and the epidermis was delaminated sequentially. The few small cut-off vessels were electrocoagulated in “coag” mode. The surgical field was covered with gauze pads impregnated with Peru balm or Lomatuell H.

The average duration of surgery was 45 minutes. In the postoperative period, no patient experienced enough pain to require analgesia. Crust removal was not forced; the area below the crusts was left to undergo re-epithelization at its own speed. No postoperative complications occurred (e.g., prolonged erythema, delayed wound healing, infection, hypopigmentation). Re-epithelization was completed after 2.5 weeks.

On a visual analog scale of 1 to 10, the mean improvement in cosmetic appearance, judged by an independent surgeon from standardized pre- and postoperative photographs, was 7.8 ± 0.8 (presurgical mean score 2, postsurgical mean 8.5).

Radiosurgery is easy to learn and relatively simple to perform, requires minimal postoperative care, and provides a satisfactory cosmetic outcome.

3.1.2. *Radiofrequency treatment of the inferior turbinate*

Our investigations in connection with the hypertrophy of the inferior turbinate were intended to prove that RF submucosal reduction is able to improve nasal breathing or other nasal symptoms in patients not responding to medication therapy, and allergic and non-allergic patients as well. The effectiveness of the method was evaluated by retrospective clinical questionnaire survey including pre-operative and post-operative impairment of nasal breathing, quality of olfaction, thickness of nasal discharge and nasal surgeries (surgery on the septum and/or FESS) mentioned in the medical history. In the period between 01. February 2010 and 31. December 2011, 47 patients (33 males, 14 females) underwent bilateral RF treatment of the inferior turbinate. Twelve of the patients had diagnosed allergic rhinitis.

The surgery was performed under local anaesthesia using a bayonette electrode inserted submucosally, through the frontal pole of the inferior turbinate on both sides. The procedure was carried out in „coag” mode, at 20 Watt, in 15 seconds and was repeated according to the size of the nasal turbinate after a repeated insertion. Patients were discharged after one hour of observation.

In the pre-operative period, only 2 out of the 47 patients reported good nasal breathing. Sufficient olfaction was reported by 21 patients, 15 patients experienced regular post-nasal drip. The twelve patients suffering from allergy were also examined separately: pre-operatively, two had good nasal breathing, seven reported having sufficient olfaction and five complained of post-nasal drip. Following surgery, all 47 patients reported the

disappearance of symptoms related to nasal breathing. While olfaction improved considerably in 24 and slightly in two patients, all allergic patients reported significant improvement with respect to olfaction. Post-nasal drip was reduced in all patients and completely disappeared in eight patients. From among the five allergic patients having suffered from post-nasal drip, three reported a reduction of this symptom subsequent to surgery.

To conclude, radiofrequency treatment of the inferior turbinate is a minimally invasive method that can be performed under local anaesthesia. It is a fast and simple procedure that is easy to learn, it is safe and retains the functionality of the nose.

3.1.3. Radiofrequency tonsillotomy

Our study involved children admitted to our department between 01. February 2011 and 31. March 2012 to undergo surgery of the tonsils, 19 patients underwent tonsillectomy (TE) (6 girls, 13 boys) and 32 underwent radiofrequency tonsillotomy (RF-TT) (16 girls, 16 boys). In the TE group, mean age was 6,8 years (3-13 years), in the TT group 4,6 years (3-8 years). All surgeries were performed under intratracheal narcosis.

The indication for surgery in the case of TE was primarily, recurrent tonsillopharyngitis (as defined by the *Paradise* criteria), indication for RF-TT was Grade III-IV tonsillary hypertrophy according to the Friedman scale, causing recurrent upper respiratory airway obstruction, noticed on physical examination.

During our pilot study, TE was carried out using bipolar electric scissors (PowerStar BP 520 model, Ethicon Inc., NJ, USA). Our experiences showed that this method helped reduce intraoperative bleeding and time of surgery as opposed to other methods applied for TE. The tonsils were removed through an incision made on the mucosa along the frontal pharyngeal arch until the root of the tongue extracapsularly, closely to the capsule. Electrocoagulation with a bipolar forceps was used to stop the bleeding.

During RF-TT, we first injected a 2-3 ml solution of 0,5% Novocain-tonogen into the tonsil tissue, primarily, to increase the fluid volume and furthermore, as a means of peri-operative pain management, to achieve local vasoconstriction and thereby, reduce bleeding. Those sections of the tonsils overreaching the pharyngeal arch were removed in a „cut-coag” mode at 25 Watt, using a 8-10 mm-diameter loop electrode. During surgery, in order to

achieve the least possible post-operative pain, pharyngeal arches were spared. If necessary, RF bipolar forceps was used for bleeding control.

