ORIGINAL CONTRIBUTION

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External nasal valve collapse - a case-control and interventional study employing a novel internal nasal dilator (Nasanita®)*

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SUMMARY

Background: *Nasal alar collapse is a common problem and difficult to assess and treat. Methods: In 10 healthy controls and 10 patients with alar collapse, the size of the external nasal valve was analyzed on standardized nasal base photographs during quiet breathing and forced inspiration. A novel internal nasal dilator (Nasanita®, Siemens & Co, Germany) was employed to assess the effects of a therapeutic intervention. In addition, active anterior rhinomanometry was performed.*

Results: *During quiet breathing, the external nasal valves were significantly smaller in patients with alar collapse (0.3 ± 0.08 cm^2) than in controls (0.7 ± 0.2 cm^2; $p < 0.001$). In healthy controls, forced inspiration did not significantly alter the size of the external nasal valve (-1.8% ± 27.5%; $p = 0.84$), whereas it significantly decreased the external valve area in patients with alar collapse (-42.1% ± 26.4%; $p = 0.001$). The internal nasal dilator significantly increased external valve areas during quiet breathing and forced inspiration and completely abolished alar collapse. Nasal airflow at a transnasal pressure difference of 150 Pa was not correlated with external valve size. Nasal airflow increased significantly after inserting the internal nasal dilator to 1300 ± 370 ml/s ($p < 0.001$) in controls and 1300 ± 300 ml/s ($p < 0.01$) in patients.*

Conclusion: *A small sized external nasal valve appears to be a major causative factor of alar collapse. A novel internal nasal dilator effectively enlarged the external nasal valve, abolished alar collapse and improved nasal airflow.*

Key words: anatomy, dilatation, image processing, nasal obstruction, nose, respiration, vestibule

INTRODUCTION

The nasal valve refers to a segment of the anterior nose that regulates nasal airflow similarly to a ventilation flap [(1)]. This functional segment starts anteriorly with Zuckerkandl's ostium internum [(2)], named isthmus nasi by Bachmann [(3)] and internal nasal valve in current literature [(4,5)]. This anterior plane of the nasal valve segment can be readily assessed with acoustic rhinometry [(6)]. It lies about 1.5 cm from the external nasal ostium, and its cross sectional area is approximately 0.5 cm^2 [(7)]. It is bounded by the caudal border of the upper lateral cartilage, with the opposing parts of the nasal septum lying medially and the nasal floor inferiorly. From this plane, the internal nasal valve segment continues several millimeters posteriorly and includes the head of the inferior turbinate and anterior parts of the erectile tissue of the nasal septum [(8)].

Rhinological surgeons frequently discern an external nasal valve [(4,5)]. The external valve is composed of cutaneous and cartilaginous structures of the vestibule wall. In his comprehensive analysis of the nasal vestibule, Cottle identified the free end of the medial crus of the lobular cartilage and the free end of the lateral crus, both extending into the nostril, as well as the floor of the piriform aperture as major anatomical baffles controlling vestibular airflow [(9)]. These structures also define the anterior plane of the external nasal valve. The impression of the lateral crus forms the vestibular fold inside the nasal vestibule [(2,10)]. Therefore all structures defining the anterior plane of the external nasal valve are visible through the nostril (Figure 1) and can be evaluated with image analysis of standardized nasal base photographs (Figure 2). Unlike the internal valve, the external valve is no physiological regulator of nasal airflow, but gains functional impact in patients in whom the lateral vestibular wall collapses towards the septum during inspiration. The vestibular

