

Empty nose syndrome: etiopathogenesis and management

Magdy Eisa Saafan, Hassan Moustafa Hegazy, Osama A. Albirmawy

Department of Otolaryngology and Head & Neck Surgery, Tanta University Hospitals, Tanta, Egypt

Corresponding to Hassan Moustafa Hegazy, MD, ENT Department, Tanta University Hospitals, Tanta 31516, Egypt Tel: + +20 128 494 8668; E-mail: hmhegazy@hotmail.com

Received 28 October 2015

Accepted 1 November 2015

The Egyptian Journal of Otolaryngology
2016, 32:119–129

Empty nose syndrome (ENS) is an iatrogenic disorder most often recognized by the presence of paradoxical nasal obstruction despite an objectively wide patent nasal cavity. It occurs after inferior and/or middle turbinate resection; however, individuals with normal turbinates and intranasal volume may also complain of ENS. Its pathophysiology remains unclear, but it is probably caused by wide nasal cavities affecting the neurosensitive receptors and inhaled air humidification. Neuropsychological involvement is also suspected. Not every patient undergoing radical turbinate resection experiences the symptoms of ENS. ENS can affect the normal breathing function of the nasal cavity, with subsequent deterioration in patients' quality of life. The diagnosis is made on the basis of the patients' history, endoscopic examination of the nasal cavity, imaging (computed tomography imaging and functional MRI), and rhinomanometry. Prevention is the most important strategy; thus, the inferior and middle turbinate should not be resected without adequate justification. Management is problematic including nasal cavity hygiene and humidification, with surgery reserved for the most severe cases. The surgery aims at partial filling of the nasal cavity using different techniques and implant materials. In this paper, we review both the etiology and the clinical presentation of ENS, and its conservative and surgical management.

Core tip

Empty nose syndrome (ENS) is encountered after inferior and/or middle turbinate resection; however, it can occur in patients with seemingly normal turbinates. Rhinologists should avoid routine resection of the inferior and middle turbinates. It is not certain why some patients develop ENS, whereas others do not. The frequent association with psychiatric disorders and possibly psychosomatic pathologies indicate the possible role of psychological stress in some patients. Its diagnosis relies on clinical suspicion and physical examination. Nasal augmentation surgery can improve the quality of life of patients by restoring nasal anatomy toward the pre-morbid state.

Keywords:

atrophic rhinitis, empty nose syndrome, endoscopic, nasal physiology, turbinate

Egypt J Otolaryngol 32:119–129

© 2016 The Egyptian Journal of Otolaryngology
1012-5574

Introduction

The descriptive term 'empty nose syndrome (ENS)' was originally coined in 1994 by Kern and Stenkvist to describe empty space in the region of the inferior and middle turbinates on coronal computed tomographic images of the patients [1]. They observed that these patients suffered from endonasal crusting and dryness, and some of them also experienced a paradoxical sensation of nasal obstruction, despite adequate intranasal airspace [2].

The term 'empty nose' has broader applications than 'empty nose syndrome' and the two terms should not be used interchangeably. As its name implies, ENS is an iatrogenic disorder that has clinical manifestations that often cause significant distress to the patients, as opposed to 'empty nose', which may or may not have associated symptoms [3].

ENS is a complication of middle and/or inferior turbinate surgery, most frequently total turbinate

excision, but also with minor procedures such as submucosal cautery, submucosal resection, laser therapy, and cryosurgery if performed in an aggressive manner [4]. The onset of this condition occurs at an interval of months or years after the procedure [3]. One point of concern is the frequent association with psychiatric disorders and psychosomatic pathologies, for example, fibromyalgia and functional colopathy, in addition to the possible role of psychological stress and neurological component in certain patients [5–7].

The diagnosis of ENS is difficult because there are no reliable objective tests; thus, the diagnosis relies on the patient's subjective symptoms. Most rhinologists often

This is an open access article distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 3.0 License, which allows others to remix, tweak, and build upon the work noncommercially, as long as the author is credited and the new creations are licensed under the identical terms.

miss the diagnosis because they look for physical signs of dryness and atrophy after turbinectomies and objective long-term complications, and neglect the patients' subjective complaints of nasal obstruction or shortness of breath, which are often viewed as psychological manifestations [2]. Like some otolaryngologic disorders (e.g. tinnitus), the fact that the symptoms are subjective and cannot be verified objectively does not imply that they are not real. In fact, many studies have found a lack of correlation between subjective and objective measures of nasal patency [8–10].

The occurrence rate of ENS after turbinectomies is not known, but the condition is rare [2,11]. It is uncertain why some patients develop ENS after turbinectomies, whereas others do not. One hypothesis is that a 'two-hit' phenomenon must take place, in which (a) the tissue is excised or damaged and (b) the sensory nerves to the area regenerate poorly. The differences in the nerve recovery after surgery and the unique patients anatomy may explain why only some patients develop ENS despite identical turbinate surgeries [3].

ENS is a diagnosis of exclusion as it must be distinguished from other diseases such as chronic rhinosinusitis, autoimmune diseases of the nose, and primary atrophic rhinitis [2]. Confusion results from similarities in the symptoms of ENS and atrophic rhinitis. Paradoxical congestion, dryness, and crusting may present in both disorders. However, atrophic rhinitis may be classified as primary or secondary, with a clear underlying cause or idiopathic in nature. In addition, resorption of the turbinate and adjacent mucosa that results from atrophic rhinitis is reflective of the underlying pathophysiology of the disease, whereas ENS is an iatrogenic disorder. Also, atrophic rhinitis has pathogenic links to the

organisms isolated from nasal cultures, but as yet, there is no pathogen associated with ENS [3].

