Surgical therapy and olfactory function

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Abstract. Surgical therapy and olfactory function. This report provides an overview of the relationship between olfaction and surgery. Surgery can be considered as treatment for some olfactory dysfunctions. Moreover, olfactory dysfunction can be analysed as a complication of some surgical procedures. An impaired sense of smell is a common problem affecting approximately 65% of patients with chronic sinusitis. Much of the literature about the effect of surgery on the olfactory system is based on subjective reports of olfactory function, which do not accurately assess objective smell dysfunction. A small number of prospective studies have been published. All studies looking at the sense of smell have found overall post-operative improvement compared with pre-operative symptoms. The range of improvement compared with pre-operative scores ranged from 13 to 91%, with a median of 31%. Olfaction dysfunction can be a complication of various surgical procedures such as laryngectomy, septoplasty, rhinoplasty, ethmoidectomy, and some neurosurgical procedures.

Introduction

All pathology of the upper respiratory tract may be associated with impaired sense of smell. Nasal obstruction induced by septal deviation or turbinate hypertrophy is frequently associated with olfactory dysfunction. Only a few studies have discussed the relationship between olfactory ability and septoplasty, turbinoplasty, turbinectomy, and surgery of choanal atresia. Chronic rhinosinusitis is the most common chronic inflammatory disease, and is frequently associated with olfactory disturbance. The main symptom of nasal polyposis is anosmia. Functional endoscopic sinus surgery is widely accepted as treatment for chronic rhinosinusitis and/or nasal polyposis in the setting of failure of medical management. All studies looking at the sense of smell have stated overall post-operative improvement compared with pre-operative symptoms. On the other hand, all nasal sinusurgical surgery may involve a risk for olfaction. Only a few studies have investigated correlations between olfaction and surgical procedures: laryngectomy, anterior or skull base surgery, rhinoplasty, septoplasty, turbinectomy and turbinoplasty.

The aim of this paper is to review all these relationships between surgery and olfaction.

Surgery as treatment for olfactory dysfunction

Anatomical surgery (septoplasty, rhinoplasty, turbinectomy) and olfactory function

The volume and shape of the nasal cavity influence olfactory physiology. The number of olfactory molecules transported to the olfactory neuro-epithelium varies as a function of the intranasal airflow.\(^1\) The relationship between olfactory ability and nasal structure is complex. Leopold et al.\(^2,3\) have studied the relationship between olfactory function (odour identification test, odorant confusion matrix) and nasal anatomy (evaluated using computed tomography) in hyposmic patients. They identified three factors that influence olfaction: (i) the space anterior to, and no more than 5 mm below, the cribriform plate, (ii) the space between 10 and 15 mm below the cribriform plate, and (iii) the space posterior to, and between 10 and 15 mm below, the cribiform plate. Recently, Damm et al.\(^4\) have measured olfactory function (phenyl ethyl alcohol threshold, odour discrimination and identification) in 50 healthy subjects, and compared these olfactory results with intranasal volume measured by magnetic resonance imaging. Significant correlations were found between odour thresholds and the volumes of the anterior part of the right lower and upper meatus. These results suggest the
interest for nasal surgery, mainly for inferior turbinate resection and septoplasty, of two anatomical segments: (i) the segment in the upper meatus below the cribiform plate, and (ii) the anterior segment of the inferior meatus.

Nasal obstruction induced by septal deviation or turbinate hypertrophy is frequently associated with olfactory dysfunction.\textsuperscript{1-8} Septoplasty and turbinectomy constitute a common procedure for the treatment of nasal obstruction related to an anatomical abnormality. The effects of nasal surgery on olfaction have not been well documented in the literature. The available data on olfactory outcome after such nasal surgery is limited.

