Objective Parameters for Evaluating Internal Nasal Valve Compromise: Beyond the Angle Perspective

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CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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AUTHOR CONTRIBUTIONS

Conceptualization: SJK, KHL. Data curation: JHB. Methodology: SJK, JHB, KHL. Project administration: SJK, KHL. Writing–original draft: SJK. Writing–review & editing: SJK, JHB, KHL.
HIGHLIGHTS

- Lack of standard test to diagnose nasal valve compromise leads to controversy over surgical indications and insurance coverage.
- Relying solely on angle of internal nasal valve (INV) has limitations in evaluating compromised INV.
- INV area on axial computed tomography scans and minimal cross-sectional area in acoustic rhinometry, hold potential as objective parameters for evaluating INV compromise.
Objective Parameters for Evaluating Internal Nasal Valve Compromise: Beyond the Angle Perspective

Abstract

Objectives. Since nasal valve surgery for internal nasal valve (INV) compromise has gained popularity, controversies over its indications and insurance coverage disputes have emerged due to the absence of a gold-standard evaluation. Therefore, we aimed to identify the objective parameters for the INV compromise.

Methods. We analyzed 186 INVs in 93 patients who underwent nasal valve surgery. The data included facial computed tomography images, acoustic rhinometry, modified Cottle test, and symptom scores. The patients were categorized based on their symptoms and modified Cottle’s test results. We measured the INV angle, area, volume, lateral wall thickness, septal angle, and nasal bone area using computed tomography (CT).

Results. The compromised INV group (nasal obstruction with a positive modified Cottle test) was characterized by smaller INV areas on both the coronal and axial views, smaller INV volume on the axial view, and thinner lateral wall on the coronal view (all $P < 0.05$). Acoustic rhinometry revealed a smaller minimal cross-sectional area and volume in the compromised INV group (both $P < .001$). Regression analysis revealed significant associations between a compromised INV and the INV area on the axial view and the minimal cross-sectional area on acoustic rhinometry.

Conclusion. Relying solely on the INV angle in CT scans has limitations in assessing compromised INV. Instead, the INV area on axial CT scans and the minimal cross-sectional area on acoustic rhinometry hold potential as objective parameters for evaluating INV compromise.
- **Keywords:** Nasal Valve Surgery; Nasal Valve Compromise; Objective Parameters; Computed Tomography; Acoustic Rhinometry
INTRODUCTION

The internal nasal valve (INV) is the narrowest part of the nasal cavity, thus exhibiting the greatest resistance to airflow [1, 2]. Anatomically, the INV is a three-dimensional region lying under the upper lateral cartilage, bounded medially by the septum, laterally by the upper lateral cartilage, and inferiorly by the head of the inferior turbinate [1]. The INV angle between the upper lateral cartilage and the septum is known to be 10–15° in Caucasians [2, 3] and larger in Asians [4]. The INV compromise refers to a condition in which the INV region is anatomically narrowed, typically due to deviations in the caudal or dorsal septum, septal turbinate hypertrophy, lateral wall deformities, or weaknesses that lead to lateral wall collapse.

Surgery to treat INV compromise either widen the INV cross-sectional area or strengthen the lateral sidewalls [1, 5]. Spreader grafting is the gold-standard treatment for widening a narrowed INV. Flaring sutures or butterfly grafting also increases the valve angle [5]. There is no dispute regarding the efficacy and necessity of nasal valve surgery for patients with appropriate indications. However, the rising demand for this procedure has led to increasing disputes between patients and insurance companies, particularly regarding the denial of insurance claims. The underlying issue stems from the absence of well-defined diagnostic criteria to objectively demonstrate INV compromise and justify the necessity for surgery.