Types

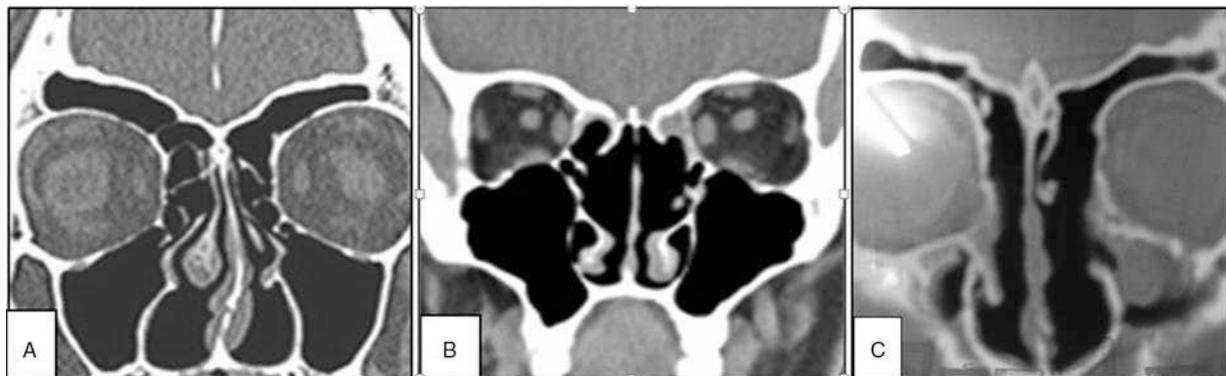
Houser distinguished several subtypes of ENS according to the resected turbinate: inferior, middle, both, or a subtype in which turbinates appear normal [4]. ENS-IT (empty nose syndrome-inferior turbinate) is the most frequent type (Fig. 1a). The basic complaint is paradoxical nasal obstruction [12]. ENS-MT (empty nose syndrome-middle turbinate) is rarer; in addition to the nasal obstruction, patients may complain of pain on respiration because of circulating cool air striking the area of the sphenopalatine ganglion, which is no longer protected by the MT (Fig. 1b) [13]. ENS-both is mostly associated with a nasal cripple and the patient is iatrogenically disabled (Fig. 1c) [13]. In the ENS type, a patient has seemingly normal turbinates, but suffers from ENS symptoms after surgery [2].

Pathophysiology

The pathophysiology of ENS remains poorly elucidated, but several hypotheses can be found in the literature. ENS may result from loss of the physiological nasal functions (humidification, warming, and cleansing of the inhaled air) because of reduced mucosal area [14].

Passali *et al.* [15] reported a disruption of nasal physiology (mucociliary clearance, IgA secretion rates, and general heating and humidification capacities) in 45 patients who had undergone total inferior turbinectomies. Naftali *et al.* [16] and Elad *et al.* [17] used computerized simulations to show that removal of the inferior turbinate reduces the overall heat and water vapor flux in the nose by 16% and removal of the middle turbinate or removal of the

Figure 1



Computed tomography (CT) scan of the paranasal sinuses showing: (a) bilateral total inferior turbinectomy (ENS-IT), (b) bilateral near total middle turbinectomy (ENS-MT), (c) bilateral total inferior and middle turbinectomies (ENS-both).

inferior and middle turbinates together reduces vaporization by 12 and 23%, respectively.

Naftali *et al.* [16] also reported that the turbinates and nearby septal and lateral wall mucosa were responsible for about 60–70% of the air conditioning and the overall heating of the inspired air. The efficacy of nasal air conditioning was reduced by 12% when the middle turbinate was missing and by 16% when the inferior turbinate was missing.

In a study carried out by Scheithauer [1], the air-conditioning function of the nose was examined in a group of 10 ENS patients using MRI-based numerical airflow dynamics simulation models during inspiration and expiration; compared with the healthy control group, absolute humidity at all measuring points was lower in ENS patients, especially in the nostril region. These lowered humidity values are responsible for the dry nose sensation and increased crust formation experienced by ENS patients.

Role of thermoreceptors in empty nose syndrome

The specific trigeminal cool thermoreceptors involved in the sensation of nasal patency are TRPM8, which are activated when high-speed air moves through the nostril and induces evaporation of water from the epithelial lining fluid. The fluid remaining has a lower temperature, which leads to reduced fluidity of membrane phospholipids that is sensed by TRPM8 receptors, causing depolarization of neurons that connect to the brainstem respiratory center [18]. The 'cool' message is interpreted as patent nostrils and open airways, leading to a decrease in the intercostal and accessory muscle work of breathing [18]. The brain interprets the lack of stimulation as an 'uncool' signal, which induces apnea and increases the work of breathing with sensations of nasal 'fullness' [2,18]. These receptors fail to be activated in the following cases:

- (1) ENS patients as the surface area of the nasal passages are reduced and the airflow pattern is altered, which compromises mucosal cooling [2].
- (2) Nasal mucosal thickening and excessive mucus production, which limit the evaporation and hinder the degree of mucosal cooling.
- (3) Anesthetized nasal mucosa.

