Assessment of the anterior superior alveolar nerve and its impact on surgery of the lateral nasal wall*

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Abstract
Background: The anterior superior alveolar nerve (ASAN) plays a major role in innervation of the lateral nasal wall. Its damage during nasal surgery can cause dental paraesthesia and numbness around the upper lip.

Methodology: Retrospective evaluation of the computed tomographic (CT) scans of 50 consecutive patients analysing 100 sides. We measured the mean distance from the shoulder of the inferior turbinate to the descending portion of the anterior superior alveolar nerve, to the anterior superior alveolar canal and the anterior-posterior distance between the "shoulder" of the inferior turbinate and the pyriform aperture.

Results: The mean distance from the shoulder of the inferior turbinate to the descending portion of the anterior superior alveolar nerve was 6.4 ± 2.33 mm, with no difference between sides The mean relative height of the shoulder in relation to the anterior superior alveolar nerve canal was 4.78± 2.31mm with no significant difference between the two sides. The anterior-posterior distance between the "shoulder" of inferior turbinate and the pyriform aperture was 6.96± 2.28mm, with no significant difference between the two sides.

Conclusions: We found the anterior superior alveolar nerve to be a constant landmark in the lateral nasal wall. Therefore, the course of the ASAN should be assessed on a CT scan when a surgical approach through the pyriform aperture or anterior medial wall of the maxillary sinus is planned.

Key words: computed tomography, endoscopic sinus surgery, endoscopic skull-base surgery, maxillectomy, sinus anatomy

Introduction
Since the beginning of the 20th century, the surgical approach to the maxillary sinus has changed considerably. Wide surgical approaches such as used in the Denker procedure in 1906[1,2] where an incision is made in the nasal vestibule, followed by drilling of the piriform crest along with the medial wall and/ or part of the anterior wall of the maxillary sinus, have been abandoned. More selective techniques such as the modified Sturmann-Canfield approach, first described in 1908[3,4] have been superseded. Advances in visualization and instrumentation have allowed the medial buttress, nasolacrimal duct and anterior third of inferior turbinate to be preserved. In recent years, more conservative transnasal endoscopic approaches such as the prelacrimal window approach (PLWA) and pyriform turbinoplasty (PT) have become increasingly popular in gaining access to the maxillary sinus and to the pyriform aperture [5,6].
A high incidence of persistent paraesthesia has been described in association with the more extensive surgical approaches to the maxillary sinus. Damage to the anterior superior alveolar nerve (ASAN) is the probable cause of persistent dental paresthesia [7-9].
The ASAN is a branch of the infraorbital nerve (V2). The ASAN leaves the infraorbital foramen in an osseous canal within the anterior and medial wall of the maxillary sinus adjacent to

Table 1. Measurements of distances.

	Minimum	Maximum	Average ± SD
Distance 1 – right side (mm)	2,9	14,45	6,64±2,301
Distance 1 – left side (mm)	0,1	11,57	6,25±2,362
Distance 2 – right side (mm)	1,35	14,28	4,86±2,385
Distance 2 – left side (mm)	0,98	10,67	4,71±2,247
Distance 3 – right side (mm)	2,55	12,09	6,95±2,174
Distance 3 – left side (mm)	2,92	14,03	6,96±2,410

Distance 1 = shoulder to the ASAN in the maxillary wall, distance 2 = vertical height of the shoulder in relation to the ASAN, distance 3 = distance from the shoulder to the pyriform aperture.

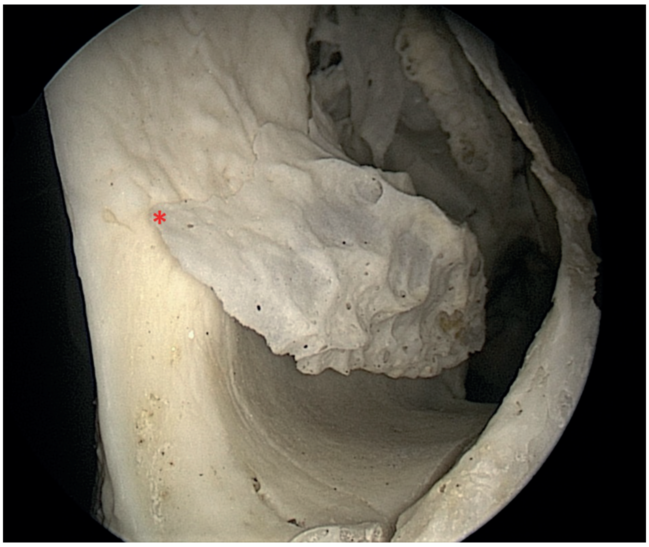

Figure 1. Bony anatomy of the right anterior lateral nasal wall. The junction between the attachment of the inferior turbinate bone and the frontal process of the maxilla is defined as shoulder of the inferior turbinate (*).

