ORIGINAL CONTRIBUTION

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Physiological and pathological septal deviations: subjective and objective functional rhinologic findings*

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SUMMARY

Objective: *A high incidence of septal deviation with significant inter-rater variability has been reported. An explanation could be the presence of physiological septal deviation besides pathological ones. We differentiated an unselected cohort by their nasal resistance into groups with physiological normal and pathologically increased resistance to detect differences and analogies in comparison to healthy subjects and a pathological cohort.*
Study Design: *Prospective cohort study.*
Setting: *A total of 356 patients were assessed using rhinoresistometry, acoustic rhinometry, endoscopy and visual analogue scales. After definition of a benchmark between physiological and pathological nasal resistance, group differences were calculated and correlations analysed.*
Results: *The normal one-sided inspiratory nasal resistance was defined as less or equal to 0.35 sPa/cm^3 at a flow-velocity of 250 cm^3/s (R250). Using this benchmark, the unselected group of non-rhinological patients was differentiated into 114 subjects with physiological nasal resistance and 44 with pathological septal deviation. Nasal resistance after decongestion was significantly lower for normal or patients with a physiological septal deviation in comparison to the rhinological one on both nasal sides.*
Healthy subjects and patients with physiological septal deviation showed similarities in objective rhinological parameters as well as rhinological patients and patients with pathological septal deviation derived from the unselected group of non-rhinological patients.
Furthermore, this benchmark of nasal resistance shows significant correlations with subjective assessment of nasal breathing.
Conclusion: *Inspiratory nasal resistance obtained at a flow-velocity of 250 cm^3/s using rhinoresistometry may be useful to distinguish patients with physiological and pathological septal deviation. Correlation with subjective assessment and endoscopic findings is improved.*

Key words: septal deviation, rhinoresistometry, acoustic rhinometry, nasal resistance, endoscopy

INTRODUCTION

The majority of ENT specialists regard a straight nasal septum as normal and as a desirable endonasal condition after septoplasty. To achieve equal nasal resistance on both sides and similar space to allow regular swelling within the nasal cycle, the septum has to divide the nose into functionally similar, but not necessarily symmetrical cavities. Zuckerkandl was the first to define a "physiological septal deviation" [1] as a bended septum within the asymmetrical human skull. This concept is supported by the high incidence of septal deviation reported using endoscopic or radiographic methods (30-75% [2-6] for children and between 13-96% in adults [7], with strikingly less patients reported to suffer from subjective problems [8,9]. Differentiation between physiological and pathological septal deviation needs a sharp defined, objective parameter obtained by a rhinologic diagnostic procedure. From our point of view, a physiological septal deviation will be characterized by normal endonasal resistance. Therefore rhinoresistometry may be a promising tool to distinguish the two entities.

We conducted a prospective cohort study to evaluate the value of a benchmark for physiological nasal resistance as obtained via rhinoresistometry to define pathological septal deviations. Our aim was to evaluate the prevalence of physiological septal deviation in an unselected cohort and to evaluate whether this benchmark helps to improve the correlation of objective

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parameters, obtained by rhinoresistometry and acoustic rhinometry, with the findings of nasal endoscopy and the subjective complaints of the patient.

MATERIAL AND METHODS

Study design

In a prospective study, three cohorts were recruited. All measurements were made after obtaining informed consent at the Department of Otorhinolaryngology, Head and Neck Surgery of the University of Greifswald. All subjects included were of Caucasian origin and had no history of recurrent acute or chronic rhinosinusitis, allergy and aspirin intolerance. Other exclusion criteria were previous surgery of the nose or face, systemic medication, facial trauma, illiteracy and psychiatric disorders.

All patients underwent nasal endoscopy before and after decongestion using a 0° and / or 30° endoscope (Storz, Tuttlingen, Germany). Extent and location of septal deviation and endonasal pathologies were noted. All three cohorts were examined using rhinoresistometry, acoustic rhinometry, and nasal endoscopy.

In a first group (n = 105), adult healthy subjects were examined using rhinoresistometry, acoustic rhinometry and nasal endoscopy. Inclusion criteria were a straight septum and age between 18-40 years. Additional exclusion criteria for this cohort were any subjective nasal complaints and pathologies of outer or inner nose.