Effect of change of airflow pattern

- (1) Turbulent airflow is required not only for cooling of the nasal mucosa but also for inspired particulate

material to come in contact with the nasal mucosa [19]. With reduced mucosal surface area and a lack of physiologic turbulent airflow in ENS patients, the nasal mucosa cannot carry out its primary functions of air conditioning and cleansing. Similarly, olfactory particles are less likely to deposit in the olfactory cleft, reducing the capacity to smell [2].

- (2) Another observation made in the context of flow simulation in the ENS patients is that the inspired air is accelerated through the posterior apertures of the nose, hitting the back wall of the nasopharynx at a high speed [1], together with insufficient air humidification by nasal mucosa, causing dehydration and dryness of the pharyngeal mucosa.
- (3) During normal expiration, warm moist air from the lungs mixes with a cool moist environment within the nose; thus, the portion of the temperature and humidity given off to the mucosa by convection during inspiration can be extracted from the mucosa again during expiration [1]. In ENS patients, warm dry air is met instead, and so this process is disrupted that, in conjunction with reduced mucosal surface area, does not allow the moisture from the lungs to be reabsorbed during exhalation, thus perpetuating nasal dryness [2].

Dyspnea in empty nose syndrome

- (1) Cool thermoreceptors in the nasal mucosa are connected to the respiratory centers. Thus, if the mucosal cooling fails to stimulate such receptors, the brain perceives a lack of airflow and produces the sensation of congestion and shortness of breath. This is supported by the following:
 - (a) In animal experiments, menthol as a specific stimulant of cool thermoreceptors causes respiratory depression [20].
 - (b) A study conducted by McBride and Whitelaw [21] showed that the degree of diaphragm contraction inhibition increased with increasing nasal flow and cooler air during inspiration. The effect was no longer observed following local anesthesia of the nose and pharynx.
 - (c) Breathing cool air through the nose inhibits the ventilatory response to the carbon dioxide [22].
- (2) The turbinates are related to the nasal meati, which offer resistance to limit the total amount of airflow and serves to increase the velocity of airflow, ensuring a mostly laminar pattern. As a result, a maximal conductive air–mucosal interface exists,

which provides maximum sensation. In patients with loss of turbinate tissue, there is eventual disruption and destruction of the meatal structure, causing turbulent, less efficient, and less sensate airflow [23,24]. These patients seem to be in a constant state of dyspnea and may describe the sensation as suffocating.

- (3) The nasal resistance is centrally important in providing wider opening of the peripheral bronchioles and enhancing alveolar ventilation. This in turn improves gas exchange, increases negative thoracic pressure, and enhances cardiac and pulmonary venous return [3]. Clinical research indicates that nasal resistance to expiration helps to maintain lung volumes and may indirectly affect arterial oxygenation [25].
- (4) Although air entering the nose in ENS patients fails to stimulate the cool thermoreceptors in the nasal mucosa, it still activates pulmonary stretch receptors, signaling the brain that adequate ventilation is occurring [2]. This conflicting message may explain the distress associated with breathing in ENS patients. This conflicting message has been reported in a study that used functional MRI to measure brain activity by detecting associated changes in blood flow. The differences in areas of brain activation between ENS patients and controls indicated abnormal signaling to the brain that may contribute toward the feeling of respiratory distress in ENS patients. Because ENS patients are in a constant state of dyspnea, they become highly preoccupied with their breathing, which leads to the inability to concentrate (aproxia nasalis), chronic fatigue, frustration, irritability, anger, anxiety, and depression [4,14].

Neurosensory system aberrations

- (1) Turbinate resection causes nerve damage that, if improperly healed, may result in ENS. Many studies have shown a link between uncomplicated surgery and postoperative sensory deficits. Aasvang and Kehlet [26] examined sensation deficits in postherniotomy patients and found that cutaneous sensory detection thresholds were increased for all sensory modalities on the operated side (cold, warmth, and mechanical pressure), along with decreased brush sensation during mapping. Relating this to the ENS patients, an increased detection threshold for cold means that a greater degree of mucosal cooling must occur to activate nasal mucosa cool thermoreceptors [14].

- (2) The turbinates are recognized as a source of nerve growth factor, a protein critical for the survival, maintenance, and repair of sympathetic and sensory neurons [27,28]. When the turbinates are removed or their mucosa are severely damaged, there is no conductor to orchestrate the healing process. Anomalous nerve connections could be formed during the healing process, whereas some nerves could be lost altogether. Consequently, some corrupted pathways would be activated where the message is not carried to the correct destination, whereas some nerve pathways would fail to be activated at all [2].

Diagnosis

It is difficult to diagnose the ENS because of the lack of a consensual clinical definition, the variety of symptoms, and the associated psychological and sometimes social distress.

Clinical diagnosis

Subjective symptomatology

The characteristic presenting symptom is the paradoxical nasal obstruction, sometimes associated with sensations of suffocation, breathlessness, dyspnea, or difficult breathing. Other symptoms such as pain, headache, loss of concentration (nasal aprosexia), chronic fatigue, frustration, anxiety, irritability, and depression are also reported. The patients may also have symptoms of pharyngitis and laryngitis. Symptom intensity varies and may restrict everyday activities [3].

Other reported symptoms are as follows [29,30]:

- (1) Sensation of excessive airflow and emptiness of the nasal cavity.
- (2) Lack of sensation of nasal airflow.
- (3) Hypersensitivity to cold air.
- (4) Sleep disordered breathing.
- (5) Patients with ENS often report a quantitative decrease in smell sensation, although their qualitative identification of odors remains intact [31].