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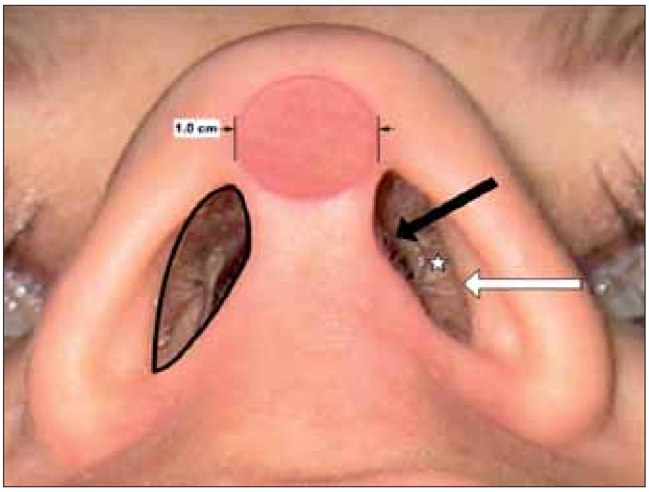

Figure 1. Structures of the nasal vestibule in computer assisted nasal base planimetry in a healthy Caucasian female. Vestibular fold (white arrow) formed by the free border of the lower lateral cartilage, Cul du sac (star) formed by convexity of the lower lateral cartilage and overlapping of the inferior margin of the upper lateral cartilage (black arrow). The black circle indicates the margins of the external valve area.

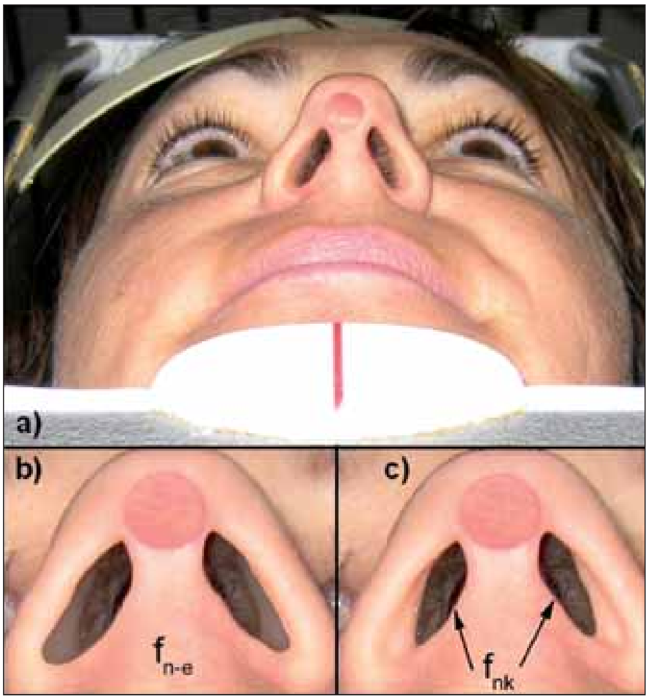

Figure 2. (a) Experimental setup, (b) nostril area (shaded), (c) outer nasal valve area (shaded).

wall is the least rigid part of the lateral nasal wall and this may explain why alar collapse occurs in this region, although it is not the narrowest part of the nasal airway [11]. In patients with alar collapse, transmural pressures during inspiration are not sufficiently counterbalanced. Common reasons for this condition include outer nasal muscular weakness, alar deformities or abnormal vestibular wall flaccidity [7].

Size and respiratory movements of the external nasal valve are difficult to measure, because in most instances the measuring device must be coupled to the nostrils and thus interferes with the size of the object of measurement. Particularly alar collapsibility during forced inspiration is hardly assessable with current investigative techniques. Image analysis of digital photographs obtained at fixed head position (computer assisted nasal base planimetry) allows non-contact area measurements of the external nasal ostium and the external valve during quiet breathing and forced inspiration. In a prospective case-control study, nasal base planimetry data in healthy controls and in patients with symptomatic inspiratory alar collapse were to be compared. We questioned in detail how the size of the external ostium and the internal valve plane differ during quiet breathing and forced inspiration in healthy individuals, what differences between controls and patients with inspiratory alar collapse can be detected and how a novel internal nasal dilator affects nasal base planimetry measurements in the two groups.