A second cohort (n = 158) consisted of unselected, "non-rhinologic patients". These patients with an age of 18-75 years were undergoing an examination or hospital stay unrelated to nasal or sinus complaints. These non-rhinologic patients were classified into two subgroups based on the one-sided inspiratory nasal resistance at a flow-velocity of 250 cm^3/s, measured using rhinoresistometry: patients with physiological endonasal resistance ≤ 0.35 sPa/cm^3 were classified as having a physiological septal deviation and those with increased resistances > 0.35 sPa/cm^3 as suffering from a pathological septal deviation.

In a third group (n = 93; "rhinologic patients"), patients before septoplasty were recruited. These patients suffered from nasal obstruction. In this cohort, other etiologies of nasal blockage were excluded by clinical examination and if applicable additional testing to achieve best possible evidence that the septal deviation is the cause of nasal obstruction.

In all groups, endonasal polyps were excluded using endoscopic examination. A CT scan of the paranasal sinuses was used if available or in case of any doubt. The study was performed according to the Declaration of Helsinki and Tokyo following approval by the local university ethics committee.

Acoustic rhinometry and rhinoresistometry

Acoustic rhinometry and rhinoresistometry (RhinoScan® and RhinoStream®, Rhinometrics, Assens, Denmark) were applied according to the recommendations of the most recent consensus conference (10) before and after decongestion with xylometazoline 0.1%. In brief, patients were examined at 20°C after sitting for > 30 min by the same observer. Smoking, eating and drinking were ceased more than 30 min before the measurement. Rhinoresistometry is a refinement of rhinomanometry [11-13] and uses the data measured by anterior rhinomanometry to calculate the nasal resistance at a flow-velocity of 250 cm^3/s, dividing the transnasal pressure loss by the flow velocity [10,13]. Acoustic rhinometry was performed in the same setting to measure minimal cross-sectional area 1 and 2 (MCA1, MCA2) as defined by the standardization committee [10]. All measurements were reviewed to exclude any technical incorrectness by an experienced observer.

Table 1. Characteristics of rhinoresistometry results and acoustic rhinometry in a normal cohort, unselected patients and rhinologic patients

	Normal cohort (n = 105)	**Non-rhinologic cohort (n = 158)**		**Pathological cohort (n = 93)**
		Normal Resistance (n = 114)	Increased Resistance (n = 44)	
Age [y]	26.6 ± 5.4	45 ± 17.2	46 ± 15.6	40.5 ± 13.9
Gender [female/male]	60 / 45	56 / 58	24 / 20	35 / 58
r250cr	0.36 ± 0.26	0.36 ± 0.24	0.7 ± 0.6	1.2 ± 1.2r
250cl	0.5 ± 0.42	0.32 ± 0.19	0.47 ± 0.27	1.8 ± 3.9
r250dcr	0.18 ± 0.07	0.2 ± 0.08	0.4 ± 0.26	0.6 ± 0.67
r250dcl	0.2 ± 0.08	0.2 ± 0.08	0.34 ± 0.15	0.61 ± 1.42
MCA1cr	0.60 ± 0.12	0.56 ± 0,24	0.50 ± 0.2	0.46 ± 0.19
MCA1cl	0.60 ± 0.14	0.61 ± 0.29	0.55 ± 0.18	0.39 ± 0.19
MCA1dcr	0.69 ± 0.14	0.64 ± 0.25	0.58 ± 0.28	0.56 ± 0.24
MCA1dcl	0.69 ± 0.12	0.71 ± 0.35	0.69 ± 0.35	0.52 ± 0.24
MCA2cr	1.6 ± 0.57	1.4 ± 0.54	1.7 ± 0.7	1.3 ± 0.6
MCA2cl	1.6 ± 0.46	1.6 ± 0.74	1.7 ± 0.79	1.1 ± 0.5
MCA2dcr	2.2 ± 0.54	2.1 ± 0.61	2.3 ± 0.94	1.8 ± 0.76
MCA2dcl	2.2 ± 0.5	2.3 ± 0.85	2.4 ± 1	1.7 ± 0.6

Values in mean ± standard deviation, n = number of patients; y = years. Each parameter term consists of three parts: type of parameter (R250: resistance at an inspiratory flow-velocity at 250 cm^3/s, MCA1: minimal cross-sectional area 1, MCA 2: minimal cross-sectional area 2) mode, (c: congested / dc: decongested) and side (r: right; l: left).

VAS

Subjective assessment of nasal patency and mouth bypass-breathing was obtained using 10 cm visual analogue scales from 0 (worst) to 10 (best) using a standardized questionnaire. Assessments were made before and after decongestion, for the right, left and both sides.