Septoplasty is frequently performed in patients with nasal obstruction due to septal anatomical abnormalities. Olfactory function may only be influenced indirectly, through changes associated with airflow. Only a few studies have discussed the relationship between septoplasty and olfactory ability.\textsuperscript{9} Stevens et al.\textsuperscript{6} compared olfactory thresholds of 100 patients before and after nasal surgery, including septoplasty (n = 63), rhinoseptoplasty (n = 24), inferior turbinate resection (n = 3), and polyectomy (n = 10). Data for each type of operation was not provided separately. The authors concluded that nasal surgery, including septoplasty and inferior turbinate resection, improved olfactory function. But, this conclusion is weakened by methodological considerations.\textsuperscript{9} Kimmelman\textsuperscript{10} evaluated olfactory function (UPSIT test) before and after septoplasty in 34 patients. UPSIT scores were equivalent before and after surgery. But 1% of the patients showed anosmia 2-4 weeks after septoplasty. More recently, Pfaar et al.\textsuperscript{11} evaluated septoplasty-related changes of lateralised olfactory function (Sniffin’Sticks test battery) before, 4 and 9 months after a septoplasty in 30 patients. Before septoplasty, patients had significantly higher odour thresholds for the obstructed nostril compared to contralateral thresholds. The difference in odour thresholds between obstructed and non-obstructed sides disappeared after surgery. No such results were observed for suprathreshold measures. Following septal surgery, a significant decrease in odour discrimination was found by comparison with the pre-operative results. There was no significant change in odour thresholds and odour identification after surgery. In conclusion, no significant change in overall olfactory ability was found following septoplasty.

An analysis of the literature seems to indicate that a relevant increase in olfactory function may not be expected after septoplasty.\textsuperscript{11} Nevertheless, some authors reported hyposmia and anosmia following septal surgery.

The effects of rhinoplasty on olfaction have not been well documented.\textsuperscript{9} Goldwyn and Shore\textsuperscript{1} compared olfaction in 97 consecutive patients undergoing rhinoplasty and/or submucous resection with 57 normal control subjects. Olfaction was evaluated on the basis of the subjects’ response to smelling oil of clove, oil of peppermint, and ground coffee. Two, six and twelve months after surgery, none of the patients had any change in their olfaction by comparison with the pre-operative results. Others authors\textsuperscript{12-13} also reported that subjective olfactory function was not improved after rhinoplasty. Champion has reported temporary anosmia in about 10% of patients, lasting 6 to 18 months after rhinoplasty. Kimmelman\textsuperscript{10} evaluated olfactory function (UPSIT test) before and after rhinoplasty in 15 patients (follow-up: 2 and 4 weeks). A small but significant increase in UPSIT scores was observed following surgery. However, this conclusion is weakened by methodological considerations.\textsuperscript{9} Furthermore, an analysis of the literature seems to indicate that a relevant increase in olfactory function may not be expected after rhinoplasty.

The effects of turbinectomy on olfaction have been documented in a few publications. Ophir et al.\textsuperscript{14} reported on a series of 150 patients who underwent total inferior turbinatectomy with a mean follow-up of 2.5 years. Olfactory testing consisted of a forced-choice format for standardised odourants. None of the patients were found to have anosmia, but 27% of the patients noted an improvement in olfaction. Odetoynbo\textsuperscript{15} addressed this issue by following 58 patients who underwent bilateral inferior turbinatectomy. Olfactory assessment of the patients was by questionnaire: 61% noted an improvement in olfaction. Elwany and Harrison\textsuperscript{16} compared four inferior turbinate techniques (partial turbinectomy, laser turbinectomy, cryoturbinectomy, turbinoplasty) in terms of their effects on nasal obstruction and olfaction (n = 80 patients). Olfactory thresholds were determined for citral and eugenol. Post-operative improvements in olfaction correlated positively with the patency of the nasal airway. Damm et al.\textsuperscript{17} evaluated the influence of septoplasty associated with partial inferior turbinectomy (n = 30 patients) on threshold and...
suprathreshold olfactory acuity. Olfactory function was determined with Sniffin' Sticks (odour threshold, discrimination and identification). After surgery, 80%, 70% and 54% of patients had improved olfaction in terms of odour identification, odour discrimination or odour thresholds respectively. This study suggests that septoplasty associated with partial inferior turbinectomy has a positive effect on olfaction, mainly on suprathreshold parameters. An analysis of the literature therefore seems to indicate that a relevant increase in olfactory function may be expected after turbinectomy.