PATIENTS AND METHODS

Study population

For the control group, healthy participants were recruited by a notice on the billboard of the hospital cafeteria. Male and female subjects between 30 and 75 years of age without nasal complaints were eligible. For the afflicted group, patients with alar collapse were recruited from the outpatient clinic of the Department of Otorhinolaryngology & Head and Neck Surgery of the University Hospital of Ulm, a tertiary rhinological referral center. Patients were eligible if alar collapse was diagnosed by an experienced rhinological surgeon, and if the patients complained of nasal obstruction and at least one of the following additional symptoms: pharyngeal dryness, nocturnal mouth breathing and snoring, or disturbed sleep and daytime sleepiness. Exclusion criteria for both control group and disease group included being incapable of understanding or complying with the study protocol, pregnancy or lactation, previous rhinoplasty, septal luxation occluding more than 50% of one nostril, septal perforation, acute or chronic nasal or paranasal sinus inflammation, and conditions including allergic rhinitis, or neoplasms. Subjects were additionally excluded from the control group in cases of any previous nasal surgery, alar collapse, nasal deformities including tension, deviated or saddle nose, and septal deviations considered physiologically relevant. The study was approved by the local ethics committee of the University of Ulm.

Computer assisted nasal base planimetry

Participants placed their head on the head restraint of an ophthalmological slitlamp microscope (SLM12, Zeiss, Oberkochen, Germany) to assure a standardized and reproducible head position. A digital camera (Ixus 40, Canon, Krefeld, Germany) was fixed to the head restraint so that the image plane was parallel to the nasal base plane at a distance of 24.5 cm. After the correct position of the head and camera was

Figure 3. Internal nasal dilator (Nasanita®, Siemens & Co, Bad Ems, Germany) consisting of two wing-like elastic silicone strips, expanding each nostril separately.

confirmed online on a monitor, a reference paper circle with a diameter of 1.0 cm was attached to the nasal tip and a photograph was taken during quiet breathing and during forced inspiration. For this purpose, the participant was instructed to snuffle for two seconds as strongly as if cleansing his or her nose from excess mucus. The photos were transferred to a microcomputer equipped with an interactive pen display (Cintiq 21UX, Wacom Europe GmbH, Krefeld, Germany). The diameter of the reference circle was used to calibrate the distance and area measurement features of a graphic editor (Photoshop CS2, Version 9,0, Adobe, Munich, Germany), and the areas of the external ostium and external nasal valve plane were marked on the monitor by the interactive pen. From the number of pixels indicated by the programme the area was then calculated in cm^2.

Internal nasal dilator

Following baseline planimetry and rhinomanometry, an internal nasal dilator (Nasanita®, Siemens & Co, Bad Ems, Germany) was inserted into the nostrils (Figure 3). It consists of two wing-like elastic silicone strips similar to the alar cartilages, expanding each nostril separately. Its medial branch is attached to the anterior septum, bends laterally in the nasal dome and supports the lateral vestibular wall with its lateral branch. To prevent aspiration, both internal dilators are connected with a flexible silicone-covered titanium wire that bridges the wings over the columella. If the bridge is removed, the dilator can be used unilaterally and a nasal adaptor for rhinomanometric measurements can be inserted into the contralateral side.

Subjective changes in nasal airflow sensation were judged by the participants on a 5 point balanced verbal rating scale (much worse, slightly worse, unchanged, slightly better, and much better). Discomfort associated with insertion of the nasal dilator was judged on a three point verbal rating scale.

Active anterior rhinomanometry

Active anterior Rhinomanometry was performed with an Atmos 300 rhinomanometer (Lenzkirch, Germany), regularly calibrated by the manufacturer. Measurements were carried out in the sitting patient after 15 min of accommodation to room temperature [6]. For airtight sealing of the pressure transducer, the best fitting nozzle of three available sizes was employed. Online display of pressure/flow curves allowed control of the regularity of the patient's breathing and indicated possible air leaks. The results of at least 3 regular breath cycles were stored and the average inspiratory airflow at a transnasal pressure difference of 150 Pa was calculated for each nostril separately. Rhinomanometry was performed before and after insertion of the internal nasal dilator. The titan bar connecting the two silicone wings was removed for rhinomanomtery.