the piriform aperture to provide innervation to the ipsilateral incisors and canine teeth [10].
The goal of this study was to identify the course of the ASAN on high resolution paranasal sinus CT and to define how its path varied distal to the infraorbital foramen thereby exposing the nerve to the risk of injury during PLWA or PT [8].

Materials and methods

Fifty consecutive patients were chosen at random and thereby 100 sides of their CT scans were examined at the Medical Radiologic Institute, Zurich Switzerland. The CT scans were done with a spiral data set reconstructed with 0.63mm slice thickness in axial/coronal/sagittal planes.
Patient's informed consent was obtained for anonymized anatomic assessment of their CT data. The study was conducted according to regulations established by the Helsinki Declaration. The inferior turbinate is composed of a separate bone that articulates with the inferior margin of the maxillary hiatus via its frontal process of the maxilla. It also articulates with the ethmoid, palatine, and lacrimal bones where it completes the medial wall of the nasolacrimal duct [11] (Figure 1). The key area of analysis and "anatomical landmark" was the lateral junction of the inferior turbinate with the frontal process of the maxilla and the medial wall of the nasolacrimal duct. This junction is referred to as the 'shoulder' of the inferior turbinate (Figure 1, Figures 2a, b).
The relative position of the ASAN in the vertical plane to the junction of the shoulder of the inferior turbinate with the frontal process of the maxilla was assessed.

Measurements

The point where the shoulder of the inferior turbinate meets the frontal process of the maxilla was identified in the coronal plane. In this plane, we identified the ASAN and measured the distance from the superior margin of the shoulder to the descending portion of the ASAN (distance 1 - red line) and the relative height of the superior margin of the shoulder in relation to the ASAN (distance 2 - blue line) (Figure 3a). Distance 1 is related to distance 2 as a right-angled triangle. In the corresponding axial plane, a tangential line through the junction of the "shoulder" of the inferior turbinate with the frontal process of the maxilla was made. Parallel to this line, another line was drawn anteriorly through the pyriform aperture, and this distance was also measured (distance 3) (Figure 3b).

Statistics

Statistical analysis was performed using Statistical Package for Social Science (SPSS) (v:27). Normality was assessed using a Shapiro-Wilk test. For normally distributed values, descriptive results are expressed as mean ± SD. Independent t-test/ Mann Whitney test was used to compare continuous variables between two groups. A Pearson correlation coefficient/ Kendall's tab analysis was used to examine the relationship of two related variables. A chi-squared test was used for comparison between two attributes. The normality of the samples was assessed by histogram and plot visual analysis, and according to this, a non-parametric test – Mann-Whitney – was our test of choice for comparison between sides. A two-sided p-value < 0.05 was considered statistically significant.

Results

Our sample consisted of 30 women and 20 men, aged between 18 and 79 years (mean 43.62 ± 14.59 mm).
For the entire series, the mean distance from the shoulder of the inferior turbinate to the descending portion of the ASAN (distance 1) was 6.4 ± 2.33 mm (minimum 0,1 mm, maximum 14,45