The three questionnaires used in our study were compiled according to the article published by *Hultcrantz et al (2004)*. Parents were asked to complete all three, children were asked to complete 2 of the questionnaires. Questionnaires were administered and the information about the completion was given by the same physician in the case of all the patients.

The first questionnaire focused on pre-surgical status. Questions relating to medical history were answered by parents. The questionnaires aimed at eliciting information about previous pharyngitis or tonsillitis, obstructive sleep apnoea, frequent upper respiratory infection, joint problems, abscesses and whether the symptoms affected the children's speech or swallowing. Body weight on an empty stomach was also recorded on the morning of surgery.

The second questionnaire aimed at providing us information about pain experienced during the first 24 hours after surgery. Parents were asked to mark the intensity of pain their child experienced on a 7-point scale, on a range between 0-6, where 0 meant "no pain" and 6 meant "unbearable pain". At the same time, children were asked to show how strong a pain they were experiencing on a visual analogue scale, the so-called "face pain scale" (FPS).

The third questionnaire contained several sub-sections focusing on the post-operative period from day 2 to day 10. Pain assessment was carried out three times daily following the example on the second questionnaire. Additionally, parents recorded the consistency of food (liquid, mashed, normal) and the quantity (the usual amount, less than the usual amount, more than the usual amount), consumed by their child with each main meal (three times daily, 27 times total). Parents were also asked to record the frequency of analgesic administration and measured the children's body weight on the 10th post-operative day.

Questionnaire results were analysed statistically using independent-samples T-test.

Duration of surgery was 11 minutes 53 seconds in the case of TE on average and 12 minutes 27 seconds in the case of RF-TT. No significant intraoperative bleeding was observed in either case. Neither of the two groups reported post-operative bleeding.

When assessing **postoperative pain**, FPS, developed for children, did not prove reliable enough. Consequently, when assessing the results, we considered degree of pain and frequency of analgesic administration as recorded by parents.

In the *TE group*, pain-free status was achieved after an average of 9 days (8.2 +/- 2.1 days). In the *RF-TT group* an average of 4 days (4.8 +/- 2.3 days) were needed to reach pain-free status.

As regards **consistency of food consumed**, patients having undergone TE reportedly consumed significantly less solid food. No statistically significant difference was found in fluid consumption between the two groups.

Regarding the **amount of food** consumed, significantly more patients in the *RF-TT group* consumed the same amount as they did prior to surgery, and reportedly ate even more. Patients in the *TE group*, however, consumed significantly less in the post-operative period than they used to.

Concerning **changes in bodyweight**, a statistically significant difference was found between the two groups. Average decrease in body weight in the *TE group* was markedly bigger than in the *RF-TT group*. In the *TE group*, average decrease in body weight was 1.15 kg, that is 4.2% of the initial body weight, while in the *RF-TT* patients it was 0.37 kg, 1.8% of their initial body weight.

To conclude, RF-TT is less invasive than TE. Our study revealed that RF-TT means less stress and burden for patients with respect to all parameters examined.

3.1.4. Radiofrequency Transoral Microsurgical Procedures in Benign and Malignant Laryngeal and Hypopharyngeal Lesions (Institutional Experiences)

Transoral microsurgeries using radiofrequency were carried out at our department in 23 cases between 01. January 2011. and 01. March 2013., in 14 cases due to benign (Table 1.) and in 9 cases due to malignant histopathological lesions (Table 2.). Micro-Larynx RF Probes powered by Surgitron Dual 4.0 MHz Frequency RF (Ellman International, Oceanside, NY, USA) were used with needle-tip and ball-tip electrodes. Needle-tip electrodes enable precise surgical incision making, while ball-tip electrodes ensure focused electrocoagulation. The first postoperative controll happened in the 7-10th day, the second controll on the 14-17th day.

Histologically benign laesions	Number of cases	Notes
Unilateral vocal cord pachydermy	4	following irradiation, 1 hypopharynx, 1 vocal cord tumour
Unilateral vocal cord polyp	2	1 sessile, 1 pedunculated
Laryngeal papilloma	1	unilateral vocal cord and anterior commissure localisation, complete removal
Laryngeal amyloidosis	2	isolated amyloidosis on the vestibular fold
Laryngeal lipoma	1	on the right vestibular fold
Polyp at the oesophageal entrance	1	following larygectomy, it disturbed implantation of the voice prosthesis
Tracheal stricture	1	at the level of the first tracheal cartilage
Post-irradiation oedema of the laryngeal entrance	2	focused treatment of the arytenoid area to improve swallowing

Table 1: Histologically benign laesions and our findings

Two interesting and rare cases were those of two patients with isolated laryngeal amyloidosis. Systemic amyloidosis was excluded in both cases with clinical examinations. Another rare disorder was seen in a 57-year-old male patient, a lipoma causing the prominent vestibular fold on the right side and thereby a constant feeling of a lump in the throat and difficulty swallowing. In one case, in consequence of permanent intubation, tracheal stricture occurred. RF ablation carried out on the arytenoid mucosa made swallowing easier in both patients.