The SNOT-20 [32] and the modified SNOT-25 [3] are the most common standardized questionnaires useful for the assessment of patient symptoms (Table 1).

Examination

Physical examination indicates wide nasal cavities, with missing or markedly reduced inferior and/or

Table 1 SNOT-20 and modified SNOT-25 Questionnaires for assessment of ENS

SNOT-20 [32] and SNOT-25 [3]. Nasal symptoms	SNOT-20 and SNOT-25 assessment for ENS					
	Scoring range (0–5)					
	0 (no symptoms)	1	2	3	4	5 (severe symptoms)
1. Need to blow nose						
2. Sneezing						
3. Runny nose						
4. Cough						
5. Postnasal discharge						
6. Thick nasal discharge						
7. Ear fullness						
8. Dizziness						
9. Ear pain						
10. Facial pain/pressure						
11. Difficulty falling asleep						
12. Waking up at night						
13. Lack of good night's sleep						
14. Waking up tired						
15. Fatigue						
16. Reduced productivity						
17. Reduced concentration						
18. Frustration/restlessness/irritability						
19. Sadness						
20. Embarrassment						
Houser modification adds						
21. Dryness						
22. Difficulty with nasal breathing						
23. Suffocation						
24. Nose is too open						
25. Nasal crusting						

Figure 2

Endoscopic view of the right nasal cavity in a case with empty nose syndrome.

middle turbinates from previous surgery. The mucosa is generally pale and dry, with crusting (Fig. 2) [5].

Diagnostic test

Cotton test: using an isotonic sodium chloride solution, cotton is moistened and placed within the nasal cavity in a region in which an implant may be feasible, without local anesthesia or decongestant, for better patient selection. The cotton is kept in place for 20–30 min and the patient is asked to breathe comfortably and report any changes in the symptoms. Patients who report a subjective improvement from the cotton test and whose symptoms and physical examination findings seem consistent with ENS are offered submucosal implantation [4].

The cotton test is an office-based procedure that is not only used as a diagnostic tool but also for preoperative evaluations to select the feasible location and the

amount of the implant required to reduce the nasal cavity volume [33].

Imaging

The diagnosis of ENS is clinical, but variable nonpathognomonic signs may still be found on computed tomographic imaging of the patients that include (a) mucosal thickening of the paranasal sinuses, (b) loss of definition of the ostiomeatal complex secondary to destruction of the ethmoid bulla and uncinat process, (c) opacification of the maxillary sinus, (d) enlargement of the nasal cavities, and (e) bony destruction of the inferior and middle turbinates [30,34,35].

Functional MRI study [14,36] shows specific activation patterns in the temporal and cerebellar regions and the amygdala in ENS patients.

Freund *et al.* [14] compared ENS patients with the control group by functional MRI with inhalation of menthol and limonene in comparison with room air and using rhinomanometry to measure nasal patency. Despite similar results of rhinomanometric measurements, the subjective nasal patency was worse for ENS patients than for controls that improved after menthol or limonene inhalation. Patients are distinguished by specific deactivation of the bilateral (paralimbic) temporal cortex and the Broca's area.

Rhinomanometry

Rhinomanometry is not useful for the diagnosis of ENS [14], but generally confirms the absence of any anatomical obstruction [4].

Rhinomanometry may not correlate with the subjective patient nasal patency as it focuses on the nasal obstruction attributable to anatomical factors. Many studies have documented the sensation of obstruction without any demonstrated anatomical causes, for example, topical application of local anesthetics in the nostril produces an artificial sensation of nasal obstruction with no change in objectively measured patency, whereas topical application of menthol produces the sensation of decongestion without actually altering nasal morphology [37].

Other investigations:

- (1) Bronchopulmonary functional exploration is useful in case of lower respiratory tract symptoms.
- (2) Bacteriology is also recommended in case of crusts and suppuration; it enables adapted antibiotic therapy.

- (3) The role of cytologic and pathologic analysis together with the mucociliary function of the turbinate mucosa remains to be determined.

Treatment

Prevention of empty nose syndrome

Because the nasal mucosa is the functional entity involved in the air conditioning, minimally invasive surgery on the turbinate that preserves the nasal mucosa and cool thermoreceptors is the key to achieve optimal results and reduce the risk of developing ENS [2].

Surgical techniques for the management of the inferior turbinate hypertrophy vary widely and have evolved considerably in the past four decades as new technologies have emerged [38]. They include turbinate outfracture, partial turbinectomy with resection of the anteromedial 1/3 of the inferior turbinate, and extramucosal destruction of the inferior turbinates by diathermy or laser [most commonly with a carbon dioxide (CO₂) or an Nd : YAG laser]. Along with the laser, cryosurgery can be used, which enables intracellular formation of ice crystals with cell membrane destruction. Although lasers and cryosurgery gained favor in the 1990s and the early 2000s, they are less frequently used nowadays [38].