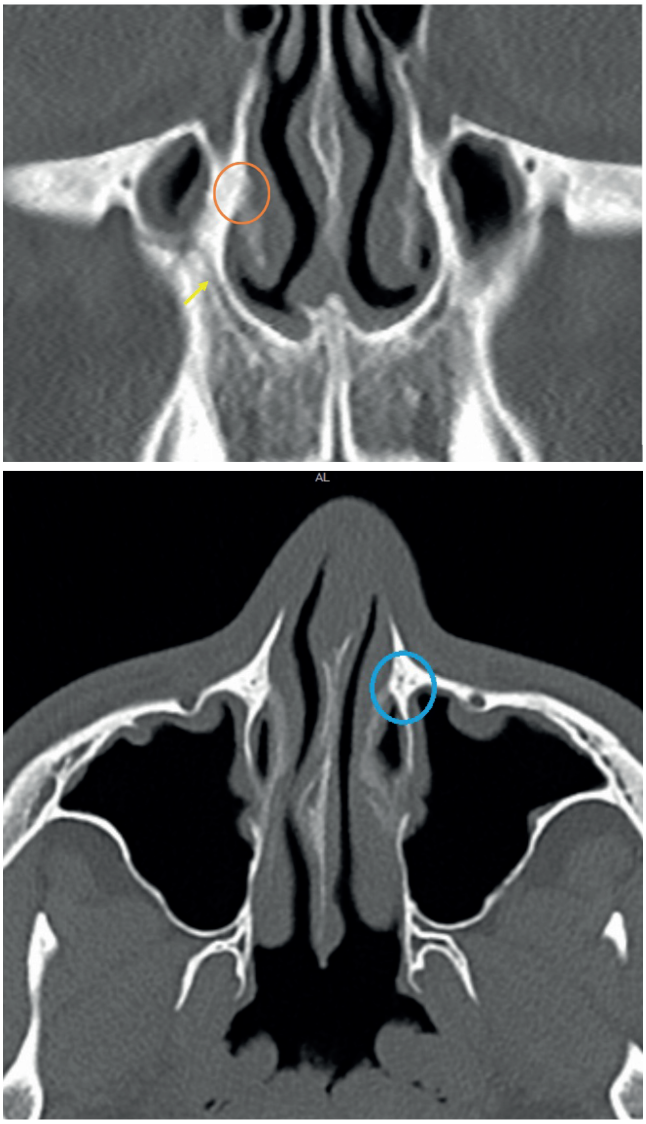

Figure 2. a) Coronal CT depicts the junction of the shoulder of the inferior turbinate with the frontal process of the maxilla (orange circle). The anterior superior alveolar nerve course is defined by the yellow arrow. B) Corresponding axial CT slice of figure 2a, with the blue circle corresponding to the junction of the shoulder of the inferior turbinate with the frontal process of the maxilla.

mm) (Table 1). On the right and left side distances were 6.64 ± 2.301 mm (minimum 2.9 mm, maximum 14,45 mm) and 6.25 ± 2.362 mm respectively (minimum 0,1 mm, maximum 11.57 mm) without any statistical difference between the two sides ($p>0.05$; 0.842) (Table 1, Figure 4a).

The mean relative height of the shoulder in relation to the ASAN canal (distance 2) was 4.78± 2.31 mm (minimum 0.98 mm, maximum 14.28 mm). There was no significant difference between the two sides ($p>0.05$; 0.942) (Table 1, Figure 4b).

The anterior-posterior (AP) distance between the "shoulder" of the inferior turbinate and the pyriform aperture (distance 3) was 6.96± 2.28mm (minimum 2.55 mm, maximum 14.03 mm). There

