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External and internal nasal valve. Diagnostic and treatment methods for dysfunction

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ABSTRACT

The purpose of the work is the analysis of diagnostic methods of nasal valve dysfunction according to Pubmed database and national medical journals during the period from 1997 to 2019. A brief analysis of the definition of the zones of the external and internal nasal valve, diagnostic methods, including external nasal dilators, spiral computed tomography, assessment of the degree of displacement of the nasal wing using various aspirators is given. Various methods for treating nasal valve dysfunction, such as external and internal dilators, strengthening the nasal wings, suture techniques, expanding the edge of the pear-shaped hole, implantation of absorbable polymers into the side wall of the nose are critically evaluated. Our own original correction method is described for dysfunction of the external nasal valve caused by the vertically located legs of the inferior lateral cartilage.

Keywords: nasal valve, nasal valve dysfunction, treatment of nasal valve dysfunction.

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The "nasal valve" term was proposed by Mink in 1903 to describe the slit-like opening at the junction between the upper and lower lateral cartilage and the nasal septum [1]. More than 116 years have passed since that time, however, the diagnosis and treatment problem of pathology of the nasal valve (NV) is still relevant for modern otorhinolaryngology, plastic and aesthetic rhinoplasty [2, 3, 4].

The NV zone is considered the most bottleneck in the nasal cavity and plays an important role in the regulation of air flow. The lack of improvement in nasal breathing after surgery on the nasal septum and nasal concha for some patients is the reason for a critical analysis of other causes of nasal dysfunction [5, 6, 7, 8]. After examining 500 patients, S. Elwany and H. Thabet found dysfunction at the level of NV in 65 cases (13%), wherein the obstruction was one-sided for 57 patients (88% of all pathological cases) [9]. According to P. Paccoi and V. Di Peco, many patients with complaints of nasal breathing, in addition to deformation of the nasal septum, have a curvature of the base of the nasal columella, the bottom of the vestibule or the lateral wall of the nose. However, these factors are too often underestimated by the surgeons [10].

The external nasal valve (ENV) and internal nasal valve (INV) notions should be distinguished. The latter is formed of a triangular space bounded on the medial by the cartilage of the nasal septum, the lateral – by caudal edge of the triangular cartilage, on the bottom – by the bottom of the nasal cavity or the anterior end of the inferior nasal concha [11]. While there is no discussion on definition of the anatomical boundaries of the ENV, then it exists regarding the INV [11, 12]. We agree with P.P. Cheng and H. Riechelman that ENV is the part of the nose located caudally from the internal nasal valve [4, 12].

The lack of a common algorithm for the diagnosis and treatment of ENV and INV dysfunction is a serious problem of modern otorhinolaryngology [1, 2, 3]. Though it should be noted that

the number of publications in national journals devoted to this issue has increased recently. On the one hand, this reflects the interest of the medical community to the topic, and on the other, it initiates scientific research in this direction.

The aim of this publication is a critical review of diagnosis and treatment methods for nasal valve dysfunction. That review includes papers devoted to this problem, published in the Pubmed database, as well as in national medical editions since 1997 till nowadays.

Diagnosis of nasal valve dysfunction

Diagnosing NV insufficiency is not always an easy task. The doctor's attention to the valve zone is caused by the unsatisfactory result of the operation on the nasal septum and nasal concha [10, 12, 13]. Patient complaints about problems with nasal breathing require a mandatory examination of the vestibule of the nose without nasal mirror. Only after studying the anatomical structures of this zone can we proceed to an instrumental study of the deeper parts of the nose [9, 14, 15]. The classic way to assess NV dysfunction was proposed by M.H. Cottle [11]. However, it to a greater extent demonstrates disturbances in the area of INV than ENV [3, 11]. In our opinion, the algorithm proposed by M. Friedman et al. can be considered a more reliable and simple way. It includes an examination of the vestibule of the nose, a Cottle test, and a positive test using a cotton applicator [14]. Also N. Fuleiham agrees with this and supplements the algorithm with forced inspiration [16].

From a practical point of view, it is important to distinguish between static and dynamic collapse of NV [11]. Static is characterized by anatomical narrowing of the lateral walls of the cartilaginous part of the external nose, dynamic — by their medial displacement on inspiration. Therefore, we believe, while assessing the ventilation function of the nose by the method of anterior active rhinomanometry, special attention should be paid to the indicators of the total volume flow and total resistance precisely on inspiration. Static collapse is often exacerbated by a dynamic component, and vice versa [3, 4, 5, 11].