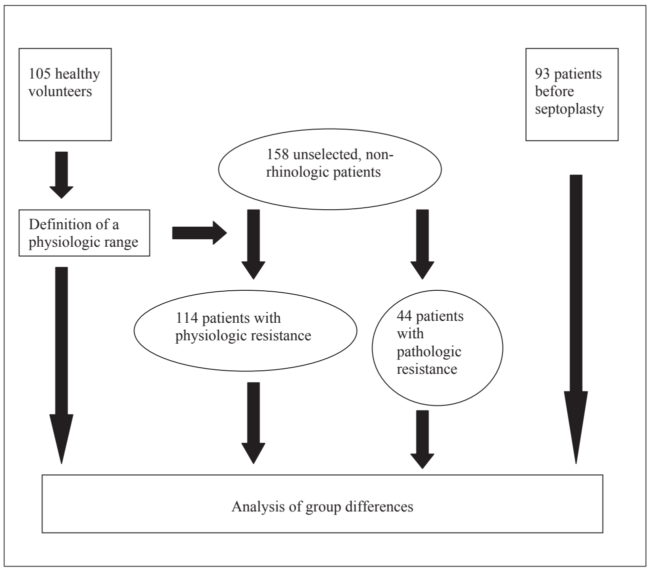
The physiological range of one-sided inspiratory nasal resistance was defined as mean ± 2 standard deviation [14] in a cohort of healthy subjects. The upper benchmark, 0.35 sPa/cm^3 at a flow-velocity of 250 cm^3/s was used to differentiate the patients of the unselected group into patients with physiological septal deviation (R250 ≤ 0.35 sPa/cm^3 on both nasal sides) or pathological septal deviation (R250 > 0.35 sPa/cm^3 on at least one side) (cf. Flowchart 1), resulting in a total of four groups of patients included into this study.

Statistics

Statistical analysis was performed using SPSS® Version 17.0. All parametric data were tested characterised by mean ± standard deviation and analysed for normal distribution. Group differences were tested using one-way ANOVA at a level of significance of $p \leq 0.05$ with post hoc Bonferroni correction. For all statistical tests employed, $\alpha = 5\%$ and $\beta = 20\%$ were used. Analysis of residuals and correlations was performed to assure independence and well-fitting tests. No outliers were removed prior to the analysis. Adjusted contingency coefficient C was calculated to analyse nominal scaled classification of nasal resistance in comparison to endoscopic, subjective and objective parameters.

RESULTS

Data of 356 patients were included in this study. The mean values and standard deviation of rhinoresistometric and acoustic rhinometric findings of the three cohorts are shown in Table I. According to the cohort of healthy subjects, both nasal sides have a physiological range of nasal resistance (mean ± 2 standard deviation) of roughly 0.03-0.35 (right 0.03-0.326; left 0.043-0.359) sPa/cm^3. Based on this range, we defined 0.35 sPa/cm^3 as upper benchmark for a physiological one-sided nasal resistance and used this value to distinguish in our non-rhinologic group between patients with physiological and pathological nasal resistance (cf. Flowchart I) in comparison to a cohort with obvious endonasal pathologies.



Flowchart 1. Classification of patients by means of clinical assessment and nasal resistance.

Analysis for the unselected group of non-rhinologic patients

Out of 158 patients in the unselected group, 114 (72.2%) revealed physiological nasal resistance on both nasal sides, 34 (21.5%) showed pathological increased nasal resistance on one

Table 2. Level of significance for group differences (One way ANOVA with post-hoc Bonferroni correction).

Parameter	Test non-rhinologic cohort with normal resistance versus normal cohort	Test non-rhinologic cohort with normal versus increased resistance	Test non-rhinologic cohort with normal resistance versus pathological cohort	Test non-rhinologic cohort with increased resistance versus normal cohort	Test non-rhinologic cohort with increased resistance versus pahologic cohort	Normal cohort versus pathological cohort
R250cr	NS	0.002	0.001	0.002	NS	0.001
R250cl	NS	NS	0.001	0.002	NS	0.001
R250dcr	NS	0.008	0.001	0.003	0.011	0.001
R250dcl	NS	NS	0.001	NS	NS	0.001
MCA1cr	NS	NS	0.001	NS	NS	0.001
MCA1cl	0.001	NS	NS	0.001	NS	0.001
MCA1dcr	0.001	NS	NS	0.001	NS	0.001
MCA1dcl	0.001	NS	NS	0.002	NS	0.001
MCA2cr	0.001	NS	NS	NS	0.001	0.001
MCA2cl	NS	NS	0.001	NS	0.001	0.001
MCA2dcr	0.001	NS	NS	0.001	0.005	0.001
MCA2dcl	0.013	NS	0.001	NS	0.002	0.001