All lesions characterised by malignant histological changes proved to be planocellular carcinomas by histological examination. Tumours of the vocal cord and T1 tumours of the hypopharynx were removed with R0 resection. In the case of vocal cord tumours, the tumours could be excised fast and with adequately delicate movements in 2 patients as primary therapy and in another 2 patients following radiation therapy. It is of note that in the case of a 92-year-old postradiotherapy patient with the help of the newly acquired JET ventilation device it was

possible to completely remove the recidivation in the posterior third of the vocal cord by eliminating the space reduction of the intubation tube. In the case of two of our patients with T1 tumours of the hypopharynx, excisions were easier due to the pedunculated nature of the tumours. Following radiotherapy, the approximately 0.5 cm diameter exulcerated tumour residuum was located in between the anterior and medial walls of the recessus piriformis, and by a resection with a free margin the patient did not require laryngectomy. In those cases where debulking of the T3, supraglottic-origin tumours was carried out, debulking was always effective and tracheotomy was not required prior to later laryngectomies in any of the more advanced cases.

Histologically malignant cases	Number of cases	Notes
Hypopharyngeal tumour (T1)	3	2 primary surgeries, 1 surgery following irradiation
Vocal cord tumour (T1)	4	2 primary surgeries, 2 surgeries following irradiation (1 located at the posterior third of the vocal cord, JET ventilation)
Supraglottic tumour (T3)	2	tumour debulking to avoid tracheotomy

Table 2: Histologically malignant lesions and our findings

The insignificant amount of bleeding during the surgeries did not interfere with precise excising. Practically, irradiated, scarred areas could be excised without bleeding. The postoperative period was without the development of laryngeal oedema or significant pain in all patients.

At the first postoperative examination reepithelisation was found to be in a more advanced stage than it would be with the use of cold-steel or laser devices. Although this is merely a subjective statement, at the second postoperative examination reepithelisation—except for the tumour debulking cases—was complete.

Radiofrequency incorporates the advantages of both CO2 laser and cold-steel techniques; it provides precise incision line, good haemostasis, and fast reepithelisation and is a cost-effective transoral microsurgical procedure.

3.1.5. The Effect of Radiofrequency Soft Palate Surgery on Snoring and Voice Quality

Six male patients (36-55 years of age, average age 43.83 years; BMI: 23-27 kg/m², average 24.5 kg/m²) participated in the study who had previously undergone nocturnal polysomnography examinations. The polysomnography results revealed benign snoring in 5 patients (Apnoe-Hypapnoe Index/AHI/<5/h), and mild Obstructive Sleep Apnoe Syndrome/OSAS/(AHI: 5,3/h) in one of our patients. In the background of the symptoms uvula elongata and atonic low-positioned soft palate was found in all the cases verified also by sleep endoscopy, performed according to international guidelines which showed antero-posterior vibration and sometimes obstruction at the level of the velum. Preoperatively and at the postoperative weeks 1 and 5 snoring of the patient and a few institutionally created sentences were recorded.

During the intervention we used a bent needle electrode. The 2 cm-long end of the electrode, inserted submucosally, is insulated 1 cm long in the proximal portion in order to avoid thermal damage to the mucosa around the insertion points. According to an earlier publication by Tagliaferro, we inserted the distal 2 cm-long portion of the electrode submucosally: via two insertion points in the midline and 2 insertion points along the paramedian line on both sides. Radiofrequency energy was set at 20 W and applied for 10-10 s, followed by the resection of the distal two-thirds of the elongated uvula with the needle electrode. Bleeding was controlled, if needed, with a RF bipolar forceps.

Follow-up examinations were organized on postoperative weeks 1 and 5. The patients' snoring was recorded with a dictaphone under standardised circumstances. During outpatient visits, in a quiet room, some sentences containing only high-pitched or low-pitched or mixed vowels, and extended vowels were recorded with dictaphone. Voice recordings were statistically analysed with the help of *CoolEdit 2000*, and our own invention compiled by the senior author (*J. Pytel*). During follow-up physical examinations, photos were taken of the changes in the soft palate and compared to the preoperative photos.

For the assessment and evaluation of subjective results, patients and their bed partners filled out a simplified version of the Berlin questionnaire, during a personal interview preoperatively and then 3-6 months postoperatively, during a telephone interview.