Currently, many of the surgical techniques for inferior turbinate reduction fall into the category of submucosal resection and turbinoplasty, which involve remodeling of the inferior turbinate with removal of submucosal tissue with or without bone removal. Anterior turbinoplasty where the mucoperiosteal flap is detached from the turbinate bone, followed by resection of the turbinate head including bone, together with the lateral mucosal plate are performed; then, the remaining medial mucoperiosteal flap is placed laterally across the defect and secured with a tamponade. Submucosal diathermy and radiofrequency are also used to shrink the submucosal tissue, but they produce high tissue temperatures and can cause significant injury to the surrounding tissue and thermal damage of the overlying mucosa. Radiofrequency ablation using a Coblator is a more recent technique that causes less thermal damage to the surrounding tissues and can be performed using a method similar to that of electrocautery. Submucosal tissue removal by a microdebrider or a bipolar equipped microdebrider can also be used for submucosal tissue removal. The ultrasonic bone aspirator is the newest technique used in inferior turbinate surgery. The key feature of this

Table 2 Comparison of various techniques of implantation in the treatment of empty nose syndrome

References	Number of patients	Material used	Technique	Results
Goldenberg <i>et al.</i> [43]	Eight patients	Plastipore	Implantation of two plastipore plates under local anesthesia into submucosal pockets into the floor of the nose and septum	Excellent results were obtained in six patients, with complete resolution of symptoms and good results and only minor crusting in two patients. One implant extruded spontaneously 18 months after implantation and was reimplanted
Rice [44]	One case	Hydroxyapatite cement	Implantation under a subperiosteal tunnel to secure the entire anteroposterior length of the lateral nasal wall to the site of inferior turbinate	Significant result were obtained
Houser [4]	Eight patients	Acellular dermis (allograft)	Implantation under general anesthesia into a submucoperichondrial or a submucoperiosteal plane or into the submucosal layer to simulate missing turbinate tissue	During the follow-up period of 6 months to 4 years, it was found that most patients reported a statistically significant improvement in their symptom scores for the SNOT-20
Tam <i>et al.</i> [33]	16 patients	Medpor	Submucosal implantation under local anesthesia mainly in the septum and nasal floor	Application of SNOT-22 (Sino-Nasal Outcome Test-22) before and after surgery showed significant postoperative improvement in most of the symptoms such as need to blow their nose, postnasal drip, thick nasal discharge, fatigue, frustration, restless or irritability, and sadness. However, there was no significant improvement in altered sense of taste or smell, aural fullness, ear pain, reduced productivity, and embarrassment
Jang <i>et al.</i> [30]	12 patients	Cartilage implants (10 patients were implanted with conchal cartilage and/or septal cartilage), autologous costal cartilage was used in one, conchal and homologous costal cartilage were used in one	Submucosal implantations of cartilage at the inferolateral nasal walls	During the follow-up period of 6–27 months, patients reported significantly improved visual analogue score (VAS) score in excessive airflow, nasal obstruction, and nasal or facial pain. Complications of surgery included undercorrection in three patients
Jiang <i>et al.</i> [45]	19 patients	Medpor	Submucosal implantation under local anesthesia	During the follow-up period of 3–18 months, all patients reported subjective symptom improvements and a statistically significant improvement in the Sino-Nasal Outcome Test-20 (SNOT-20) scores. The endoscopy images and computed tomography scans confirmed that the positive outcomes of the surgery were maintained and proved that there was no evident trace of implantation depletion. Mucociliary clearance assessments showed improvements at 3, 6, and 12 months postoperatively. Acoustic rhinometry assessments showed postoperative improvements in nasal resistance, nasal volume, and minimum cross-sectional area, with a significant overall average score
Bastier <i>et al.</i> [46]	Five patients	B-tricalcium phosphate (b-TCP)	Implantation under general anesthesia in the submucoperiosteal pocket made along the lateral nasal wall at the site of the former inferior turbinate head between the nasal floor and the ostium of the nasolacrimal duct	They reported significant improvement of Nasal Obstruction Symptom Evaluation (NOSE) and Rhinosinusitis Quality of Life (RhinoQoL) questionnaires

(Continued)

Table 2 (Continued)

References	Number of patients	Material used	Technique	Results
Jiang <i>et al.</i> [47]	24 patients	Medpor implant	Submucosal implantation under local anesthesia to reconstruct their inferior turbinate	They reported that total scores of the SNOT-25 decreased postoperatively, showing a significant difference at 3, 6, and 12 months after surgery compared with their initial visit, which indicates that the quality of life in patients with empty nose syndrome (ENS) was considerably improved
Saafan [11]	24 patients	Comparison between the efficacy and safety of acellular dermal (allograft) versus silastic sheets submucosal implants	Prospective randomized blind clinical study comparing the efficacy and safety of acellular dermal (allograft) versus silastic sheets submucosal implants under general anesthesia	The SNOT-25 scores showed that both groups experienced a significant improvement after surgery, and there was no statistical evidence for a significant difference between the two groups
Jung <i>et al.</i> [48]	31 patients	Comparison of the use of costal and conchal cartilage implants to construct neoturbinates	Retrospective case series for comparison between costal and conchal cartilage implants to construct neoturbinates under general anesthesia	Both groups showed a significant improvement in SNOT-25 scores following surgery; the group that received costal cartilage implants showed more significant improvements than the conchal cartilage group in terms of the mean difference between preoperative and postoperative SNOT-25 scores
Modrzynski [29]	Three patients with ENS and atrophic rhinitis	Hyaluronic acid preparations	Submucosal injections of hyaluronic acid preparations into the inferior nasal concha and under the mucous membrane of the septum under local anesthesia as an office-based procedure	He reported positive results and has recommended this implant for the treatment of less severe forms of ENS

instrument is tissue selectivity as it vibrates rather than spinning like a drill burr or a microdebrider blade, which results in effective bone removal while causing relatively less damage to the surrounding soft tissue. Multiple techniques (especially outfracture) may be combined to maximize effectiveness [1,38].