Only two publications of patients with choanal atresia report on the effects of surgery repair on olfaction. Gross-Isseroff et al.\textsuperscript{17} were the first to report, in 1989, on olfactory function following the repair of choanal atresia. Threshold determination and odour identification were evaluated in three cases of bilateral and one case of unilateral choanal atresia. These four patients underwent the successful choanal atresia repair procedures at ages varying between 8 and 31 years old. Patients with bilateral atresia had permanent olfactory deficits while the patient with unilateral atresia had normal olfactory function. This paper suggested that early olfactory exposure might be needed for the normal development of the olfaction system. Leclerc et al.\textsuperscript{18} reported, ten years after, on a series of 7 patients born with choanal atresia (5 bilateral and 2 unilateral). This case-control study was conducted to compare olfaction in this group of patients to a similar group of normal subjects. Olfactory investigations were conducted with the University of Pennsylvania Smell Identification Test (IPSUT). Patients with choanal atresia had a significant loss of olfaction ($p = 0.03$). Patients with choanal atresia had moderate hyposmia (score: $27/40$) while control subjects had normal olfaction (score: $37/40$).

**Surgery of rhinosinusitis and olfactory function**

Chronic rhinosinusitis is a group of pathologies characterised by the inflammation of the mucosa of the nose and paranasal sinuses for at least twelve consecutive weeks. In most cases, patients complain of nasal discharge, nasal obstruction and olfactory dysfunction. On the basis of an anatomical distinction,\textsuperscript{19} it is possible to define three main clinical entities for chronic rhinosinusitis: chronic rhinitis, localised sinusitis, and diffuse rhinosinusitis. Diffuse rhinosinusitis is mainly represented by nasal polyposis.\textsuperscript{20,21} The symptom patterns of these three main clinical entities vary considerably, particularly the olfactory symptoms. Olfactory dysfunction can consist of either hyposmia, anosmia, or cacosmia. Hyposmia is mainly present in patients with rhinitis or moderate diffuse rhinosinusitis. Anosmia is found to be rather common in patients with diffuse rhinosinusitis, particularly in nasal polyposis; it represents an important patient complaint. In contrast, cacosmia is mainly associated with localised anterior sinusitis, particularly in cases of odontogenic sinusitis or fungus balls.\textsuperscript{19}

**Surgery for localised sinusitis and cacosmia**

The surgical treatment for cacosmia is the surgical treatment of odontogenic sinusitis or fungus balls. Cacosmia is present in 21% of patients with a fungus ball.\textsuperscript{22} The prevalence of cacosmia in localised anterior sinusitis is 26%.\textsuperscript{19} The treatment of such odontogenic sinusitis usually requires a combination of medical and surgical management.\textsuperscript{23} Elimination of the cause, either by treating an infected tooth with root canal therapy or extraction, or removal of a fungus ball from the sinus, is required to prevent recurrence of the disease. After dental treatment and medical management including a 7- to 10-day course of oral antibiotics with adequate sinus coverage, persistent symptoms require functional endoscopic sinus surgery. Unfortunately, the results of surgery for odontogenic sinusitis or fungus balls never include cacosmia. For example, Dufour et al.\textsuperscript{24} reported on a retrospective series of 175 patients suffering from paranasal sinus fungus balls confirmed by histopathology or mycological culture. The study was based on analysis of medical files, operative charts, and follow-up evaluation reports. Only one case of local failure was observed in the maxillary sinus, as well as 6 cases of persisting fungus ball, in a mean follow-up of 5 years. However, the report on this large series did not include any data about cacosmia. Nevertheless, the disappearance of the infection could be associated with the disappearance of the cacosmia.
nasal polyposis has been a topic of frequent heated debate for many decades. Most authors agree that nasal polyposis management should be based primarily on a medical approach to be completed by surgical procedures only in the case of drug failure. Abundant literature has been dedicated to this treatment modality, but most of the publications deal with a single steroid administered either orally or in a spray. Intranasal steroids are the best documented type of treatment for rhinosinusitis and/or nasal polyposis. A number of placebo-controlled studies have shown a significant clinical effect. Some studies were dedicated to systemic steroid therapy, showing genuine efficacy for all symptoms, especially anosmia. Topical steroids can also be used as long-term therapy, either alone in mild cases, or in combination with systemic steroids in more severe cases. A limited number of publications have reported on the efficacy of a standardised drug administration protocol based on a short-term oral steroid prescription combined with the daily and long-term administration of topical steroids. Short courses of systemic steroids combined with long-term steroid intranasal spray treatment led to satisfactory results in 85% of the patients. In about 15% of cases, medical treatment alone fell short of the expected effects, in particular on nasal obstruction and olfaction, and surgery had to be considered.