External nasal dilators have proven themselves in the diagnosis of NV dysfunction and in its conservative treatment [17, 18]. According to R. Gruber et al., using the Breathe Right nasal strips (Breath Right®), it is possible to separately diagnose the pathology of the external and internal nasal valve, as well as combined dysfunction. The strip is fixed on the patient's nose three times: at the edge of the nostrils, in the region of the middle third of the nose, caudally from the nasal bones and in between these two places. After each examination, the patient should immediately respond which of the strips improved nasal breathing better. Of the 30 patients who had problems with nasal breathing, 12 noted an improvement in respiration from sticking strips to the projection of the INV, in 8 individuals in the ENV region, in 10 in the intermediate region. The latter, according to experts, corresponded to dysfunction of both valves [18].

We believe that Breath Right® help in the diagnosis of NV dysfunction. The difference between the indices of anterior active rhinomanometry without strips and with their sticking allows the surgeon to objectively assess the expected increase in flow rates and resistance decrease. Wearing Breath Right® for several minutes allows the patient to assess the planned improvement in nasal breathing and argues in favor of surgical intervention.

In 2018 researchers from the University of Ottawa proposed a method for assessing nasal valve collapse by visual inspection of the vestibule of the nose using a light source. Collapse was evaluated by the degree of medial displacement of the wing of the nose and the change in air flow at maximum inspiration on a three point scale. They believe that the proposed test called the "Ottawa valve collapse scale" (OVCS), is reliable, correlates with Cottle test and the NOSE (nasal obstruction symptom evaluation) questionnaire [19]. In our opinion, the using of only subjective methods in the assessment of collapse reduce its diagnostic value.

The lack of objectivity in assessing the nasal valve is a problem that many experts have tried to solve in their research. The study by W.K. Hussein et al. of the original modification of INV expansion was confirmed by axial projected spiral computed tomography (SCT) [20]. According to another research group, a coronary projection with a modified scan angle perpendicular to the anterior part of the INV can be called acceptable. Though excessive radiation exposure and economic costs are recognized. Endoscopic examination of this area with video image capture has a significant correlation with SCT. The advantage of endoscopic examination is the absence of side effects and economic efficiency. Also it makes it possible to see all nasal structures in a three-dimensional image [21].

It is the simplicity and originality of the approach to measuring the dynamic component of the nasal valve what distinguishes the study by R.A. Zoumalan et al. [22]. It was conducted on 20 patients who underwent rhinoseptoplasty. Strengthening of the nasal wing was carried out by alar batten grafts according to Toriumi [23] in various modifications. A point was made with a marker on the wing of the nose, and an aspirator tube with a minimum negative pressure of -80 kPa was brought to the nostril. The medial displacement from the marked point was measured with a calipers before and after the graft installation. It turned out to be different for the right and left sides, 2.45 and 2.75 mm, respectively. The installation of a wing alar batten graft reduced the degree of displacement to 0.6 and 0.7 mm. The authors believe that such a technique allows to determine intraoperatively the most supple spot on the lateral surface of the nose, and to assess the increase in stiffness of the nose wing after transplant placement [22].

An assessment of compliance and elasticity of the external nasal skin in patients with nasal valve collapse was carried in another study by use of a specially developed device — Cutometer MPA 580 (Courage & Khazaka Electronic GmbH). It is a cylinder with a 4 mm diameter opening in the end. The device is applied with an opening to the side wall of the nose, a negative pressure of 40 kPa is set. The degree of skin retraction is evaluated through a high-resolution optical system inside the cylinder. Of the 27 examined individuals, a significant difference was noted between skin elasticity on the side of the nose without collapse and on the side with collapse — 0.139 mm and 0.200 mm, respectively [24].

Treatment of nasal valve dysfunction

Conservative treatment of NV dysfunction includes two fundamental approaches. The first is devices that are fixed on the external nasal skin and expand the area of the NV due to their elastic properties — external nasal dilators (ENDS). The second type of device is placed on the vestibule of the nose, expanding it mechanically, preventing the medial displacement of the NV on inspiration — internal nasal dilators (INDS).

A classic ENDS are the aforementioned Breath Right®. It is interesting that the first users of these strips were not patients with NV dysfunction, but athletes. ENDS gained special popularity after the Atlanta 1996 Olympic Games, they began to use them in various sports — marathon runners, soccer players, hockey players [17, 18].