Kennedy [39] argued against routine resection of the middle turbinate and he described its protective and physiologic functions. Therefore, it is better to preserve the middle turbinate during the nasal surgeries, except when there is severe inflammation of its mucosa with or without neosteogenesis or in the case of symptomatic concha bullosa; in such cases, it can be partially resected [1].

Medical treatment

Nasal hygiene with regular intranasal irrigation remains the standard of conservative therapy by minimizing crusting and restoring nasal hydration [11,40]. Medical treatment includes nasal lavage, topical ointment, antibiotic therapy, aerosols, and local corticosteroids, although such treatments seem to be less effective in ENS than in atrophic rhinitis [30]. Adding menthol to the local treatments may be beneficial; however, its effect on the nasal patency is because of a sensory illusion rather than altered airflow [41,42].

Surgical treatment

The aims of the endonasal surgery are to reduce nasal cavity volume, increase resistance to the airflow, reduce the airflow to increase air humidity, and deviate the airflow from the surgical site toward a healthy or a nonoperated side [13].

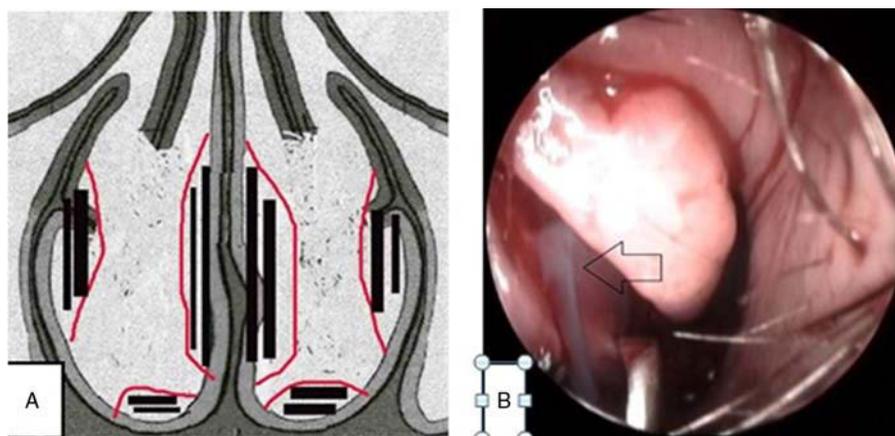
The creation of a neoturbinate is the most common surgical solution for ENS. Techniques vary from team to team, but the results have been very encouraging (Table 2). The principle consists of positioning an implant in a pocket in the septum, floor, or lateral wall of the nose [3,30,44].

The location of the implant is based on the patient's history, examination, computed tomography scan findings, and the results of the cotton test in the office. Patients who gain no benefit from the cotton test are deemed poor candidates for implantation [3].

The location of the implant should recreate the natural airflow patterns within the nose. To simulate the inferior turbinate, the implant is placed at the septum, floor, or the lateral nasal wall (Fig. 3a and b). As the head of the natural inferior turbinate enters the nasal valve region, the graft should be sufficiently anterior to replace the former inferior turbinate head [3]. A septal implant located anteriorly might function similarly. The lateral wall implant is tethered by the nasolacrimal duct and does not extend sufficiently to the anterior area, and thus may not provide adequate relief.

The treatment of ENS-MT has the least number of options because of the surrounding anatomy. It is better to avoid lateral implants because of the presence of thin mucosa within the middle meatus and the possibility of obstructing the drainage pathways of the paranasal sinuses. However, the septum may be used for grafting, which simulates a 'Bolgerized' MT [13]. In a patient who has ENS-both, the septum will be the target for grafting, with a large implant spanning the region of the middle and inferior turbinates [49].

Figure 3



(a) Implants are inserted into pockets along the nasal septum, the floor of the nose, and along the lateral nasal wall on each side. (b) Intraoperative endoscopic view: sialastic implant (arrow) is introduced after raising the left mucoperichondrial flap.

Patients with ENS-IT without any IT remnant (or a minimal remnant) may present a difficult reconstructive problem. The work of Michael Friedman and Lee [50] suggests limited success with lateral wall augmentation (0 of three patients benefited from the procedure) and the nasolacrimal duct might be obstructed.

The material used to reduce the nasal cavity volume should have cartilage-like elasticity, immunologic inertness, and combine minimal risk of extrusion, rejection, and infection with sufficient restoration of nasal cavity volume. Various materials are available including autologous (bone, cartilage, and fat) and exogenic materials (hydroxyapatite [44], goretex [29,51], teflon, plastipore) [3,4]. Although all of the synthetic implants may be effective, the use of autologous materials, such as cartilage, is considered ideal as it is cheap and available with a high level of biocompatibility. General evidence indicates long-term positive outcomes associated with the use of cartilage implants in rhinological surgeries. Septal cartilage is the most common material used in rhinological grafts; however, it is usually not enough in some patients, especially those who have undergone previous septal surgery. Conchal and costal cartilages can also be used in the procedure [48].