Functional endoscopic sinus surgery (FESS) is widely accepted as a treatment for chronic rhinosinusitis and/or nasal polyposis subsequent to the failure of medical management. Nevertheless, the literature shows that there are major variations in the way patients are selected for surgery. A range of factors have been reported as a basis for patient selection. They include symptom scores, extent of disease (i.e. endoscopic and/or CT scores) and failed medical treatment. A number of publications had poor external validity with poorly defined patient groups, a lack of clear inclusion and exclusion criteria, and little or no description of the surgical procedure. Moreover, the majority of studies of outcomes after FESS group patients with a variety of polyoid and non-polyoid diseases. The analysis of the outcomes of surgery in terms of olfaction in chronic rhinosinusitis must therefore take several criteria into account: (i) the group of patients studied (i.e. mean doses of medical treatment administered before surgery), (ii) the surgical procedure used (i.e. polypectomy, partial or radical ethmoidectomy), (iii) the method for the evaluation of olfaction (i.e. self-perceived olfactory function or quantitative measures).

The surgical options described in the treatment of chronic rhinosinusitis and/or nasal polyposis can be broadly divided into simple snare polypectomy or endoscopic sinus surgery. The only attempt at a randomised comparison of steroid therapy and polypectomy was performed by Lildholdt in 1989. In a prospective study, patients (n = 53) received continuous topical treatment with either a polypectomy or an intramuscular injection of beclomethasone dipropionate and betamethasone sodium phosphate. Patients were followed up for one year. The smell evaluation methodology was not described. Significant subjective and objective improvement was observed two weeks after treatment began in both groups, and this was maintained throughout the following year. El Nagger et al. studied olfaction in 29 patients with nasal polyposis before and after a polypectomy, followed by a 6-week course of beclomethasone nasal spray to one nostril, with the other acting as a control. The study used the University of Pennsylvania Smell Identification Test (UPSIT). Smell function did not change after this procedure, either with or without beclomethasone nasal spray.

A systematic review of the clinical effectiveness of endoscopic sinus surgery for the removal of nasal polyposis has been published by Dalziel et al. Pre-operative smell disturbance percentages varied from 16% to 100% in the publications covered. This major variation suggests that the inclusion criteria were different in these reports. Mean doses of medical treatment administered before and after surgery were not systematically reported. Nevertheless, all the studies that covered sense of smell stated overall post-operative improvement compared with pre-operative symptoms. The range of improvement compared with pre-operative scores ranged from 13 to 91% with a median of 31%.