Further scientific studies showed that the use of Breath Right® during maximum physical activity can significantly reduce the subjective perception of effort, heart rate, ventilation and oxygen consumption [17], can improve nasal breathing by 27% [25]. ENDS can be useful in the prevention of exercise-induced bronchial asthma, when performing moderate-intensity exercises and breathing through the nose [26]. In a study by J.A. Deyak et al. 8 hockey players between the ages of 18 — 23 years, due to the use of Breath Right®, noted an increase in the average skating time. Blood lactate (the end product of anaerobic glucose metabolism, indicating sufficient or deficient oxygen supply) was lower during skating and during rest. The authors concluded that the use of ENDS aids in overall performance and speed recovery of athletes [27]. A few studies in pediatric athletes confirm the usefulness of ENDS, the use of which leads to a decrease in respiratory effort and an improvement in peak aerobic performance at maximum physical exertion [28].

Difficulty in nasal breathing, which occurs in some patients after reduction rhinoplasty, can be compensated by Breath Right®, which was confirmed by the results of the sensor-analogue scale of the questionnaire. An objective assessment by acoustic rhinometry showed that the cross-sectional area increases from 0.34 cm^2 to 0.64 cm^2 [29].

Examination of 89 individuals with complaints of nasal congestion by means of the topical decongestant xylometazoline and Breath Right® as ENDS using acoustic rhinometry and visual-analogue scales confirmed the hypothesis of the researchers. They recommend ENDS as an alternative to decongestive nose sprays, especially if nasal congestion is localized in the area of the external nasal valve [30]. Another study compared the topical nasal decongestant (oxymetazoline hydrochloride) and Breath Right® using posterior rhinomanometry in 20 healthy Caucasian adults. The authors concluded that ENDS influences nasal airflow dynamics by both dilation of the nasal valve and stabilization of the lateral nasal vestibule walls under inspiratory effort [31].

Breath Right® have proven themselves in view of the comfort of use and ease of removal. Their consecutive wearing for 7 nights does not cause an inflammatory reaction of the skin at the place of application [32].

According to G. Ottaviano, an alternative to Breath Right® for athletes can be the ENDS Master-aid Roll-flex strip (Master-aid Roll-flex®). Their fundamental difference lies not only in the expansion of the NV zone, but also in raising of the tip of the nose, which is confirmed by the data of objective research methods and the results of questionnaires of 13 triathletes. In addition, Master-aid Roll-flex® can be cut to fin the individual nasal anatomy and is more economic [33].

Despite the fact that ENDS is a simple, non-invasive, painless, affordable method of improving nasal breathing [17], doctors recommending this method should not forget of the limitations in their use. According to L.G. Portugal et al. Breath Right® improve nasal breathing by 27% in Caucasian group of patients, but do not lead to significant changes in African American group [34].

In 2019, the studies on the use of INDS in athletes, in patients with obstructive sleep apnea, with snoring were published [7, 35-38]. The internal nasal dilator Nas-air® consists of two parallel plastic tubes connected at the edge with a thin jumper. Tubes are inserted on the vestibulum of the nose, expanding the valve area, preventing the wings of the nose from falling off while inhaling, while the jumper lies on the nose columella, preventing the tubes from moving inside the nasal cavity. The device reduced the perception of fatigue and did not cause local discomfort in 19 athletes when they covered 3 km in 23 minutes on a treadmill with 0° inclination [7]. Using a portable four-channel polygraph, a positive effect was noted in 19 patients with difficulty in nasal breathing and obstructive sleep apnea syndrome, namely a decrease in the apnea-hypopnea index and oxygen desaturation index. Notably there was also a positive trend for the reduction of total sleep time with HbO2 <90% [35]. The use of INDS Nas-air® can significantly increase patient compliance in treatment of obstructive sleep apnea syndrome with continuous positive airway pressure [36].

Concluding the review of external and internal nasal dilators three studies should be noted which tried to determine one the most effective. In the aforementioned study by M. Gelardi, the Nas-air® internal nasal dilator was compared with the Breath Right® nasal strips in 19 athletes. Objective research methods, such as heart rate, oxygen saturation, did not show a statistical difference. Indicators of the comfort of wearing the device, a decrease in the perception of fatigue, were noted by athletes after applying Nas-air® [7]. The duration of snoring estimated by the smartphone and the visual analogue scale for perceiving sleep quality were measured in 41 people. Significant reduction in snoring time and improved sleep quality were achieved using both devices. However, Nas-air® was more effective in more patients and showed better sleep quality than the Breath Right® [37]. In another similar study both expansion devices were offered to 13 men and 17 women with complaints of sleep disturbance due to insufficient nasal breathing. An objective assessment was performed using the peak nasal respiratory flow method, and a subjective assessment was performed using a questionnaire that assessed the symptoms of sleep disorders with poor nasal breathing. Both types of expanders had significant advantages over the control group (66.07 l/ min), however, Nas-air INDS showed higher efficiency compared to Breath Right® ENDS (138.73 l/ min and 102.17 l min, respectively) [38].