Conclusion

ENS may be encountered after inferior and/or middle turbinate resection; however, it can occur with normal turbinates. It is not clear why some patients develop ENS, whereas others do not. One point of concern is the frequent association with psychiatric disorders and psychosomatic pathologies, which indicate the possible role of psychological stress in some patients. The hallmark complaint of the patients is paradoxical nasal obstruction. Patients are preoccupied with their breathing and nasal sensations, leading to inability to concentrate, chronic fatigue, frustration, irritability, anger, anxiety, and depression, which points out that ENS is not a single disease entity and has a major impact on the quality of life of the patients. Its diagnosis relies on clinical suspicion and physical examination. Prevention of ENS is very important by preservation of the middle and inferior turbinate as much as possible. The quality of life of patients with ENS can be improved by using nasal augmentation as it restores nasal volume toward the premorbid state.

Acknowledgements

Magdy Eisa Saafan takes responsibility for the integrity of the content of the paper.

Conflicts of interest

There are no conflicts of interest.

References

- Scheithauer MO. Surgery of the turbinates and 'empty nose' syndrome. *GMS Curr Top Otorhinolaryngol Head Neck Surg* 2010;9: Doc 03.
- Sozansky J, Houser SM. Pathophysiology of empty nose syndrome. *Laryngoscope*. 2015;125:70–74.
- Chhabra N, Houser SM. The diagnosis and management of empty nose syndrome. *Otolaryngol Clin North Am* 2009;42:311–330.
- Houser SM. Surgical treatment for empty nose syndrome. *Arch Otolaryngol Head Neck Surg* 2007;133:858–863.
- Payne SC. Empty nose syndrome: what are we really talking about? *Otolaryngol Clin North Am* 2009;42:331–337.
- Amin MR, Koufman JA. Vagal neuropathy after upper respiratory infection: a viral etiology? *Am J Otolaryngol* 2001;22:251–256.
- Gracely RH, Petzke F, Wolf JM, Clauw DJ. Functional magnetic resonance imaging evidence of augmented pain processing in fibromyalgia. *Arthritis Rheum* 2002;46:1333–1343.
- Yepes-Nuñez JJ, Bartra J, Muñoz-Cano R, Sanchez-Lopez J, Serrano C, Mullol J *et al.* Assessment of nasal obstruction: correlation between subjective and objective techniques. *Allergol Immunopathol (Madr)* 2013;41:397–401.
- Yaniv E, Hadar T, Shvero J, Raveh E. Objective and subjective nasal airflow. *Am J Otolaryngol* 1997;18:29–32.
- Naito K, Kondo Y, Ohoka E, Komori M, Takeuchi M, Iwata S. New aerodynamic aspects of nasal patency. *Rhinology* 1995;33:26–29.
- Saafan ME. Acellular dermal (allograft) grafts versus silastic sheets implants for management of empty nose syndrome. *Eur Arch Otorhinolaryngol* 2013;270:527–533.
- Coste A, Dessi P, Serrano E. Empty nose syndrome. *Eur Ann Otorhinolaryngol Head Neck Dis* 2012;129:93–97.
- Houser SM. Empty nose syndrome associated with middle turbinate resection. *Otolaryngol Head Neck Surg* 2006;135:972–973.
- Freund W, Wunderlich AP, Stöcker T, Schmitz BL, Scheithauer MO. Empty nose syndrome: limbic system activation observed by functional magnetic resonance imaging. *Laryngoscope* 2011; 121:2019–2025.
- Passali D, Lauriello M, Anselmi M, Bellussi L. Treatment of hypertrophy of the inferior turbinate: long-term results in 382 patients randomly assigned to therapy. *Ann Otol Rhinol Laryngol* 1999;108:569–575.
- Naftali S, Rosenfeld M, Wolf M, Elad D. The air-conditioning capacity of the human nose. *Ann Biomed Eng* 2005;33:545–553.
- Elad D, Wolf M, Keck T. Air-conditioning in the human nasal cavity. *Respir Physiol Neurobiol* 2008;163(1-3):121–127.
- Baraniuk JN Subjective nasal fullness and objective congestion. *Proc Am Thorac Soc* 2011;8:62–69.
- Baraniuk JN, Kim D. Nasonasal reflexes, the nasal cycle, and sneeze. *Curr Allergy Asthma Rep* 2007;7:105–111.
- Lindemann J, Tsakiropoulou E, Scheithauer MO, Konstantinidis I, Wiesmiller KM. Impact of menthol inhalation on nasal mucosal temperature and nasal patency. *Am J Rhinol* 2008; 22:402–405.
- McBride B, Whitelaw WA. A physiological stimulus to upper airway receptors in humans. *J Appl Physiol Respir Environ Exerc Physiol* 1981;51:1189–1197.
- Burgess KR, Whitelaw WA. Reducing ventilatory response to carbon dioxide by breathing cold air. *Am Rev Respir Dis* 1984;129:687–690.
- Elad D, Naftali S, Rosenfeld M, Wolf M. Physical stresses at the air-wall interface of the human nasal cavity during breathing. *J Appl Physiol* (1985) 2006;100:1003–1010.
- Grützenmacher S, Lang C, Mlynski G. The combination of acoustic rhinometry, rhinoresistometry and flow simulation in noses before and after turbinate surgery: a model study. *ORL J Otorhinolaryngol Relat Spec* 2003;65:341–347.
- Swift AC, Campbell IT, McKown TM. Oronasal obstruction, lung volumes, and arterial oxygenation. *Lancet* 1988;1(8577):73–75.
- Aasvang EK, Kehlet H. Persistent sensory dysfunction in pain-free hemiotomy. *Acta Anaesthesiol Scand* 2010;54:291–298.
- Wu X, Myers AC, Goldstone AC, Toggias A, Sanico AM. Localization of nerve growth factor and its receptors in the human nasal mucosa. *J Allergy Clin Immunol* 2006;118:428–433.
- Sofroniew MV, Howe CL, Mobley WC. Nerve growth factor signaling, neuroprotection, and neural repair. *Annu Rev Neurosci* 2001;24:1217–1281.