Jafek et al. were the first to report on the concept of steroid-dependent anosmia and the influence of nasal surgery on smell function. Some publications examined a limited series of patients (i.e. fewer than 30 patients). Park et al. reported on a retrospective series of 79 patients with chronic rhinosinusitis or recurrent acute sinusitis, including 73% with nasal polyposis. Surgery consisted of
FESS, with the removal of the bulla ethmoidalis, uncinate process and anterior ethmoid cells. Olfactory disturbance was reported in 72% of patients pre-operatively compared with 38% (p < 10⁻⁴) following FESS. Lund and Scadding evaluated olfaction in 50 patients with chronic rhinosinusitis, using UPSIT and a one-year follow-up period. Endoscopic sinus surgery included different procedures: anterior ethmoidectomy and/or anterior + posterior ethmoidectomy. Surgery was followed by a 3-month period of topical steroids. Significant post-operative improvements in UPSIT scores were observed. Lund and MacKay also reported on a retrospective series of 650 patients with chronic rhinosinusitis (51%), recurrent acute sinusitis (2%) and nasal polyposis (47%). Only 23% of the patients had a smell dysfunction pre-operatively. Six months after an endoscopic sinus surgery, 21% of patients reported being the same, 79% reported improved olfaction, and 12% reported being cured. Downey et al. assessed olfactory function in 50 patients with chronic rhinosinusitis, before and after endoscopic sinus surgery, using UPSIT. After surgery, 52% of patients had higher UPSIT scores, and self-reported significant improvement in olfaction. UPSIT scores were correlated with the severity of the disease, as defined by the Kennedy staging system. Delank and Stoll reported on a prospective series of 115 patients with chronic rhinosinusitis, including 77% with nasal polyposis. FESS was conducted with a Wigand approach. Olfaction was evaluated by olfactory tests and self-rating questionnaires. Pre-operatively, 31% of patients had anosmia, 52% hyposmia, and 17% normosmia. Following FESS, 11% of patients had anosmia, 57% hyposmia, and 31% normosmia. Improvement occurred in 70% of patients with anosmia or hyposmia. Olfaction worsened following 8% of FESS procedures. There was a correlation between olfactory loss and the extent of sinus disease. Klimek et al. determined the odour identification and discrimination of 31 patients with nasal polyposis before and after surgery. Endonasal sinus surgery resulted in improved olfaction, with the best results within three months after surgery. Min et al. tested butanol thresholds before and after FESS in 80 patients with chronic rhinosinusitis. Before surgery, 33% of patients had anosmia; 45% of patients had hyposmia. After surgery, these percentages were 16% and 46%. Klossek et al. reported on a retrospective series of 50 patients with extensive nasal polyps. Pre-operatively, 100% of the patients had anosmia for at least six months per year. At three-year follow-up, 78% of the patients retained their sense of smell. This percentage was lower one year later (60%) and three years later (58%). Levine reported on a retrospective study of 250 patients with nasal polyposis (n = 131) or chronic sinusitis (n = 119). Surgery consisted of FESS, using a modified Messerklinger technique. Only 16% of the patients had a smell disturbance before surgery. After a mean follow-up of one year after surgery, 3% of patients reported anosmia. Jakobsen and Svendstrup reported on a retrospective study of 237 patients with either chronic infectious sinusitis (n = 91), or nasal polyposis (n = 146). Olfaction was evaluated by questionnaires. The length of follow-up was one year. Anosmia was reported by 48% of patients with nasal polyposis before surgery compared with 21% one year after FESS (Stammburger technique). Litvack et al. confirmed that olfactory impairment was common in 111 patients with chronic rhinosinusitis. All patients had a diagnosis of chronic rhinosinusitis based on the rhinosinusitis task force criteria. An objective measure of olfactory function, the SIT from Sensornics, Inc, was administered before and after endoscopic sinus surgery. Olfactory function improved in patients with pre-operative anosmia, and was sustained at one-year follow-up. Nevertheless, patients with pre-operative hyposmia did not improve after sinus surgery. Recently, Bonfils reported on a prospective series of 194 consecutive patients with nasal polyposis who were examined, operated on, and followed by the same surgeon. Before surgery (total ethmoidectomy), all patients received systematic and standardised medical treatment, including washing of the nasal cavities, long-term topical steroids, and short courses of systemic steroids. The minimum duration of medical treatment before surgery was six months. Patients were selected for surgical treatment when more than three systemic courses of prednisone per year proved to be necessary to control nasal polyposis symptoms. The mean follow-up duration after surgery was 6 years. 84% of patients had anosmia before surgery. The 5-year actuarial anosmia control rate was 66%. However, only 18% of the patients considered their olfaction to be normal 5 years after surgery.
Three years after surgery, the smell loss severity index was reduced by 45%. These surgical results were not modified either by the presence of allergy, bronchial hyperresponsiveness, or by the eosinophilic infiltration index of polyps.

Some publications compare the impact of different surgical approaches on the sense of smell. Jankowski et al. compared two series of patients with diffuse nasal polyposis: 37 patients undergoing functional ethmoidectomy and 39 patients undergoing radical ethmoidectomy. Olfaction was evaluated with a 10-point visual analogue scale. Both groups had similar scores pre-operatively. Improvement in olfaction was similar in both groups six months after surgery. Nevertheless, improvement was stable in the radical ethmoidectomy group but olfaction decreased after six months in the functional ethmoidectomy group.