In clinical practice, computed tomography (CT) scans are commonly used to assess INV compromise, often through angle measurements. However, the reference angle of 10–15° [2, 3], considered the true valve angle, is purely theoretical, and a diagnosis of INV compromise cannot be based solely on angles smaller than this range. Moreover, the angles measured on CT scans can vary owing to the mucosal status and different
measurement techniques [6, 7]. Additional attempts have been made to objectively diagnose INV compromise using endoscopic evaluation, acoustic rhinometry, and rhinomanometry [6, 8]. However, a universally accepted gold standard test for diagnosing INV compromise remains elusive [1]. Therefore, this study aimed to analyze various objective measurements to determine the appropriate parameters for evaluating the INV compromise.

- MATERIALS AND METHODS
  - Patients
    - We retrospectively analyzed data from 186 valves of 93 patients who underwent nasal valve surgery to treat INV compromise between September 2016 and February 2023. All surgical procedures were performed by a single author (K.H.L.) at an academic referral center. The inclusion criteria were patients with preoperative facial three-dimensional (3D) CT scans that revealed unilateral or bilateral INV compromise and age 18 years or older. The exclusion criteria were age < 18 years and the presence of any other sinonasal disease, such as sinusitis, polyposis, or sinonasal masses. This study was approved by the Institutional Review Board of the Kyung Hee University Hospital at Gangdong (IRB no. KHNMC 2023-03-005). Given the retrospective nature of the study, the requirement for informed consent was waived.
  - Modified Cottle Test, acoustic rhinometry and CT imaging
    - The Modified Cottle Test (MCT) was performed to assess the INV patency. During the MCT, the INV area on each side was gently supported using Bayonet forceps to provide lateral support at the level of the INV under a 0-degree rigid endoscope. The patient was
asked to breathe deeply through the nose. Subjective improvement in nasal airflow indicated a positive MCT result, suggesting INV compromise.

- Acoustic rhinometry was performed using an acoustic rhinometer and accompanying software (A1, GM Instruments Ltd., Kilwinning, UK), which automatically measured the minimal cross-sectional area (MCA) and nasal cavity volume. The initialization, calibration, and measurement processes adhered to the guidelines. The tests were repeated three times for each subject, and the average value was recorded.

- Facial 3D CT examinations were performed using a 64-channel multi-slice CT scanner (Brilliance; Philips Medical Systems, Cleveland, OH, USA) operating at 120 kV, 250 mA, and a slice thickness of 1.00 mm. We measured various parameters related to the INV on CT scans.

- INV categorization based on symptoms and the MCT results

We analyzed each of the 186 nasal valves obtained from 93 patients individually. Each patient contributed two INV datasets. Initially, we categorized the 186 nasal valves into four groups based on nasal obstruction and MCT results. Group 1 consisted of valves with nasal obstruction and positive MCT results, indicative of compromised INV. Group 2 consisted of valves with nasal obstruction but negative MCT results, encompassing diverse cases in which nasal obstruction was not valve-related, or severe caudal/dorsal deviation led to negative MCT results despite compromised valves. Owing to the heterogeneity of Group 2, it was excluded from the analysis. Group 3 included valves with no symptoms but positive MCT results, which were considered false positives, assuming temporary improvement during MCT. Consequently, Group 3, in conjunction with group 4, which consisted of valves without nasal obstruction and negative MCT results, was
classified as non-compromised INV. Thus, the analysis was conducted on two main groups: compromised INV (group 1) and non-compromised INV (groups 3 and 4).