- 29 Modrzyński M. Hyaluronic acid gel in the treatment of empty nose syndrome. *Am J Rhinol Allergy* 2011;25:103–106.
- 30 Jang YJ, Kim JH, Song HY. Empty nose syndrome: radiologic findings and treatment outcomes of endonasal microplasty using cartilage implants. *Laryngoscope* 2011;121:1308–1312.
- 31 Mikkelsen T, Werner MU, Lassen B, Kehlet H. Pain and sensory dysfunction 6 to 12 months after inguinal herniotomy. *Anesth Analg* 2004;99:146–151.
- 32 Piccirillo JF, Merritt MG Jr, Richards ML. Psychometric and clinimetric validity of the 20-Item Sino-Nasal Outcome Test (SNOT-20). *Otolaryngol Head Neck Surg* 2002;126:41–47.
- 33 Tam YY, Lee TJ, Wu CC, Chang PH, Chen YW, Fu CH, Huang CC. Clinical analysis of submucosal Medpor implantation for empty nose syndrome. *Rhinology* 2014;52:35–40.
- 34 Hildenbrand T, Weber RK, Brehmer D. Rhinitis sicca, dry nose and atrophic rhinitis: a review of the literature. *Eur Arch Otorhinolaryngol* 2011;268:17–26.
- 35 Berenholz L, Kessler A, Sarfati S, Eviatar E, Segal S. Chronic sinusitis: a sequela of inferior turbinectomy. *Am J Rhinol* 1998;12:257–261.
- 36 Freund W, Wunderlich AP, Stuber G, Mayer F, Steffen P, Mentzel Met al. Different activation of opercular and posterior cingulate cortex (PCC) in patients with complex regional pain syndrome (CRPS I) compared with healthy controls during perception of electrically induced pain: a functional MRI study. *Clin J Pain* 2010;26:339–347.
- 37 Eccles R, Morris S, Tolley NS. The effects of nasal anaesthesia upon nasal sensation of airflow. *Acta Otolaryngol* 1988;106(1-2):152–155.
- 38 Brunworth J, Holmes J, Sindwani R. Inferior turbinate hypertrophy: review and graduated approach to surgical management. *Am J Rhinol Allergy* 2013;27:411–415.
- 39 Kennedy DW. Middle turbinate resection: evaluating the issues – should we resect normal middle turbinates? *Arch Otolaryngol Head Neck Surg* 1998;124:107.
- 40 Moore EJ, Kern EB. Atrophic rhinitis: a review of 242 cases. *Am J Rhinol* 2001;15:355–361.
- 41 Eccles R, Jawad MS, Morris S. The effects of oral administration of (–)-menthol on nasal resistance to airflow and nasal sensation of airflow in subjects suffering from nasal congestion associated with the common cold. *J Pharm Pharmacol* 1990;42:652–654.
- 42 Eccles R. Menthol: effects on nasal sensation of airflow and the drive to breathe. *Curr Allergy Asthma Rep* 2003;3:210–214.
- 43 Goldenberg D, Danino J, Netzer A, Joachims HZ. Plastipore implants in the surgical treatment of atrophic rhinitis: technique and results. *Otolaryngol Head Neck Surg*. 2000;122:794–797.
- 44 Rice DH. Rebuilding the inferior turbinate with hydroxyapatite cement. *Ear Nose Throat J* 2000;79:276–277.
- 45 Jiang C, Shi R, Sun Y. Study of inferior turbinate reconstruction with Medpor for the treatment of empty nose syndrome. *Laryngoscope* 2013;123:1106–1111.
- 46 Bastier PL, Bennani-Baiti AA, Stoll D, de Gabory L. β -Tricalcium phosphate implant to repair empty nose syndrome: preliminary results. *Otolaryngol Head Neck Surg* 2013;148:519–522.
- 47 Jiang C, Wong F, Chen K, Shi R. Assessment of surgical results in patients with empty nose syndrome using the 25-item Sino-Nasal Outcome Test Evaluation. *JAMA Otolaryngol Head Neck Surg* 2014;140:453–458.
- 48 Jung JH, Baguindali MA, Park JT, Jang YJ. Costal cartilage is a superior implant material than conchal cartilage in the treatment of empty nose syndrome. *Otolaryngol Head Neck Surg* 2013;149:500–505.
- 49 Ly TH, deShazo RD, Olivier J, Stringer SP, Daley W, Stodard CM. Diagnostic criteria for atrophic rhinosinusitis. *Am J Med* 2009;122:747–753.
- 50 Michael Friedman HI, Lee G. A simplified technique for treatment of atrophic and hypotrophic rhinitis. *Oper Tech Otolaryngol Head Neck Surg* 2002;13:211–214.
- 51 Cook PR, Begegni A, Bryant WC, Davis WE. Effect of partial middle turbinectomy on nasal airflow and resistance. *Otolaryngol Head Neck Surg* 1995;113:413–419.