Data analysis

Based on preliminary data, a sample size of ten participants per group was considered sufficient to prove mean differences of planimetric data greater than 25%, assuming an alpha-error level of 0.05 and a beta-error level of 0.8. Data are presented as mean ± standard deviation. Parametric data analysis included Pearson's correlation, and paired and unpaired t-tests. Frequencies were compared with Fisher's exact test.

RESULTS

Study population

Between February and August 2006, ten healthy subjects without nasal complaints and ten patients with alar collapse referred to the Department of Otorhinolaryngology & Head and Neck Surgery of the University Hospital of Ulm for nasal corrective surgery were included. All study participants were Caucasians. Average weight was higher in the patient group, otherwise anthropometrical data did not differ relevantly between the two groups (Table 1).

Computer assisted nasal base planimetry

The size of the external ostium and external nasal valve area was significantly larger in controls than in patients with inspiratory alar collapse. During quiet breathing the area of the external ostium was 2.2 ± 0.6 cm^2 in controls and 1.6 ± 0.4 cm^2 in

Table 1. Anthropometrical data and nose related symptoms.

Parameter	Control group	Disease group	p
n=	10	10	
Age [years]	30 ± 9	37 ± 11	ns
Height [cm]	171 ± 8	178 ± 12	ns
Weight [kg]	65 ± 16	78 ± 11	0.05
Gender m/f [n]	5/5	7/3	ns
Nasal obstruction	0	9	< 0.001
Dry throat	0	8	< 0.001
Nocturnal mouth breathing/ snoring	0	9	< 0.001
Sleep disturbance/ daytime sleepiness	0	4	< 0.01

ns: $p > 0.05$

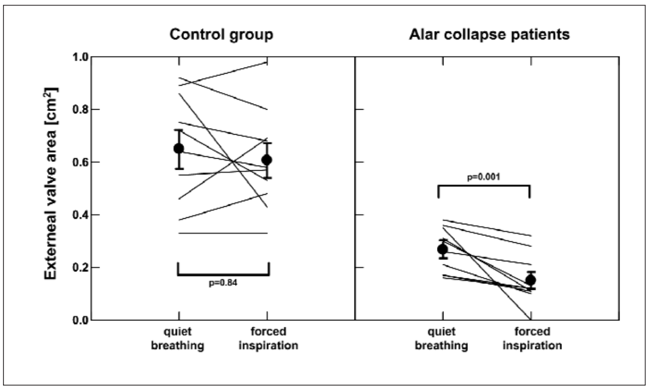

Figure 4. External valve area in 10 healthy subjects (control group) and ten patients with alar collapse during quiet breathing and during forced inspiration.

patients ($p = 0.014$). During forced inspiration, the area of the external ostium was 2.1 ± 0.5 cm^2 in controls and 1.1 ± 0.5 cm^2 in patients ($p < 0.001$). During quiet breathing the size of the external nasal valve area was 0.7 ± 0.2 cm^2 in controls and 0.3 ± 0.08 cm^2 in patients ($p < 0.001$), and during forced inspiration it was 0.6 ± 0.2 cm^2 in controls and 0.2 ± 0.09 cm^2 in patients ($p < 0.001$).

In healthy controls, forced inspiration did not significantly alter the size of the external ostium and of the external nasal valve when compared with quiet breathing. The area of the external ostium decreased on average 5.3% ± 16.6% ($p = 0.34$). In contrast, the average external ostium area decreased significantly during forced inspiration in patients with alar collapse (33.9% ± 24.3%; $p = 0.002$). The area of the external nasal valve remained consistently almost unchanged during forced inspiration in controls (1.8% ± 27.5%; $p = 0.84$), whereas the external valve area decreased significantly in patients (42.1% ± 26.4%; $p = 0.001$, Figure 4).