- **CT measurements of the INV**
  - The parameters related to INVs were measured using conventional axial and coronal images from facial 3D CT scans, and the reformatted images were not used.
  - Measurements were performed using a Picture Archiving and Communication System (PACS) (ZeTTA PACS; TaeYoung Soft Co. Ltd. Anyang, Republic of Korea) and the Aquarius workstation iNtuition edition program (ver.4.4.12.249, TeraRecon Inc., Foster City, CA, USA). Before measurement, the INV level was determined by identifying the caudal margin of the upper lateral cartilage using scout navigation by scrolling through the images (Fig. 1). Although variations existed among the patients, the selected section typically corresponded to the first cut, where the scroll area disappeared and was anterior to the inferior turbinate. All measurement sections were confirmed via scout navigation and appropriately adjusted by reference to the anatomical variations [9].
  - Measurements were taken for the INV angle, area, and volume (in the axial view only), lateral wall thickness at the INV level, and the septal angle on both the axial and coronal planes. In addition, the nasal bone area was measured on the 3D lateral view (Fig. 2).
  - We measured the INV angle using two methods: 1) placing the vertex at the outer boundary of the soft tissue [4, 10-12] and 2) positioning the vertex within the inner mucosal lining [7]. The former method involves averaging the contour irregularities of the nasal cavity lumen to draw a medial line along the septum and a lateral line along the lateral wall. The angle between these two lines was then measured with the vertex positioned at the outer boundary of the soft tissue [4, 10-12] (Fig. 2A and 2B). By contrast, the latter method involves measuring the angle of the apical region along the
inner mucosal lining. Here, the angle between the septum and lateral wall was measured, with the vertex located at the point where the septum and lateral wall diverged [7] (Fig. 2C and 2D). The INV area was measured in the coronal view along the mucosal lining within the nasal cavity [10] (Fig. 2E). In axial view, the INV area was measured along the inner margin of the mucosa, with a horizontal line passing through the inferior turbinate head serving as the posterior boundary [13] (Fig. 2F). The INV volume was measured using the Aquarius workstation iNtuition edition program (ver.4.4.12.249, TeraRecon Inc., Foster City, CA, USA). The INV region was identified in the axial view and the volume was measured within a defined range from the cut where the scroll disappeared to the section where the inferior turbinate head was visible. Volume was calculated three-dimensionally by combining consecutive sections.

Next, we measured the lateral wall thickness. The thickness of the entire lateral wall from the inner mucosal lining to the outer boundary was measured perpendicular to the axis of the lateral wall at the INV level (Fig. 2G and 2H). Additionally, we measured the angle between the dorsal/caudal septum and midline. The midline was defined as the line connecting the anterior nasal spine to the crista galli in the coronal view [14] (Fig. 2I). In the axial view, the midline was the line connecting the most posterior septum to the anterior nasal spine (not visible in the measured section) (Fig. 2J). In addition, we measured the nasal bone area on lateral reconstructed 3D images (Fig. 2K and 2L). All measurements were conducted bilaterally, except for the septal angle, and were performed by the author (J.H.B.) who was blinded to the purpose of the study and any patient information.

- Statistical analysis
The Chi-square or Fisher’s exact tests were used to compare the binary demographic variables between groups. Student’s t-test was used to compare numerical variables such as age, CT measurements, and acoustic rhinometry data between the groups. Binary (retrograde conditional) regression analysis was used to identify the predictors of clinically compromised INV. The accuracies of these predictors were compared using receiver operating characteristic (ROC) curves. The areas under the curve (AUCs) for all possible predictors and their significance were calculated. All statistical analyses were performed using the SPSS version 26.0 (IBM SPSS Statistics, Armonk, NY, USA) or R version 4.3.0 (R Foundation for Statistical Computing, Vienna, Austria). A p-value < .05 was considered at significant.

RESULTS

A total of 186 valves from 93 patients were analyzed. The patients comprised 150 men (80.6%) and 36 women (19.4%), with a mean age of 37.15 years (range, 18–74 years). Of the 186 valves, 89 exhibited compromised INV and 44 had non-compromised INV. The remaining 42 evidenced nasal obstruction but negative MCT results and were thus excluded from the analysis.

The non-compromised INV group had a higher mean age than the compromised INV group (P = 0.011). However, no inter-group differences were seen in sex, history of trauma or nasal surgery, allergic rhinitis, or dorsal or caudal deviation (Table 1).

Table 2 compares the CT measurements and acoustic rhinometry results. On coronal measurements, the compromised INV group exhibited a smaller INV area (P < 0.001) and a thinner lateral wall (P = 0.032) than the non-compromised INV group. Axial measurements showed that the compromised INV group had a smaller INV area (P =
0.003) and volume ($P = 0.002$) than the non-compromised INV group. No between-group differences were noted in the INV or septal angles on the coronal and axial views, or the nasal bone area on the 3D lateral view (all $P > 0.05$). In terms of the acoustic rhinometry data, the compromised INV group exhibited a significantly smaller MCA ($P < 0.001$) and volume ($P = 0.001$) than the non-compromised INV group.