Surgical treatment of nasal valve dysfunction

A method combining the strengthening of the ENV zone and the reduction in the width of the nose tip was proposed by A.T. Tellioglu and C. Cimen. The cephalic part of the lateral crus was folded and fixed to reinforce the lateral crus. The study included 17 women and 15 men. As the advantage of the method the authors consider the use of autotransplant, a simple technique, and good aesthetic and functional long-term results, traced for 12 months [39]. In our opinion, another asset of this method is the possibility of its use with closed rhinoplasty.

A method for expanding the pyriform aperture in case of NV dysfunction was proposed by J.E. Gilde. The procedure consists of an incision made anterior to the inferior turbinate along the inferior aspect of the lateral bony pyriform. The periosteum is elevated, and a rongeur is used to widen the exposed bone. A bone fragment of 7-8 mm laterally, up to 10 mm in height, is removed. The idea of increasing the clearance of the valve zone is not new, however, the originality of the method consists in subsequent Z-plasty of the skin in this area. Of the 6 patients included in the study, three had NV dysfunction. For the rest the procedure was combined with other surgical interventions on the nose. In four individuals, the expansion was bilateral, in two — ipsilateral. All patients reported subjective improvement, with mean NOSE scale scores of 15.7 preoperatively and 9.7 postoperatively. Five patients had long-term results with follow-up periods of 12.5 to 33 months. During the early postoperative period, two complications were noted: local inflammation in anticipation of the nose, which was stopped by conservative methods

(in one patient), and left-sided facial pain (in another patient) [40]. In our opinion, the described is the method of restoration of nasal breathing after excessively reducing rhinoplasty.

Nasal valve stabilization method with the use of nasal valve suspension was proposed by E. Weaver. An indication for the operation is the collapse of the NV, visually diagnosed with moderate inspiration, a test with a cotton applicator that lifts the nose wing from the inside. After local anesthesia injected into the soft tissue overlying the piriform rim a needlepoint electrocautery incision is made over the piriform rim up toward the upper lateral cartilage and nasal bone. Subperiosteal dissection along the medial and lateral aspects of the rim exposes 5 mm of the bony rim up toward the nasal bones and inferiorly toward the attachment of the inferior turbinate bone. A 0.76 mm diameter drill bit is used to drill 3 or 4 holes in the piriform rim 1 to 2 mm from the bony rim. A suture is used to anchor the upper lateral cartilage to the bony rim. The suture is passed through the top drill hole from lateral to medial, then through the upper lateral cartilage into the nasal cavity and back through the nasal mucosa overlying the upper lateral cartilage, through the cartilage into the surgical wound anterior to the bony rim. This results in a loop of suture through the upper lateral cartilage and around the bony bridge between the drill hole and edge of the piriform rim stabilizing the inner nasal valve.

According to the author, the technique is simple, provides secure bony anchor points, does not change nasal appearance, leaves no permanent foreign body, and is feasible under local anesthesia [41]. As a disadvantage of that original and pretty well illustrated publication one should consider the lack of clinical proof of the effectiveness of the method.

Another method using the suture technique was published in 2019 by a group of researchers led by H. Heppt. The first injection into the skin of the outer nose with absorbable, polylactic acid, self-retaining cone threads (Silhouette Soft) occurs in the nasion region. From this "anchor" under the skin, the threads pass to the lateral portion of the lower lateral cartilage or the caudal edge of the upper lateral cartilage, lifting and stabilizing it. The enlargement of the INV zone was confirmed by the endoscopy. The satisfaction of 41 patients was evaluated on a visual-analog 10-point scale preoperatively and after 1 week and 1, 6, 12, 18 and 24 months after the intervention. The authors acknowledge a decline in the effect of breathing improvement is recognizable as threads are dissolved, but underline that patients' satisfaction in improvement of nasal breathing is persistent in most cases, even at long-term observation [6].

A group of scientists from the University of Munich proposed a method for correcting dysfunction, of both external and internal NV. It consists in placing of an implant up to 20 mm long and 2 mm wide, a polylactic acid copolymer with a delivery tool within the nasal wall to provide lateral cartilage support. The operation was performed on 30 patients, both under general and local anesthesia. There were no adverse changes in cosmetic appearance at 12 months postprocedure. Of the 56 implants introduced, three implants in three subjects required retrieval within 30 days postprocedure. In the immediate postoperative period, one hematoma and one case of local inflammation were noted. The study included endoscopic monitoring, photographing, questioning in 1, 3, 6, 12 months period after surgery. The NOSE questionnaire showed a halving of the number of points after 1 year [42]. Continuing the monitoring of this group of patients for 24 months, it was noted the preservation of the quality of nasal breathing, confirmed by the NOSE questionnaire. A long observation period allowed researchers to conclude that this method is safe and effective in patients with dynamic collapse of the nasal valve [43].