Effect of internal nasal dilator

Insertion of the internal nasal dilator significantly increased the external ostium and external valve areas during quiet breathing and forced inspiration in both controls and alar collapse patients (Table 2). Subjectively, after insertion of the nasal dilator nasal patency was judged as being slightly better by 12 and much better by 8 participants. Major reasons for discomfort were pressure feeling, foreign body sensation, and hypersecretion (Table 3).

Rhinomanometry

Nasal airflow at a transnasal pressure difference of 150 Pa did not differ significantly between the two groups, being 960 ± 415 ml/s in controls and 900 ± 380 ml/s in patients. However, in both groups after inserting the internal nasal dilator the mean nasal airflow increased significantly to 1300 ± 370 ml/s ($p < 0.001$) in controls and 1300 ± 300 ml/s ($p < 0.01$) in patients.

DISCUSSION

The internal nasal valve is a physiological regulator of nasal airflow. As the most resistive nasal segment, it also plays a key role in pathological nasal obstruction [8]. The nasal valve segment can be assessed objectively with acoustic rhinometry [6]. However, in a number of patients alar collapse significantly contributes to nasal pathology. Alar collapse frequently occurs at the mobile lateral wall of the nasal vestibule anterior to the internal nasal valve. This region has as yet been difficult to assess, because its anatomy is easily altered when measuring devices are coupled to the nostrils.

With computer assisted nasal base planimetry, non-contact measurements of the anterior parts of the nasal vestibule can be performed. In previous experiments, this technique has been validated in healthy subjects. The obtained planimetric data were normally distributed and well reproducible. During both quiet breathing and forced inspiration, intraclass correlation coefficients greater then 0.8 were obtained in 30 healthy volunteers measured on three consecutive days. The interrater variability was less than 5%, and the coefficient of variation in healthy controls was below 30%. The nasal base plane is parallel to the image plane, so that relevant perspective distortions are unlikely. Actually, measures of nasal base height and width corresponded well with data from anatomical specimens [12]. The anterior plane of the external nasal valve is more or less in line with the external ostium at its medial and superior parts. Inferiorly and laterally the external nasal valve plane is inclined

Table 3. Nasal discomfort associated with the internal nasal dilator.

	not present	slightly	strong
pressure feeling	7	13	0
foreign body sensation	3	13	4
dryness	18	2	0
irritation	16	3	1
hypersecretion	10	8	2
itching	19	1	0

Table 2. Effect of a novel nasal dilator (Nasanita®) on size [cm^2] of external ostium and external nasal valve in alar collapse patients and controls during quiet breathing and forced inspiration.

		controls			patients		
		without dilator	*with dilator*	*p*	*without dilator*	*with dilator*	*p*
external ostium	*quiet breathing*	2.2 ± 0.6	3.1 ± 0.7	< 0.001	1.6 ± 0.4	2.7 ± 0.5	< 0.001
	forced inspiration	2.1 ± 0.5	3.1 ± 0.5	< 0.001	1.1 ± 0.5	2.6 ± 0.4	< 0.001
external valve	*quiet breathing*	0.7 ± 0.2	1.2 ± 0.4	< 0.001	0.3 ± 0.1	0.7 ± 0.1	< 0.001
	forced inspiration	0.6 ± 0.2	1.2 ± 0.3	< 0.001	0.2 ± 0.1	0.7 ± 0.1	< 0.001

approximately 30° towards the sagittal plane directing the airflow upwards and towards the septum and internal nasal valve. Due to this inclination the external nasal valve area is subjected to perspective distortions and calculated cross sectional areas may underestimate the true size of the external valve. However, this did not influence comparisons between the quiet breathing and forced inspiration groups, because systematic bias similarly affected all measurements.