**Olfactory dysfunction as a complication of surgery**

**Olfactory dysfunction and anaesthesia**

Is there a relationship between olfactory dysfunction and general anaesthesia? A very limited number of publications have reported on the effects of anaesthesia on olfaction. For some authors, anosmia may occur after general anaesthesia during the course of surgical interventions not necessarily associated with naso-sinusal surgery. Adelman related changes in taste and smell experienced approximately 6 weeks after having received a general anaesthetic for cystoscopy. The anaesthetic consisted of 50 mg lidocaine and 200 mg propofol administered intravenously for induction, 80 mg succinylcholine to facilitate tracheal intubation, and 1-2% isoflurane in 60% N2O with oxygen for maintenance. The anaesthetic was uneventful; the patient was discharged the same day. The anaesthetist did believe there was a causal relationship. An expert related the patient’s symptoms to the anaesthetic she had received. Specifically, he stated that halogenated hydrocarbons could induce taste and smell distortions. The lawsuit was dismissed. A variety of drugs have been described as altering taste and smell after oral administration, systemic injection or topical application. Some of these drugs are used in local and general anaesthesia. Benzocaine, hydrochloride, and lidocaine interfere with the taste system; cocaine and lidocaine interfere with the smell system. An unpleasant smell of halogenated volatile agents can be perceived during inhalational induction but without any definitive smell loss.

**Olfactory dysfunction after total laryngectomy**

Olfaction is frequently altered after total laryngectomy. Severe hyposmia has been reported in two-thirds of patients who underwent laryngectomy, and moderate hyposmia was found in the remainder. The reason for olfactory loss is still a matter for debate. Some authors propose an anatomical explication: after total laryngectomy the absence of olfaction and perception of flavours could be due to the compromised transport of odorant molecules to the olfactory mucosa because of the loss of the ability to sniff air through the nose. Other authors have suggested that surgical interference with sensory nerves from the larynx might alter olfactory function through a complex feedback mechanism.

This clinical evaluation was confirmed by olfactometry and chemo-sensory evoked potentials. The psychophysical data revealed that laryngectomees are either functionally anosmic or hyposmic. Olfactory evoked potential studies suggested that, in two-thirds of the patients, the olfactory system retained some function, even up to 22 years after laryngectomy. Van Dam et al. analysed 63 post-laryngectomy patients with two different olfactory tests: an odour-detection test and an odour-differentiation test. Patients’ assessments of their own olfaction were assessed with a questionnaire, and by means of self-reports. One-third of the patients were able to smell the odorous substances used in the olfactory tests. The smellers used a variety of methods to smell; in most patients the method consisted of
the active use of facial muscles. The non-smellers reported a more severe decrease in gustation after the operation. Patients who reported the deterioration of olfaction and gustation tended to experience negative consequences such as the inability to smell smoke, leaking gas, or agreeable odours. Leon et al. studied the retronasal and orthonasal olfactory function after laryngectomy: 36 volunteer patients who underwent laryngectomy were compared with 36 control subjects without laryngectomy. Scores were established using psychophysical tests (Connecticut Chemosensory Clinical Research Center) for orthonasal and retronasal olfaction and self-rating scores for smell using a visual analogue scale. The assessment of orthonasal olfactory ability yielded a mean composite score of 4.3 for the laryngectomy group and 5.3 for the control group. The evaluation of retronasal olfactory ability resulted in mean scores of 11.0 for the laryngectomy group and 14.3 for the control group. The mean self-rating scores for smell were 2.9 and 6.6 for the laryngectomy group and control groups respectively. The differences were significant. Self-assessment with a simple visual analogue scale successfully identifies many laryngectomy patients who have objective evidence of olfactory dysfunction.