NS= no significant difference. Values in mean ± standard deviation; N= number of patients; y= years. Each parameter term consists of three parts: type of parameter (R250: resistance at an inspiratory flow-velocity at 250 cm^3/s, MCA1: minimal cross-sectional area 1, MCA 2: minimal cross-sectional area 2) mode, (c: congested / dc: decongested) and side (r: right; l: left

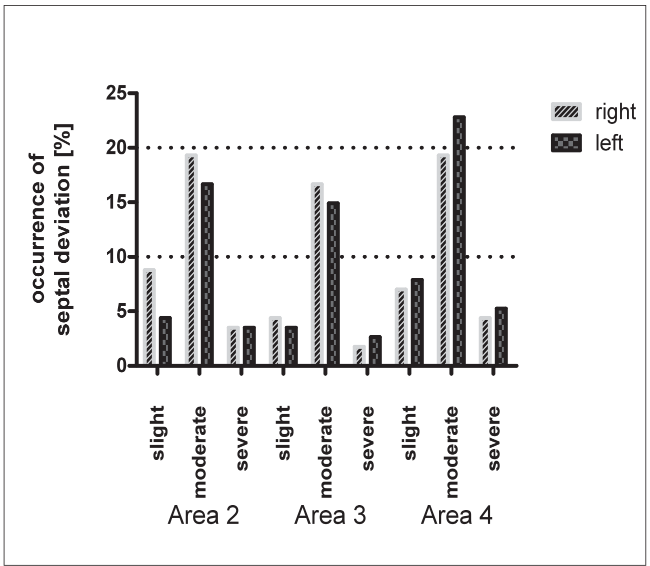


Figure 1. Localisation and extent of septal deviation in patients with physiological septal deviation. Localisation and extent of septal deviation in percent (%) for right and left side according to Cottle Area 2-4 graded as slight, moderate, and severe.

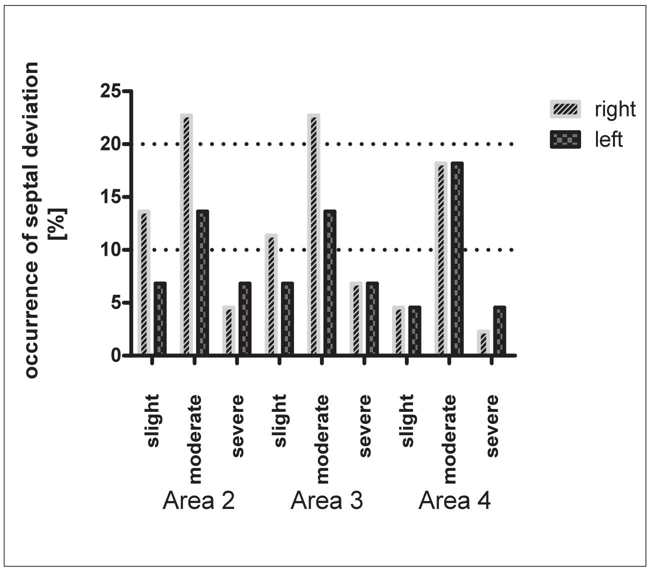


Figure 2. Localisation and extent of septal deviation in patients with increased nasal resistance. Localisation and extent of septal deviation in percent (%) for right and left side according to Cottle Area 2-4 graded as slight, moderate, and severe.