One finding of this study was that the size of the external nasal valve did not decrease significantly during forced inspiration in normal subjects. Forced inspiration led to a cross sectional area reduction of –2% with a 95% confidence interval of approximately –20% to +20%. This is consistent with one previous study in which only minor lateral wall movements were observed during nasal respiration under physical exercise [13]. As expected, the size of the external nasal valve decreased significantly during forced inspiration in alar collapse patients. This decrease was on average –40% (95% confidence interval –60% to –20%). Generally, increased collapsibility of the lateral vestibular wall is attributed to insufficient tissue rigidity, weakness of the alar dilator muscle, weak connective tissue attachments of the alar cartilages, and alar deformities [7]. We found that already during quiet breathing the external nasal valve plane was about half the size in alar collapse patients when compared with healthy controls. Because the transmural (static) pressure is proportional to $(A1/A2)^2$-1, the transmural pressure in the external valve plane was on average approximately 3 times higher in alar collapse patients. We therefore consider the undersized external valve to be a significant cause of alar collapse. Major reasons for the small external valve area in this patient group included oversized caudal ends of the medial alar crus protruding into the nostril, concave formation of the lateral crus narrowing the vestibule and slit-like formation of the external valve area in patients with tension noses (Figure 5). Patients with septal luxation and patients with previous rhinoplasties were not included in this trial. In patients with septal luxation, unilateral alar collapse is a frequent finding and is associated with unilateral narrow external nasal valves. In patients with previous rhinoplasty procedures, overtrimmimg of the cephalic margins of the lower lateral cartilages frequently results in insufficient support by the upper lateral cartilages and abnormal lateral wall weakness. In these patients, alar collapse may also occur with normally sized external valves.

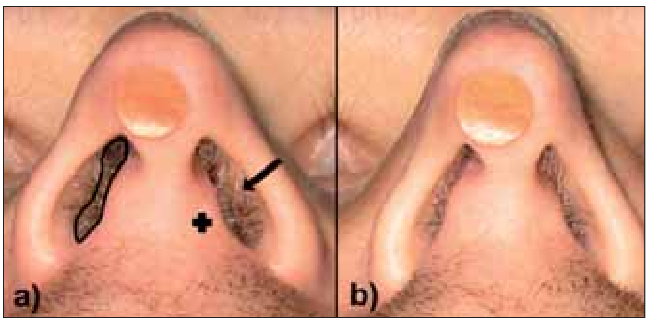

Figure 5. Frequent constellation in alar collapse patients without previous surgery: small slit-like formation of the external valve area (circle), oversized caudal ends of the medial alar crurae protruding into the nostril (+), concave formation of the lateral crus. a) quiet respiration, b) forced inspiration.

In all study participants, measurements were repeated after insertion of a novel internal nasal dilator. The internal nasal dilator doubled the size of the external valve during quiet breathing and forced inspiration in healthy controls and patients, and completely abolished alar collapse in all patients. Consistent with previously reported results, all study participants reported that the internal nasal dilator gave an improved sensation of nasal patency [14]. In all participants, the dilator caused some discomfort, which was considered minor by 14 and strong by 6. Frequency and intensity of reported discomfort did not differ between patients and controls. Nasal airflow was assessed with active anterior rhinomanometry at a transnasal pressure difference of 150 Pa. In both controls and alar collapse patients, nasal airflow at 150 Pa was not correlated with the size of the external nasal valve ($p > 0.2$). Nasal airflows at a transnasal pressure difference of 150 Pa correspond to airflows during slight physical exercise. Under these conditions, the internal nasal valve is the relevant resistor. This may explain why airflow and external valve size did not correlate. The internal nasal dilator increased nasal airflow significantly. It appears likely that this effect also reflects a widening of the inner nasal valve [15,16].

In conclusion, plausible and reproducible data on the role of the external valve in alar collapse were obtained by employing a simple and cheap investigational set-up. In patients not previously operated, the small size of the external nasal valve appears to be a major causative factor of alar collapse. This method also allows an objective assessment of the effect of a therapeutic intervention such as a novel internal nasal dilator, which effectively increased the external nasal valve size and decreased the nasal airway resistance. The authors assume that computer assisted nasal base planimetry will help to classify nasal vestibule pathologies better as well as helping to improve evaluating and standardizing surgical procedures directed at the external nasal valve.

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