Furthermore, the use of larynx bypasses demonstrates that subnormal olfactory function is present in patients after laryngectomy. Larynx bypasses have been used to rehabilitate olfactory function in patients after laryngectomy. Göktas et al. have evaluated olfaction in 16 post-laryngectomy patients. Patients were asked to use the device at home for at least 30 minutes a day for 3 months. They were also asked to use a diary to record subjective ratings of their sense of smell and the practicability of using the device every day. Three months later, patients experienced a significant olfaction improvement as assessed with the Sniffin’ Sticks test. One year later, the same authors compared the larynx bypass with a new instrument: the scent-diffusing ventilator. Olfactory function significantly improved with the two systems but the scent-diffusing ventilator was much easier to use than the larynx bypass. They concluded that technical improvements are necessary to make the scent-diffusing ventilator an established part of the rehabilitation of the olfactory function in patients with laryngectomy.

Olfactory dysfunction after nasal surgery
Implicit in all types of nasal surgery is the potential for a worsening of olfactory function. Hyposmia or anosmia may be attributable to several mechanisms: scar tissue, granulation tissue, persistent mucosal oedema or inflammation, or olfactory neuro-epithelium lesions. Such olfactory dysfunction can be observed after rhinoplasty, septoplasty, turbinectomy and functional endoscopic sinus surgery. Kimmelman examined 93 patients undergoing various types of nasal surgery, including ethmoidectomy, polypectomy, Caldwell-Luc procedure, open reduction of nasal fracture, closed reduction of nasal fracture, rhinoplasty, and septoplasty. Olfactory function was evaluated using the University of Pennsylvania Smell Identification Test (UPSIT).

Sixty-one patients (66%) had either improved or unchanged UPSIT scores after surgery; the remaining 32 patients (34%) had lower scores. One patient (1%) became anosmic. Stevens et al. reported on a prospective study of 100 patients undergoing nasal surgery. Olfaction was evaluated pre- and post-operatively. Eight patients experienced impaired olfaction after surgery. Two of these cases were related to allergic rhinitis. One patient had a total loss of olfaction following septorhinoplasty. The authors conclude that most patients undergoing nasal surgery will experience either an improvement or no change in olfaction after surgery. In conclusion, the occurrence of olfactory disease after endonasal surgery has been reported to be as high as 1%.

Olfactory dysfunction after neurosurgery
Olfactory function is often sacrificed to gain access to the anterior and central cranial base. Olfactory structures, mainly the olfactory bulb, constitute a natural obstacle to the approach of the anterior cranial fossa. Anosmia is therefore a major sensory complication associated with this surgery. Passagia et al. suggested that the most important consideration is to respect the blood supply to the olfactory bulb. New techniques, modified approaches, and microneurosurgery have been described as potential ways to preserve olfactory function. In 1993, Spetzler et al. preserved olfaction in four consecutive patients with extradural anterior cranial base tumours by circumferentially cutting the cribriform plate, and leaving the neuro-olfactory...
epithelium attached to it. Feiz-Erfan et al.\textsuperscript{72} reported on the long-term impact on olfactory function in 24 patients who underwent anterior craniofacial surgery and a cribriform plate osteotomy to preserve olfaction. Olfactory evaluation was defined by the subjective ability to detect smells such as coffee, chocolate, roses, and orange juice regardless of the intensity of the sensation, and the follow-up was based on phone calls to patients without any olfactory tests (except in 5 patients). Olfaction was spared in 22 patients, and was confirmed by olfactory testing in 5 patients. Only two patients were therefore anosmic. The authors concluded that olfaction can be preserved in selected patients undergoing anterior craniofacial surgery. At least 1 cm of nasal mucosa should remain attached to the cribriform plate. This can be achieved by including the nasal bone in the osteotomy of the orbital bar. Olfaction can therefore be preserved in selected patients undergoing anterior craniofacial surgery. This procedure is particularly suitable for benign or low-grade malignant tumours, primarily extradural tumours, or for intradural tumours with an extradural extension if the cribriform plate is not involved by the tumour.\textsuperscript{72}