In 2002, J. M. Clark proposed an original technique for INV extension, which he called 'Butterfly' Graft. He performed surgery on 72 patients who had previously undergone at least one rhinoplastic procedure and had severe nasal obstruction. During the two-year follow-up period, only 3% reported less than total resolution of their difficulty breathing through their nose; the remaining 70 patients (97%) reported complete resolution of their nasal airway problems. Improvement in the appearance of their nose was noted by 86% of the operated, 11% did not see the changes, 3% felt that the appearance of their nose was made worse by the procedure. Analyzing 15 years of experience in operations performed by 512 patients using the 'Butterfly' Graft, the author modified the technique of surgical intervention. Previously, a fragment of the auricle cartilage was placed on the back of the nose and was sutured on both sides to the caudal edge of the superior lateral cartilage, which could be unacceptable for patients with thin skin in the area of the nasal dorsum. The modified technique of the operation involves the creation of a "saddle" by excising a thin strip of dorsal part of the superior lateral cartilage from two sides and a quadrangular cartilage. The the auricle cartilage is placed on this "saddle", fixed with sutures to the triangular cartilages, forming an even nasal back [5, 44].

Hussein et al. [20] proposed a modification of known since 2011 Pepper and Baker's "autospreader flap" technique [45], in patients with rhinokyphosis and INV dysfunction. The essence of the changes is that after tucking the dorsal part of the upper lateral cartilage, cut off from the septum of the nose, it is fixed with sutures to the quadrangular cartilage only with its medial part. The lateral part of the superior lateral cartilage, free from the suture, plays the role of a spring, expanding the area of the INV. The effectiveness of such a modified technique was confirmed in 22 patients with the help of SKT, endoscopic examination, the NOSE questionnaire [20].

In 1997, D.M. Toriumi et al. first proposed alar batten grafts from the cartilage of the nasal septum or from the auricle [23]. We modified this method for patients with ENV dysfunction caused by vertically oriented lateral legs of the lower lateral cartilage [46]. Placing a "classic" Toriumi transplant medial or lateral to the lateral leg of the lower lateral cartilage will increase the thickness of the nose wing, but will not improve nasal breathing. Our technique differs in the excision of that lateral part of the wing cartilage, which is involved in the displacement towards the vestibule of the nose, and the installation of an autogenous batten in its place, even with a slight bend. The place of graft sampling can be both a quadrangular cartilage of the nasal septum or the patient's auricle. Installation is possible, both with open rhinoseptoplasty and closed, through the underwing access, retreating 3 mm from the edge of the nostril. The length of the graft is 15-20 mm, width 5 mm, thickness 1-1.5 mm, its medial edge is placed on the remaining lateral leg of the lower lateral cartilage. The lateral edge of the cartilaginous strip is placed in the formed "pocket" of soft tissues on the bone edge of the pyriform aperture. In case of deficiency of autogenous material, the use of Alloplant allogeneic cartilage is possible. We hope to present clinical studies of the effectiveness of our proposed technique after a sufficient number of o bservations.

Thus, the analyzed sources confirm that one of the main causes of nasal breathing disorders, along with the curvature of the nasal septum and hypertrophy of the nasal concha, is nasal valve dysfunction [1, 2, 3, 11]. Insufficient awareness of surgeons about the causes of difficulty in nasal breathing, in addition to

the displaced nasal septum and enlarged lower nasal concha, can lead to patient dissatisfaction with the results of the operation. The second point that the surgeon needs to pay attention to is reduction rhinoplasty, when the doctor consciously goes for a resection of the base of the nose wings (base resection) [47] to give the nose a more aesthetic, in his opinion, shape. We share the opinion that impaired nasal breathing after rhinoplasty is a complication that can significantly decrease the patient's quality of life [8]. And if in the first case, repeated surgical intervention can correct the NV zone, then in the second it is much more difficult to do, and in some situations even impossible.

The complexity of the methods for restoring the function of the external and internal nasal valve is due to the variety of reasons that cause their dysfunction. Often, one can count up to three to four causes of nasal breathing difficulties associated with the NV zone. Understanding the mechanism of dysfunction, the use of adequate diagnostic methods and possible methods of surgical correction will lead to an increase in the professional level of the otorhinolaryngologist and patient satisfaction with the results of surgical treatment.

The authors declare no conflict of interest.

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