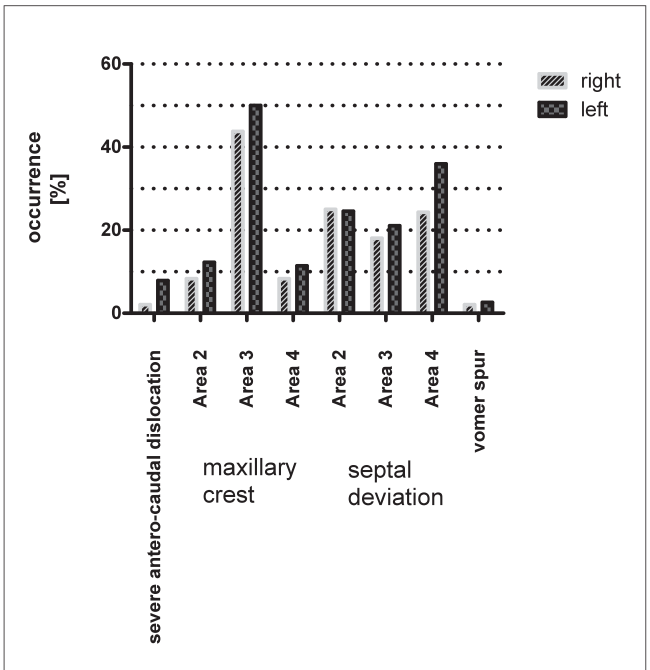


Figure 3. Frequency of structural particularities in patients with normal nasal resistance. Occurrence of different anatomical variations (as percentage) is indicated for the right and left nasal side sorted according to the affected antero-caudal septal edge, the Cottle Area 2-4 and the vomer. Occurrence of different anatomical variations in percent (%) for right and left side according to antero-caudal septal edge, Cottle Area 2-4 and vomer.

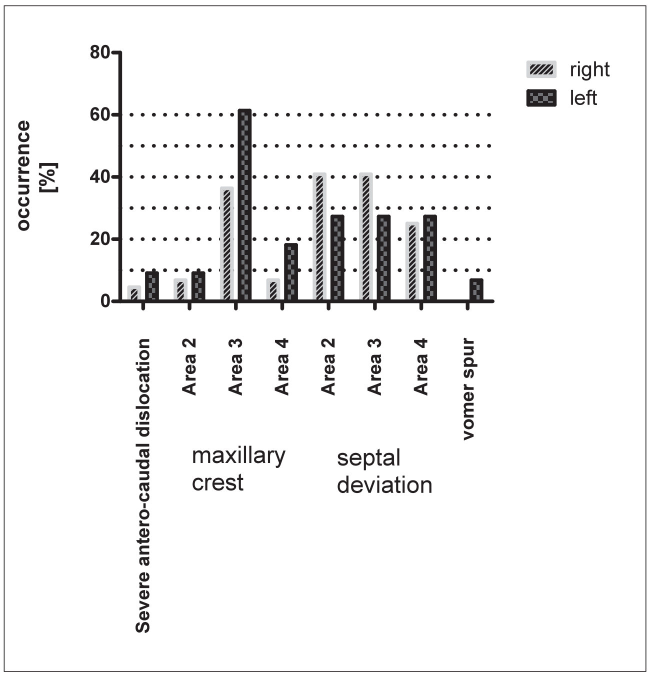


Figure 4. Frequency of structural particularities in patients with increased nasal resistance.

Occurrence of different anatomical variations in percent (%) for right and left side according to antero-caudal septal edge, Cottle Area 2-4 and vomer.

side (14 left, 20 right), while 10 subjects (6.5%) showed pathological increased resistance on both sides.

Nasal endoscopy in the unselected group revealed septal deviations to the right in 53 patients, thereof n = 36 (67.9%) with physiological resistance, consecutively defined as having physiological septal deviation. Deviations to the left occurred in 58 patients (n = 44 / 75.8% with physiological septal deviation). Of these, 34 patients showed septal deviation towards both sides (n = 23 / 67.6% with physiological septal deviation), and 13 patients (n = 11 / 84.6% with physiological resistance) were without septal deviation (Figures 1-4).

Overall, out of 145 patients with septal deviation, 103 (71%) showed resistance within our normal range ("physiological septal deviation"). Maxillary crests were observed on the right in 31 patients (n = 35 with physiological resistance), on the left in 43 patients (n = 26 with physiological resistance), on both sides in 52 patients (n = 41 with physiological resistance) and 32 patients showed no maxillary crest (n = 21 with physiological resistance; cf. Figures 3 and 4). The group difference in frequency of maxillary crests on the right was statistically significant ($p < 0.023$).

Results of rhinometric measurements for rhinologic patients are indicated in Table 1. All patients showed septal deviation, most often with turbinate hypertrophy (data not shown).
One-way ANOVA was used as results were normally distributed. This revealed significant differences in rhinometric measurements between the four cohorts as illustrated in Table 2. Post-hoc Bonferroni correction was used to adjust for multiple testing.

We were able to define 12 objective parameters detecting significant differences between healthy subjects and rhinologic patients (Table 2). The differences between patients with physiological and pathological septal deviation were only detected by measures of resistance. This could be regarded as direct consequence of the application of the benchmark. If analysed in comparison to the healthy subjects and rhinologic patients, 7/12 parameters detected significant differences between patients with physiological septal deviation and rhinologic patients and 7/12 (by part different) parameters detected differences between and patients with pathological septal deviation and healthy subjects.