- Table 3 lists the results of binary logistic regression analysis to identify the predictors of clinically compromised INV. The covariates included age, INV area, and lateral wall thickness on the coronal view; INV area and volume on the axial view; and MCA and volume as measured by acoustic rhinometry. The results indicated that after adjusting for age, the INV area on the axial view and MCA, as measured by acoustic rhinometry, were significant predictors of a clinically compromised INV.

- To assess predictive performance in terms of INV compromise, the AUCs of the ROC curves were examined (Fig. 3). The AUCs for the potential predictors identified via regression analysis, adjusted for age, were 0.723 for the INV area on the axial view and 0.733 for the MCA as measured by acoustic rhinometry. When these two predictors were combined, the AUC value increased to 0.753.

- **DISCUSSION**

- A notable finding of this study is that the INV angle was not a predictor of a clinically compromised INV and even did not differ significantly between the compromised and non-compromised INV groups. In the existing literature, the normal INV angle is known to be 10°–15° in Caucasians [2, 3]. This angle has been widely cited without consideration of anatomical variations or mucosal conditions. Angle measurements are primarily
performed using CT scans; however, applying this angle uniformly to patients with diverse valve shapes can be challenging and may lack reproducibility [6, 7].

- The INV angle is typically measured by averaging two lines along mucosal contour irregularities on CT images, with the vertex positioned at the outer margin of the soft tissue [4, 10-12]. Using this method, the INV angle in reformatted planes was 9.71–12.09° [10-12], similar to the theoretical angles, and were larger in Asians (average 21.6°) [4]. In the present study, the INV angle measured on the axial plane was 18.73 ± 7.52° (19.16 ± 7.38° after the exclusion of Group 2) for all enrolled patients. The angle in the compromised INV group (18.90 ± 7.42°) was narrower than that in the non-compromised INV group (19.68 ± 7.35°); however, the difference was not significant (P > 0.05).

Moreover, this measurement method has limitations owing to subjective factors, as the angle can vary based on how the endpoint on the opposite side of the vertex [6, 7]. In addition, in cases involving the septal turbinate or lateral wall attachment to the septum, measuring the angle may not be feasible [6].

- To address this issue, we measured the INV angle along the inner lining of the mucosa [7]. Although none of the INV angles showed statistical significance, the P-values for the INV angle inner showed marginal significance, suggesting that measurements along the inner mucosal lining, rather than placing the vertex at the outer margin as in the conventional method, may better reflect the INV compromise. To the best of our knowledge, no previous studies have compared methods of measuring the INV angle. When evaluating the INV angle, using the inner vertex may have more potential than using the conventional outer-vertex method. However, owing to the lack of related studies, further validation using additional data is necessary. Besides, measuring the angle with the inner vertex also faces limitations, such as arbitrary placement of the vertex in cases with blunt angles and subjectivity in setting a straight line.
Moreover, INV angles measured using endoscopy have yielded inconsistent results, with a wide range from $9.1^\circ$ to $52.04^\circ$ [6, 15]. This is probably due to distortions caused by the tilting or rotation of the measurement plane, resulting in poor reproducibility [4]. In other words, the measured INV angles varied according to the evaluation tool used and measurement method.

Furthermore, most studies on surgical treatments for INV compromise have employed subjective symptom improvement as the primary outcome measure rather than objective measurements such as the INV angle [1, 5, 16]. Even in a study that assessed the INV angle before and after surgery, no significant differences were observed despite symptom improvement after surgery, and no correlation existed between the angle and symptom scores [17]. Taken together, relying solely on two-dimensional angle measurements has limitations in evaluating clinically compromised INV, which aligns with our findings.