On the postoperative day 7, the insertion points on the palatal mucosa and the resection surfaces of the uvula were covered with fibrin in nearly all cases. No serious

complications occurred. According to the photo documentation, on the postoperative week 5, the soft palate was tighter and elevated in all the cases.

Summarising the subjective experience of the patients and their bed partners, both reported a decreased intensity of snoring and the majority of the bed partners observed an improvement in the patients' snoring. Telephone interviews revealed no changes in voice according to the subjective experiences of the patients.

With the help of the voice analysing program, we could graphically demonstrate the patients' snoring sounds recorded through the night prior to and after surgery. Results measured after the intervention showed a similar improving tendency with respect to the intensity of snoring in all patients.

Analyzing the sound during a section of inhalation burst there was a 24.06 dB difference in loudness between the pre- and postoperative snoring sounds, however, only with respect to smaller periods of snoring but not through the entire night. Moreover, the enlarged pictures of the curves clearly demonstrate that the noise-like effect modified into a music-like sinus wave.

The sonagram shows that the overtones above the fundamental tone are clearly distinguishable on the postoperative recordings as well, that means, the tone of the patients' voice did not change. No professed differences were found in voice intensity either. Duration of extended vowels was above 15 sec. in all patients both pre- and postoperatively.

Radiofrequency uvulopalatoplasty (RF-UPP) is an effective way to treat socially disturbing benign snoring and mild OSAS, being fast it can be performed in an ambulatory setting and is well-tolerated by patients. The above method does not cause changes in voice quality. According to international guidelines, sleep endoscopy is recommended prior to any snoring or OSAS surgery, to determine the exact localisation of the vibration or obstruction, to make the correct therapeutic decision and to provide adequate information for the patients.

3.2. Experimental study (Animal modell)

Histological consequences of laser (KTP- and Nd:YAG-) and radiofrequency inferior turbinate reduction in animal modell. A comparative pilot study.

To the best of our knowledge, no other study has reported comparative morphological and histological effects on the inferior turbinate in the short- and mid-term postoperative period in an animal model following the application of RF or KTP (Potassium-Titanyl-Phosphat) or Nd:YAG (Neodymium-Yttrium-Aluminium-Garnet) laser also with comparative examinations by scanning electron microscopy (SEM).

A porcine model was chosen for this study in view of the histological resemblance of porcine ciliated respiratory cells to human respiratory cells.

Twelve Duroc pigs with an average weight of 19.25 kg (range 16-21 kg) were studied. All the pigs were anesthetized for induction and intubation with 1.5 mL of ketamine hydrochloride, including a premedication cocktail consisting of azaperonum (160 mg), ketamine (125 mg), diazepam (10 mg), and atropine sulfate (1 mg). Endotracheal intubation was followed by the maintenance of anesthesia with 0.5% halothane.

The inferior turbinates were randomly treated either with RF device or with a KTP or Nd:YAG laser under videoendoscopic control. With the randomization 2 different procedures were compared in each animal (intraindividual examination). Among 12 pigs 4 groups (control, RF, KTP, Nd:YAG) were created containing 6 inferior turbinates in each group.

Tissue samples were taken at the end of postoperative weeks 1 and 6. The narrow passageway of the nasal cavity of the piglets necessitated endoscopy with a 2.7 (outer diameter) × 106 mm otoscope (Karl Storz GmbH & Co, Tuttlingen, Germany). Prior to the surgical treatment, the nasal mucosa was anesthetized with tetracain-naphasolin solution.

In the RF group, turbinate reduction was achieved with a Surgitron 4.0 MHz Dual Frequency RF device (Ellman International, Oceanside, NY, USA) with a power setting of 20 W for 15 seconds in the COAG mode. The bayonette turbinate electrode was inserted submucosally at the anterior pole of the turbinate.

In both laser groups, the laser beam was applied to the surface from the posterior to the anterior part of the inferior turbinate at 10 W for 15 seconds in CONTACT mode (LaserScope Orion, Santa Clara, CA, USA).

Before and after all procedures, the anatomy of the nasal cavity was assessed in all 3 groups following decongestion of the nasal mucosa, and was compared with the nasal anatomy of the control group. Biopsies were taken under short-term general and topical anesthesia at the end of postoperative weeks 1 and 6.

Macroscopical investigations

Macroscopic changes (mucosal swelling, fibrin deposition, ulceration, hematoma, necrosis, crusting, etc) were examined endoscopically and documented with photos and video records. A scoring system was set up for evaluation of the results of the macroscopic findings.

Tissue samples were evaluated pathologically from the view of necrosis, remodeling, and other histological changes. SEM (JSM 6300 Scanning Microscope, JEOL, Tokyo, Japan) was implemented to demonstrate variations in the respiratory epithelium.