In the unselected cohort, adjusted contingency coefficient C revealed significant correlations for the classification of resistance as normal or increased and the visual analogue scale rating of nasal breathing after decongestion for the left (0.222; $p < 0.008$), the right (0.217; $p < 0.011$) and both sides (0.226; $p < 0.007$). Furthermore, employment of mouth breathing was more frequent (0.32; $p < 0.001$) in patients with increased resistance.

Based on nasal endoscopy, extent of septal deviation to the right side in Cottle Area 2 (0.192; $p > 0.018$), Area 3 (0.265; $p < 0.001$) and to the left in Area 3 (0.275 $p < 0.005$) was associated with increased nasal resistance.

DISCUSSION

Using a benchmark of 0.35 sPa/cm^3 at a flow-velocity of 250 cm^3/s for the one-sided inspiratory nasal resistance after decongestion, we were able to detect an incidence of 72.2% physiological septal deviation in an unselected cohort. Seven objective parameters were able to confirm differences between patients with physiological septal deviation and rhinologic patients, and between patients with pathological septal deviation and healthy subjects. In the unselected cohort, after application of the benchmark we obtained significant correlations for endoscopic parameter and extent of subjective complaints. Significant parameters of endoscopy were limited to the extent of septal deviation and most pronounced in Cottle Area 3.

The lack of correlation between subjective complaints, objective findings and endonasal anatomy is a long existing dilemma for rhinologists. Based on a pilot study, we conducted this Level 2b study to evaluate the value of a refined technique to assess endonasal resistance for future patients.

The high incidence of 72.2% physiological septal deviation in an unselected cohort is impressive. This figure is supported by the high prevalence of septal deviation and endoscopic and radiographic studies.
Furthermore, it may be a suitable explanation on the unsatisfactory results of septoplasty [15]: patients with physiological septal deviation may suffer from problems unrelated to this endoscopic finding. Thus surgical correction will fail any improvement leading to unsatisfactory results of septoplasty.

Positive effects for correction of preoperative increased nasal resistance have been reported for long-term outcome of septoplasty [16]. Mathematical analyses suggested the importance of anterior septal deviations [17,18]. We observed a significant correlation of the classification based on nasal resistance with endoscopy findings of an anterior septal deviation. However, the correlation coefficient is relatively small (about 0.2). This may be attributed to the limited number of increments (small, moderate, severe) for the extent of septal deviation, as well as the subjective character of the endoscopic assessment by the observer.

The functional relevance of anterior structural deformities of the septum is in accordance with our previous model studies [19]. The reported benefit of patients with anterior deformities from septoplasty [20] does also support the concept of nasal resistance [21] as a helpful parameter. In contrast, the increased number of structural deformities in the posterior parts of the septum in patients with physiological septal deviations indicate a limited impact on endonasal airflow.

Table 2 indicates limited value of endonasal areas measured by acoustic rhinometry to differentiate physiological from pathological. From our point of view, this corresponds to the observation, that (e.g. decreased) resistance is much more a result of (e.g. more circular) formation of the endonasal area rather than of the amount of area itself.
By limiting the age range for normal subjects, we yielded to exclude the effect of aging. Certainly, specific physiological values for different age groups are mandatory. The here presented benchmark of 0.35 sPA/ml should therefore be regarded as a first step. Further evaluations in different age groups are warranted.

Using a visual analogue scale to evaluate subjective complaints, we were unable to detect an initial group difference. As a study of reliability is missing for this tool, this could be regarded as a methodological drawback of our study. We regard subjective complaints a complementary dimension to an objective analysis using rhinoresistometry and acoustic rhinometry. We recommend the combined use of these techniques to assess nasal obstruction.

CONCLUSION

Normal volunteers provide a well-defined physiological range for inspiratory nasal resistance at a flow-velocity of 250 cm^3/s. Septal deviation in 72.2% of an unselected cohort was accordingly judged as "physiological". Patients with physiological resistance showed similar results when compared to normal subjects, while patients with increased nasal resistance were similar to patients before septoplasty with regard to objective parameters obtained by rhinoresistometry. Above a benchmark of > 0.35sPa/cm^3 for the one sided nasal resistance after decongestion, we were able to detect some significant correlations with subjective complaints and extent of septal deviation.

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