Another objective method for INV evaluation is to measure the INV area [13]. Compared with angle measurements within the same CT section, measuring the INV area along the inner mucosal lining offers a relatively lower measurement error and higher reproducibility. Moreover, the area may prove more advantageous than the angles in assessing INV compromise, as it can be measured across various INV types irrespective of anatomical variations, such as blunt angles or cases with angles occupied by the septal turbinate. In this study, the INV area on both the coronal and axial views was significantly smaller in the compromised INV group, and regression analysis indicated that the INV area on the axial view was a significant predictor of compromised INV. Similarly, another study reported that the area measured on the axial CT scan correlated with a clinically narrow INV [13].

Regards to lateral wall thickness, we found that the compromised INV group exhibited a significantly thinner lateral wall on the coronal view, which was no longer a risk factor for
clinically compromised INV after adjusting for age. While racial and individual differences may exist, a thin lateral wall can imply a thin cartilage thickness that can cause lateral wall collapse because it lacks the necessary structural integrity to withstand negative pressure during inspiration, leading to dynamic collapse [18]. However, skin thickness has been reported to be unrelated to the degree of lateral nasal wall collapse, which is consistent with our study results [19].

- Aging is known to cause structural changes within the nasal cavity [20, 21]. In addition to mucosal atrophy, aging increases the overall intranasal volume, including the valve area, which affects nasal airflow patterns. Altered airflow can cause symptoms such as nasal obstruction [20]. Furthermore, age-related loss of cartilage structural integrity leads to INV stenosis and collapse [21]. Our results showed that the compromised INV group had a younger age. This is likely due to a selection bias, as the study included only patients who underwent nasal valve surgery, thereby excluding elderly patients and primarily selecting younger patients who were more actively treated.

- Additionally, we investigated the contribution of caudal/dorsal septal deviation to INV compromise; however, no significant differences were detected between the groups. Although caudal/dorsal septal deviation is a potential cause of INV compromise, quantifying its impact is challenging because a structured and standardized measurement method for objectively evaluating caudal/dorsal septal deviation is lacking [22].

- In the nasal bone area, a shorter nasal bone is often associated with relatively longer and weaker upper lateral cartilage, which increases the risk of INV insufficiency [23]. In this study, although the nasal bone area was smaller in the compromised INV group, no significant difference was found between the two groups.

- In this study, certain parameters obtained from CT and acoustic rhinometry emerged as potential predictors of INV compromise. However, a combination of these parameters
cannot be considered the gold standard for evaluating INV compromise or serve as a basis for insurance coverage. Moreover, the diagnostic value of these tests is not essential to the extent that they outweigh concerns about radiation exposure or cost. Nonetheless, the authors assert that INV compromise cannot be simply defined by angles theoretically; rather, considering the intrinsic complexity and diversity within the INV compromise, various assessment methods may exist.

- The strengths of this study are as follows. First, we objectively quantified various numerical measurement variables to assess the INV compromise in 186 valves from 93 individuals who underwent valve surgery. Second, the outcome evaluation considered both the MCT results and subjective symptoms, enabling a comparison based on clinically compromised INV. Additionally, we employed conventional coronal and axial planes in the CT scans instead of reformatted images. Although some studies have suggested that the INV angle in the reformatted planes perpendicular to the acoustic axis is closer to the theoretical INV angle [10, 11], such reformatted images are not routinely available in clinical practice [13]. With the growing number of insurance-related disputes, the demand for objective parameters to assess INV compromises is increasing. Thus, this study utilized easily obtainable images in clinical practice to enhance clinical utility.