Histopathological investigations

HE (hematoxylin-eosin) staining was used to identify the changes in the structure of the turbinates. PAS (Periodic-Acid-Schiff) staining was used to quantify the goblet cells, which correlated well with the function or dysfunction of the nasal respiratory epithelium.

Scanning Electron Microscopy

The surfaces of the samples were photographed in order to view the laser-treated tissue, including its ablation and coagulation zones, and cross-sections of the samples were investigated to reveal the effects of treatment on the deeper tissue layers.

Macroscopic findings

In the RF group, at the end of postoperative week 1, the turbinates generally presented a normal epithelium, except at the points of insertion of the RF electrodes: in 2 such cases smooth fibrin was observed, and in 1 case a slight crust. In 2 instances, the turbinates were somewhat swollen, but there was no apparent bleeding, synechia or pathological discharge. At

the end of postoperative week 6, the epithelium of all the turbinates appeared to be intact; in 1 case it was swollen, but in the remaining cases the volume was considerably reduced.

In the KTP laser group, at the end of postoperative week 1, a thin fibrin deposit was seen along the inferior turbinates in 2 cases and a dense crust in 1 case. Four of the inferior turbinates were swollen. At the end of postoperative week 6, the turbinates were damaged, and crust-covered in 2 cases, and 1 was swollen, but 5 were diminished.

In the Nd:YAG laser group, a thick fibrin deposit was observed along the inferior turbinates in 2 cases and there was a thick crust in an additional 2 cases at the end of postoperative week 1. Four turbinates were markedly swollen. At the end of postoperative week 6, all the turbinates were damaged, to various degrees, including extreme ruffling and shrinkage of the soft tissue, and in 1 case synechia between the septum and inferior turbinate was apparent.

Microscopic findings

In the RF group an intact epithelium, a focal torn stratum, intact glands, and an intact cartilaginous skeleton were observed at the end of postoperative week 1. No further histological changes were detected at the end of postoperative week 6, apart from minimal submucosal chronic inflammation.

At the end of postoperative week 1, the *KTP laser* caused a moderate focal thickening of the epithelium, granulocyte penetration, submucosal scar tissue deposition, and dilated blood vessels, and broadening of the perichondrium of the nasal turbinate cartilage. At the end of postoperative week 6, remarkable necrotizing sialometaplasia in the lamina propria, cystic dilated glands with excess mucus production and a widened perichondrium with cartilage destruction were also observed.

At the end of postoperative week 1, an intact epithelium, dilated blood vessels, granulocyte infiltration, and submucosal sialometaplasia were detected after *Nd:YAG laser* treatment. Interestingly, the cartilage remained intact. At the end of postoperative week 6, squamous metaplasia, including a moderate widening of the epithelium, was seen in the lamina propria, and submucosal dilated blood vessels, dilated glands, and excess mucus were also observed. Following the treatment, the cartilage remained intact.

The PAS-stained sections exhibited similar histological states in the RF-treated group and the control group: In most cases, intact states with normal glandular functions were observed. Both the KTP and the Nd:YAG laser treatment worsened both the status and the function of the submucosal glands.

Scanning Electron Microscopic findings

The surface of the *RF-treated* inferior turbinate was similar to that in the control group at the end of postoperative week 1. After postoperative week 6, the cells were shallower than in the control group, but the cilia were not damaged. In both the *KTP and the Nd:YAG groups*, the ablation zone was surrounded by a coagulation area at the end of postoperative week 1.

Additionally, the destruction of the superficial respiratory epithelium was observed. After postoperative week 6, the attachments between the cells were unrestrained, but the cilia were intact in the KTP group. Interestingly, distinct polygonal-like squamous cells were observed in the Nd:YAG group.

4. Discussion

As a result of low temperature heat generated sideways during radiofrequency interventions, damage to the surrounding tissue can be avoided, intraoperative bleeding can be reduced, the procedure itself facilitates healing and the degree of post-operative pain is also less.

Discussion of clinical investigations

In case of **rhinophyma** radiofrequency combines the advantages of laser and “cold tool” techniques. The loop electrode is easy to use for tissue removal and remodeling of the nose demands precise work. The removal of tissue below the depth of the pilosebaceous unit will result in a smooth atrophic scar rather than a normal porous nasal skin. In contrast with laser vaporization, the excised tissue pieces are suitable for histological examinations, and thus any hidden malignancy could readily have been revealed.