Bifrontal craniotomy can be used to treat anterior communicating artery aneurysms. Suzuki et al.\textsuperscript{73} described a series of 110 cases. The olfactory tracts were preserved bilaterally or unilaterally in 65% of the cases. 33% of the patients with bilateral olfactory tract damage reported subjectively normal olfactory. The objective examination of olfaction showed that 84% of the patients reporting normal olfaction had normal olfaction, whereas 91% of those reporting anosmia were anosmic. On the other hand, Martin et al.\textsuperscript{74} compared two groups of patients (n = 39 patients) with anterior communicating artery aneurysms. Olfactory function was assessed using the University of Pennsylvania Smell Identification Test (UPSIT). A significant and severe olfactory impairment was observed in patients with ruptured anterior communicating artery aneurysms compared with the control group. Only one control subject had a smell identification deficit versus 17 patients with ruptured aneurysms (44%). In this series, 17 patients underwent aneurysmal clip placement, and 22 underwent coil embolisation. 59% of the patients who underwent aneurysmal clip placement and 28.5% of patients who underwent coil embolisation scored below the 25th percentile on the UPSIT. The olfactory test performed worse in patients subjected to endovascular coil embolisation when cerebral vasospasm or frontal cerebral lesions were present. This difference was not observed in patients who underwent surgery. The authors concluded that olfactory deficits were present in both groups of patients treated with the two techniques.

Only a few publications report on the olfactory function after surgical resection of olfactory groove meningiomas. Bassiouni et al.\textsuperscript{75} reported on a series of 56 consecutive patients suffering from olfactory groove meningiomas treated microsurgically. Preoperative neurological examination revealed deficits in olfaction in 71.7%. The tumours were resected via a bifrontal craniotomy (n = 36), a pterional route (n = 13), a unilateral frontal approach (n = 4), and in a supra-orbital approach (n = 3). The extent of tumour resection according to Simpson’s classification system was grade I in 42.9%, and grade II in 57.1% of the cases. Olfaction was preserved in 24% of patients. Welge-Luessen et al.\textsuperscript{76} examined twelve patients with olfactory meningiomas. In 8 cases, the meningioma was lateralised (five left, three right), and in four patients, the meningioma was bilateral. Olfactory testing was performed using the “Sniffin’ Sticks” test. Before surgery, six patients were found to be anosmic on the side of the tumour; two were hyposmic. Four patients were normosmic. After surgery, four patients had lateralised anosmia on the operated side, three were normosmic on the contralateral side and one was hyposmic. The remaining eight patients were completely anosmic post-operatively. The preservation of olfaction ipsilateral to the tumour therefore seems to be extremely difficult, irrespective of tumour size or surgical approach. However, the likelihood of normal post-operative olfactory function contralateral to the tumour was high when the tumour was less than 3 cm in diameter and pre-operative normosmia had been established.

Cerebrospinal fluid rhinorrhoea can be managed either by neurosurgeons or otorhinolaryngologists. Neurosurgeons often use an intracranial approach and otorhinolaryngologists an extracranial approach. Recently, transnasal endoscopic techniques have been introduced that significantly reduce the morbidity of surgical repair by comparison with intracranial approaches. Olfaction was preserved in all patients who
underwent the endoscopic repair of their cerebrospinal fluid leak when olfaction was present preoperatively. The results of transnasal endoscopic repair now make it the treatment of choice for most anterior cranial and sphenoid cerebrospinal fluid leaks, with the exception of defects in posterior wall of the frontal sinus or defects larger than 5 cm.⁷⁷,⁷⁸

Conclusion

An analysis of the literature seems to indicate that a relevant increase in olfactory function may not be expected after septoplasty or rhinoplasty. The analysis seems to indicate that a relevant increase in olfactory function may be expected after turbinectomy or turbinoplasty. In chronic rhinosinusitis, all studies that looked at the sense of smell have stated overall postoperative improvement compared with preoperative symptoms after endoscopic sinus surgery. The range of improvement compared with preoperative scores ranged from 13 to 91% with a median of 31%. The incidence of olfactory disease after endonasal surgery has been reported to be as high as 1%.

On the other hand, olfactory dysfunction may be a complication of surgery or anaesthesia. A limited number of publications report on the effects of anaesthesia on olfaction. Olfaction is frequently altered after total laryngectomy and some neurosurgical procedures.

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