- This study had several limitations. First, factors other than INV compromise, such as allergies, the effect of the nasal cycle, or structural issues unrelated to the valve, may have contributed to nasal obstruction. However, even in prospective studies, it remains challenging to completely differentiate conditions coexisting with or mimicking INV compromise [1]. To address this limitation, we restricted the inclusion to patients who underwent MCT and valve surgery. Second, the dynamic collapse of the Bernoulli effect was not considered. We did not distinguish between dynamic and static collapse; however, doing so may have yielded more meaningful results. Third, we did not explore additional
objective measures, such as peak flow or nasal endoscopy, which might have been correlated with the symptoms. Fourth, since most of the included patients were of Korean ethnicity and the data were obtained from a single academic referral center, caution should be exercised when generalizing our results to the entire population. Finally, given the retrospective design, a risk of bias, including selection bias, may exist. Considering these limitations, a prospective study with a larger sample size is expected to yield a meaningful approach for evaluating INV compromise in the future.

**CONCLUSION**

- Our study indicates that relying solely on conventional angle measurements on CT scans may not be sufficient to evaluate clinically compromised INV. Instead, parameters such as the INV area on the axial view and MCA measured by acoustic rhinometry may serve as potential objective parameters for evaluating INV compromise. Given its inherent complexity and diversity, defining the diagnostic criteria for INV compromise may be challenging. However, with cumulative efforts toward diagnostic approaches, the current diagnostic ambiguity and associated controversies may gradually decrease over time.
REFERENCES


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- **Figure legend**

- **Fig. 1.** Selected sections of facial computed tomography scans for internal nasal valve measurements. The red dotted line indicates the midline. (A) Coronal view. (B) Axial view.

- **Fig. 2.** Measurement parameters in selected computed tomography scans. (A) INV angle with outer vertex on coronal view. (B) INV angle with outer vertex on axial view. (C) INV angle with inner vertex on coronal view. (D) INV angle with the inner vertex on the axial view. (E) INV area on the coronal view. (F) INV area on axial view. (G) Lateral wall thickness on coronal view. (H) Lateral wall thickness on axial view. (I) Septal angle on coronal view. (J) Septal angle on the axial view. (K, L) Nasal bone area on the reconstructed 3-dimensional lateral view. INV, internal nasal valve.

- **Fig. 3.** AUC values for the significant predictors identified in the regression analysis, along with their combination, to predict INV compromise based on the ROC curve. Age adjusted. AUC, area under the curve; ROC, receiver operating characteristic.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Compromised INV (n = 89)</th>
<th>Non-compromised INV (n = 44)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>35.58 ± 12.88</td>
<td>41.75 ± 13.14</td>
<td>0.011</td>
</tr>
<tr>
<td>Sex (male)</td>
<td>70 (78.7)</td>
<td>35 (79.5)</td>
<td>0.905</td>
</tr>
<tr>
<td>Trauma history</td>
<td>68 (77.3)</td>
<td>31 (72.1)</td>
<td>0.517</td>
</tr>
<tr>
<td>Revision</td>
<td>11 (12.9)</td>
<td>3 (7.7)</td>
<td>0.545</td>
</tr>
<tr>
<td>Allergic rhinitis</td>
<td>57 (71.3)</td>
<td>23 (74.2)</td>
<td>0.756</td>
</tr>
<tr>
<td>Caudal deviation</td>
<td>62 (69.7)</td>
<td>36 (81.8)</td>
<td>0.134</td>
</tr>
<tr>
<td>Dorsal deviation</td>
<td>34 (38.2)</td>
<td>19 (43.2)</td>
<td>0.581</td>
</tr>
</tbody>
</table>

- Values are the means ± standard deviation, or numbers (percentages).
- INV, internal nasal valve.
- Bold values are statistically significant.
### Table 2. Internal nasal valve measurements on computed tomography scans and acoustic rhinometry