Our questionnaire survey on the **hypertrophy of the inferior turbinate** was carried out based on favourable results reported in the international literature with the aim to further confirm our experiences. In order to protect the mucosa, interstitial RF interventions on the inferior turbinate are performed submucosally, with the aim to reduce the volume of the inferior turbinate and thereby to provide an increased nasal airflow. Due to the intact ciliary, respiratory mucosa the cleaning and humidifying functions of the nose also remain intact. In our study, RF interventions improved nasal breathing in all patients, nearly all patients reported an improved olfaction, it stopped post-nasal drip in half and improved it in the remaining patients. Subsequent animal experiments verified our clinical findings.

Partial removal of the tonsils i.e. **tonsillotomy** has several advantages from a surgical perspective as compared to total tonsillectomy. These include a more moderate and shorter duration post-operative pain as a result of which, children are able to consume a normal amount of food. Further advantages include less frequent post-operative bleeding, if it occurs, however, blood loss is markedly less. Children are able to return back to the community consequently, parents spend less time on sick leave. All the advantages detailed above justify the procedure to be the treatment of choice in certain well-indicated cases.

Based on our experiences with radiofrequency tonsillotomy (RF-TT), it can be clearly stated that, although, no significant changes were found with respect to the duration of the two surgical interventions, post-operative morbidity was markedly more pronounced among patients having undergone tonsillectomy. The reason primarily is the stronger and longer post-operative pain, as a result of which, the children's eating habits differ from pre-surgery eating habits. Children consumed less food, correspondingly, their bodyweight decreased considerably during the investigation period. Moreover, children having undergone TE had to stay away from school longer and their parents could not go to work for longer periods. The later obviously had a negative impact on the families' financial status.

During TT, the incision made on the tonsil leaves the pharyngeal arch intact, the remaining tonsillary tissue protects the surrounding muscles from thermal damage, therefore post-operative pain is experienced for a shorter time and is less intense. Additionally, the risk to damage the vessels near the capsule is reduced, thus the risk of post-operative bleeding is also decreased.

According to *Hultcrantz et al*, previous infections causing hypertrophy are no longer considered as contraindication of tonsillectomy, which is supported by our experiences as well. Those few patients of ours that had undergone TT, indicated by their recurrent tonsillopharyngitis, experienced no disadvantages result from the new surgical technique. *Reichel et al* found no higher risk after TT to develop abscesses or of recurrent infection either. Our findings also showed similar results. Investigations carried out by *Hultcrantz, Johnson and Paradise*, who took into consideration several different intervals and revealed no difference as regards the number of (tonsillo)pharyngitis cases developed after conservative therapy, TT or TE, let us conclude that, we do not always have to stick with traditional methods, therapeutic decisions have to be guided by the family history and the intention to choose the treatment modality that least burdens the child.

In cases of tonsillary hypertrophy causing obstructive symptoms and recurrent tonsillopharyngitis, if their occurrence does not fulfill the Paradies criteria, instead of TE we recommend the RF-TT technique, especially in children under 6 years. Our study clearly demonstrates that post-operative morbidity is considerably better with tonsillectomy than with tonsillectomy.

Two important requirements should be fulfilled for surgeons during **transoral microsurgical interventions**:

- (i) a precise surgical incision with satisfying special controllability,
- (ii) effective bleeding-control with the least possible tissue damage.

The traditional cold-steel technique meets the first criterion; however, our experiences showed that bleeding during excisions disturbs evaluation of margins; moreover, heat from later electrocoagulation can be quite significant. In our study according to the histopathological findings the resection margins were clear in all cases except for tumour debulking. Preparations could be carried out practically without any bleeding. Postoperative oedema developed in only an insignificant number of cases, pain or dysphagia did not occur, and hospitalisation time decreased significantly.

In the case of CO2 laser surgeries good results can be expected both in terms of precise incision making and effective bleeding control. One disadvantage can be due to the

spreading features of the CO₂ laser beam; namely, the possibility to curve an incision spatially is limited. Another disadvantage is that devices are more costly. Special devices and much more expensive laser intubation tubes are required to prevent accidents caused by the laser beam. Whereas the former is a one-time investment, the latter increases the costs of every intervention using laser. The use of JET ventilation allows better access to the surgical area and the use of the laser tube can also be spared. Besides less collateral heat, RF excision provides all advantages of CO₂ laser surgery. It is also easier to manipulate the excision line in space as a result of the bayonet-shaped tip of the device which makes the tip visible throughout the surgical procedure.

Our experiences showed that this “shoulder” of the device may get stuck in some marginal positions and thereby may make excision and surgical manipulation more difficult. This method does not require any special complementary devices.

In the present study, similar to international experience and findings, precise surgical excisions and precise bleeding control could be achieved with minimal bleeding in the majority of cases. In the postoperative period neither laryngeal oedema nor intense pain occurred. Reepithelisation was faster than it usually is in the case of cold-steel or CO₂ laser procedures.

Corresponding to *Blumen's* findings regarding intensity of snoring and partner satisfaction, **RF UPP** proved to be a successful surgical therapy in the treatment of snoring caused by localised obstruction at the level of the velum and mild OSAS in the majority of our patients. An advantage of the RF method is the less lateral heat affecting the tissues, resulting in less pain and faster postoperative wound healing. Similar to *Kezirian's* study, on the first follow-up, insertion points on the surgical areas and the resection surfaces of the uvula were covered with fibrin in nearly all cases.

Soft tissue vibration during snoring is reduced due to the tightening of the soft palate. According to our study the sound energy spectrum of soft palate snoring is within a lower spectrum of frequency. During the spectrum analysis of snoring we observed, that snoring is characterised by a fundamental frequency and several harmonics within a broad frequency band, and our only patient with mild OSAS showed the same results as well.

Our observation supports the fact that treatment of the soft palate alone does not cause changes in voice. None of our patients exhibited any of the above complications.

Discussion of experimental studies

The RF energy causes fibrosis of the underlying stroma due to submucosal coagulative necrosis, leaving the epithelium intact. Following wound healing, submucosal scar formation and retraction of the tissue, reduction and stiffening of the turbinate evolve. In the course of time, partial resorption of the scar tissue results in a further volume reduction.

The KTP laser emits light at 532 nm (ie, green light), which is absorbed by hemoglobin, resulting in consecutive protein denaturation, endothelium impairment, and microvessel occlusion. As a result, selective coagulation of the surface mucosal vessels is possible to a depth of up to 0.5 mm. The Nd:YAG laser produces light at 1064 nm, that is, in the near-infrared (invisible) range. Characteristically, due to the strong backward and forward scattering, thermal coagulation and necrosis may extend up to 4 mm deep and laterally over the surface, making precise control impossible. The KTP crystal gives double the frequency (half the wavelength) of the Nd:YAG laser. The applied laser instrument provides the possibility of varying the wavelength from 1064 nm (Nd:YAG) to 532 nm (KTP laser), with a resulting change in tissue absorbance of the laser beam.

Our extensive clinical experience with RF and KTP and Nd:YAG lasers led us to conduct a comparative histological pilot study of the potential effects of RF and KTP and Nd:YAG laser treatments on the inferior turbinate mucosa in an animal model.

It was noteworthy that at the end of postoperative week 6 we did not identify any focal metaplasia within the RF group, whereas focal metaplasia was seen in the Nd:YAG group, which may also prolong the time of mucociliary transport.

At the end of the postoperative week 1, marked signs of damage were observed in both laser groups, with potential crust or synechia formation; however, with an increase of control, this can be prevented.

Our SEM findings showed the development of cilia at the end of postoperative week 6 in all 3 groups, yet the shape of the cells was changed. These changes most probably do not impair the function of the cells.

For the application of laser equipment, several additional protective accessories, the costs of the laser intervention are more expensive than that of the RF procedure.

5. Novel results

1. The present comprehensive study is the first in the Hungarian literature to investigate nearly all applications modalities of the radiofrequency method in otorhinolaryngology. The present thesis outlines our experiences and analyses our results in the light of national and international literature.
2. Our clinical investigations were the first to support the applicability and usefulness of radiofrequency tonsillotomy in Hungary in the light of other international studies.
3. The present study has been the first in Hungary to introduce the microlaryngeal radiofrequency method on an adult patient population on the basis of findings published in international literature.
4. We have been the first to perform the analysis of snoring and speech sounds of patients having undergone radiofrequency uvuloplasty.
5. On two animal models, we investigated the effects of laser versus radiofrequency volume reduction on the inferior turbinate by histology and electron microscopy. As regards our experiments, to date, no similar investigation has been published in the international literature.

6. Publications

6.1. Publications of the author contributing to the present thesis

Somogyvári K, Battyáni Z, Móricz P, Gerlinger I. Radiosurgical excision of rhinophyma. *Dermatologic Surgery* 2011; 37(5): 684-7 (**IF 1.798**)

Somogyvári K, Móricz P, Szanyi I, Bocskai T, Gőcze K, Gerlinger I. Tonsillectomia versus rádiófrekvenciás tonsillotomia gyermekkorban (Pilot study). *Fül- Orr- Gégegyógyászat* 2014; 60 (4): 155-60.