<table>
<thead>
<tr>
<th>Variable</th>
<th>Compromised INV (n = 89)</th>
<th>Non-compromised INV (n = 44)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CT coronal view</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>INV angle outer (°)</td>
<td>17.25 ± 11.00</td>
<td>20.44 ± 13.35</td>
<td>0.145</td>
</tr>
<tr>
<td>INV angle inner (°)</td>
<td>17.51 ± 10.61</td>
<td>21.47 ± 13.59</td>
<td>0.068</td>
</tr>
<tr>
<td>INV area (cm²)</td>
<td>0.43 ± 0.24</td>
<td>0.65 ± 0.44</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Lateral wall thickness (mm)</td>
<td>5.68 ± 1.30</td>
<td>6.22 ± 1.48</td>
<td>0.032</td>
</tr>
<tr>
<td>Septal angle&lt;sup&gt;a&lt;/sup&gt; (°)</td>
<td>15.92 ± 6.50</td>
<td>13.77 ± 5.99</td>
<td>0.074</td>
</tr>
<tr>
<td><strong>CT axial view</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>INV angle outer (°)</td>
<td>18.90 ± 7.42</td>
<td>19.68 ± 7.35</td>
<td>0.569</td>
</tr>
<tr>
<td>INV angle inner (°)</td>
<td>25.20 ± 10.30</td>
<td>28.62 ± 8.90</td>
<td>0.063</td>
</tr>
<tr>
<td>INV area (cm²)</td>
<td>0.86 ± 0.38</td>
<td>1.08 ± 0.45</td>
<td><strong>0.003</strong></td>
</tr>
<tr>
<td>INV volume (cm³)</td>
<td>0.58 ± 0.28</td>
<td>0.76 ± 0.38</td>
<td><strong>0.002</strong></td>
</tr>
<tr>
<td>Lateral wall thickness (mm)</td>
<td>5.44 ± 1.21</td>
<td>5.31 ± 1.25</td>
<td>0.588</td>
</tr>
<tr>
<td>Septal angle&lt;sup&gt;a&lt;/sup&gt; (°)</td>
<td>14.50 ± 6.17</td>
<td>15.16 ± 6.85</td>
<td>0.598</td>
</tr>
<tr>
<td><strong>CT 3D lateral view</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nasal bone area (cm²)</td>
<td>1.66 ± 0.42</td>
<td>1.82 ± 0.51</td>
<td>0.245</td>
</tr>
<tr>
<td><strong>Acoustic rhinometry</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MCA (cm²)</td>
<td>0.46 ± 0.29</td>
<td>0.68 ± 0.30</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>volume (cm³)</td>
<td>2.16 ± 0.67</td>
<td>2.67 ± 0.97</td>
<td><strong>0.001</strong></td>
</tr>
</tbody>
</table>

- Values are the means ± standard deviation. Bold values are statistically significant.
- CT, computed tomography; INV, internal nasal valve; 3D, 3-dimensional; MCA, minimal cross-sectional area.
- <sup>a</sup>The septal angle is the angle between the septum and the midline.
**Table 3.** Binary logistic regression analysis of predictors for clinically compromised internal nasal valves

<table>
<thead>
<tr>
<th>Variables</th>
<th>B</th>
<th>S.E.</th>
<th>Wald</th>
<th><em>P</em>-value</th>
<th>Exp(B)</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>INV area on CT axial view</td>
<td>-1.379</td>
<td>0.605</td>
<td>5.204</td>
<td><strong>0.023</strong></td>
<td>0.252</td>
<td>0.077-0.823</td>
</tr>
<tr>
<td>MCA in acoustic rhinometry</td>
<td>-1.979</td>
<td>0.788</td>
<td>6.295</td>
<td><strong>0.012</strong></td>
<td>0.139</td>
<td>0.030-0.649</td>
</tr>
</tbody>
</table>

- Age adjusted. Method: Retrograde conditional.
- CT, computed tomography; INV, internal nasal valve; MCA, minimal cross-sectional area; B, coefficient; S.E., standard error; Exp(B), odds ratio; CI, confidence interval.
- Bold values are statistically significant.
Fig. 1.
Fig. 2.
Fig. 3.

The figure shows a Receiver Operating Characteristic (ROC) curve with the following details:

- **Sensitivity** on the y-axis.
- **1 – Specificity** on the x-axis.
- Three different lines represent different parameters:
  - **Both parameters** with an AUC of 0.753.
  - **MCA on acoustic rhinometry** with an AUC of 0.733.
  - **INV area on CT axial view** with an AUC of 0.723.