Somogyvári K, Gerlinger I, Lujber L, Burián A, Móricz P: Radiofrequency transoral microsurgical procedures in benign and malignant laryngeal and hypopharyngeal lesions (Institutional experiences), *Scientific World Journal* 2015: Paper 926319. 4 p. (**IF: 1.219**)

Somogyvári K, Móricz P, Gerlinger I, Faludi B, Bocskai T, Pytel J. Rádiófrekvenciás lágyszájpad kezelés hatása a horkolásra és a beszédhangra. *Fül- Orr- Gégegyógyászat* 2016; 62 (1): 12–21.

Somogyári K, Móricz P, Gerlinger I, Kereskai L, Szanyi I, Takács I. Morphological and Histological Effects of Radiofrequency and Laser (KTP and Nd:YAG) Treatment of the Inferior Turbinates in Animals: A Comparative Pilot Study. *Surgical Innovation* 2017; 24 (1):5-14. (**IF: 1.909**)

6.2. Lectures held by the author contributing to the present thesis

MFOE 42. Nemzeti Kongresszusa, Pécs, 2012. 10.17-20.

Somogyvári K., Móricz P., Gőcze K., Tóth Z., Gerlinger I.: Rádiófrekvenciás tonsillotomia versus hagyományos tonsillectomia gyermekkorban

MFOE 42. Nemzeti Kongresszusa, Pécs, 2012. 10.17-20.

Somogyvári K., Móricz P., Gőcze K., Tóth Z., Gerlinger I.: Az alsó orrkagylók rádiófrekvenciás ablációja (Retrospektív tanulmány)

Somogyvári K., Móricz P., Gőcze K., Tóth Z., Gerlinger I.: Hagyományos tonsillectomia vs. rádiófrekvenciás tonsillotomia gyermekkorban

Rádiófrekvenciás fül-orr-gégészeti beavatkozások, Pécs, 2012.12.07-08.

Somogyvári K., Móricz P., Gerlinger I.: Rhinophyma rádiófrekvenciás excisioja

MFOE Gyermek Fül-Orr-Gége Szekciója 20. Jubileumi Kongresszusa, Visegrád, 2013.10.03-05.

Somogyvári Krisztina dr., Móricz Péter dr., Szanyi István dr., Benedek Pálma dr., Bocskai Tímea dr., Gőcze Katalin dr., Gerlinger Imre dr.: Gyermekkori rádiófrekvenciás tonsillotomiával szerzett tapasztalataink a PTE KK Fül-, Orr-, Gégészeti és Fej-, Nyaksebészeti Klinikán

Magyar Alvásdiagnosztikai és Terápiás Társaság IX. Kongresszusa, Budapest, Honvéd Kórház, 2013.11.15.

Somogyvári Krisztina, Móricz Péter, Faludi Béla, Gerlinger Imre, Pytel József
Rádiófrekvenciás lágyszájpad kezelés hatása a horkolásra és a beszédhangra

Szegedi Rhinológiai Napok (Rhinodays Szeged - 2014) 2014.04.25-26., SZTE ÁOK, Orvosi Készségfejlesztési Központ (Skills Labor)

Dr. Somogyvári Krisztina: Rádiófrekvenciás lágyszájpad kezelés hatása a horkolásra és a beszédhangra

Workshop: Dr. Somogyvári Krisztina, Dr. Móricz Péter Ph.D. : Radiofrekvenciás műtéti lehetőségek a fül-orr-gégészetben

MFOE 43. Kongresszusa Tapolca, 2014. okt. 15-18.

Somogyvári Krisztina, Gerlinger Imre, Móricz Péter, Faludi Béla, Pytel József
Rádiófrekvenciás lágyszájpad kezelés hatása a horkolásra és a beszédhangra

Szegedi Rhinológiai Napok III. (Rhinodays Szeged – 2015) 2015.04.10-11., SZTE ÁOK, Orvosi Készségfejlesztési Központ (Skills Labor)

Dr. Somogyvári Krisztina – Radiofrekvenciás kezelési lehetőségek horkolás esetén
(Workshop)

Magyar Sebész Társaság Kísérletes Sebész Szekció XXV. Kongresszusa - Sebészeti kutatások klinikai szemmel 2015.05.14-16.

Dr. Somogyvári Krisztina (PTE KK Fül-Orr-Gégészeti és Fej-Nyaksebészeti Klinika):
Rádiófrekvenciás és lézeres (KTP, Nd:YAG) alsó orrkagyló volumenredukció szövettani hatásának összehasonlítása állaton. Pilot study

MFOE 44.Kongresszusa és az MFOE Audiológiai Szekciójának 53. Vándorgyűlése, Szeged, 2016. október 6-9.

Somogyvári Krisztina, Móricz Péter, Kereskai László, Gerlinger Imre, Takács Ildikó:
Lézeres és rádiófrekvenciás alsó orrkagyló megkisebbités szövettani következményei állat modellen. Összehasonlító, tájékoztató vizsgálat

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