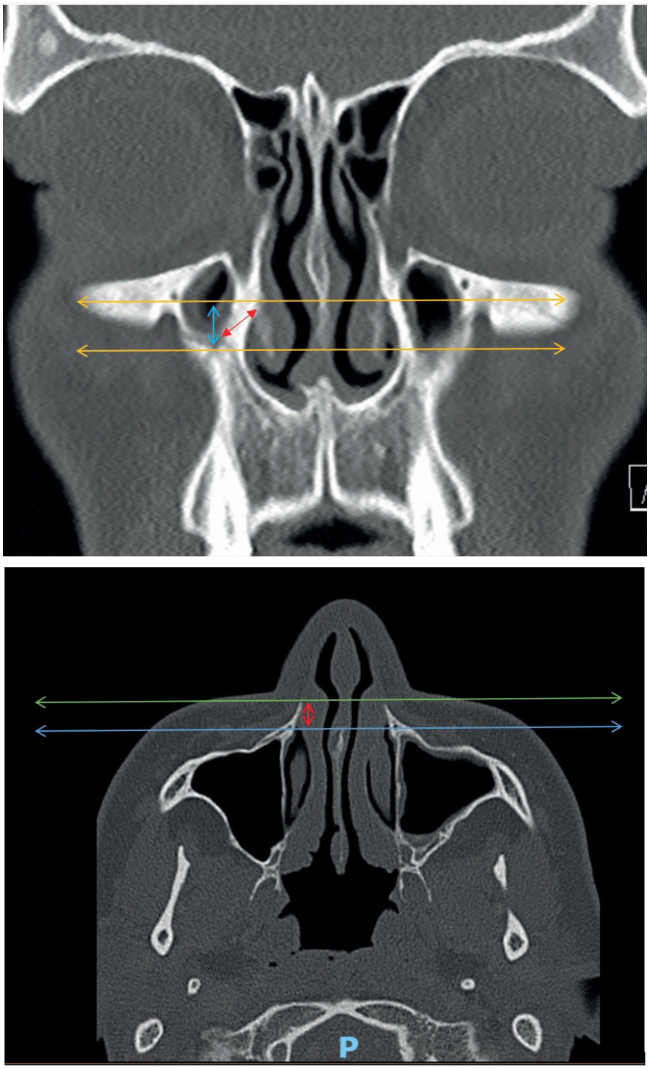

Figure 3. a) Distance 1 (red line): distance from the superior margin of the shoulder of the inferior turbinate to the descending portion of the ASAN; distance 2 (blue line): relative height of the shoulder in relation to the ASAN. This figure shows how the measurement was done on the right side. We repeated the procedure on the left side. b) Distance 3 (red line): The blue line represents a tangential line through the junction of the "shoulder" of the inferior turbinate with the frontal process of the maxilla. Parallel to the blue line, another line was anteriorly drawn through the pyriform aperture (green line). The distance between the blue and green lines was measured – corresponding to the red line. This figure shows how the measurement was done on the right side. We repeated the procedure to the left side in the studied population. Note that Figures 3a and 3b represent the corresponding locations in coronal and axial planes of CT scan, respectively.

was no significant difference between the two sides ($p>0.05$; 0.986) (Table 1, Figure 4c).

Discussion

The ASAN provides sensory innervation of the anterior inferior medial part of the maxilla including the incisors and canine teeth. Its upper branch continues to the margin of the nares, and the lower branch joins the posterior superior alveolar nerve, forming a diffuse plexus. The ASAN is continuous with the superior medial alveolar nerve, with which it forms part of the superior dental plexus and gives off a small branch to the nose. The latter runs through a canal to the side wall of the lower nasal passage (meatus nasi inferior) and supplies the nasal mucosa. Here it communicates with nasal branches of the sphenopalatine ganglion [12].

Von Arx and Lozanof [13] characterized the course of ASAN and found an individually variable course in all specimens supporting the need to perform individual measurements for preoperative planning. The same authors described the course of ASAN with an average distance of 2.8 ± 5.13mm infero-lateral to the infraorbital foramen. After a medial turn, the ASAN courses inferior to the foramen at a mean distance of 5.5 ± 3.07mm. When approaching the nasal aperture, the loop of the ASAN was on average 13.6 ± 3.07mm above the nasal floor.

In our series, the "shoulder" of the inferior turbinate was in average 6.96 mm (2,55 – 14,09 mm) dorsal to the anterior margin of the bony piriform aperture in the axial plane. Knowledge of this distance helps to identify the "shoulder". The bony canal containing the ASAN was 6,45 mm (0,1-14,45 mm) lateral and inferior to the "shoulder" following the bone in the coronal plane and the vertical distance between the shoulder and the ASAN was 4,78 mm (0,98 – 14,28 mm). These measurements demonstrate the close anatomical proximity of the ASAN to the shoulder of the inferior turbinate and explain the significant proportion of patients who have an ASAN injury after surgery in this area.

ASAN damage has an impact on the post-surgical morbidity after approaches to the medial wall of the maxillary sinus. Bertazzoni et al. [14] described hypoesthesia of the anterior superior dental hemi-arch on the operated side as related to ASAN damage with a 29% incidence as the most common long-term sequela in a cohort of patients who had an extended endoscopic maxillectomy. Suzuki et al. [7] presented results that also deserve attention as they describe that 13,7% of patient who

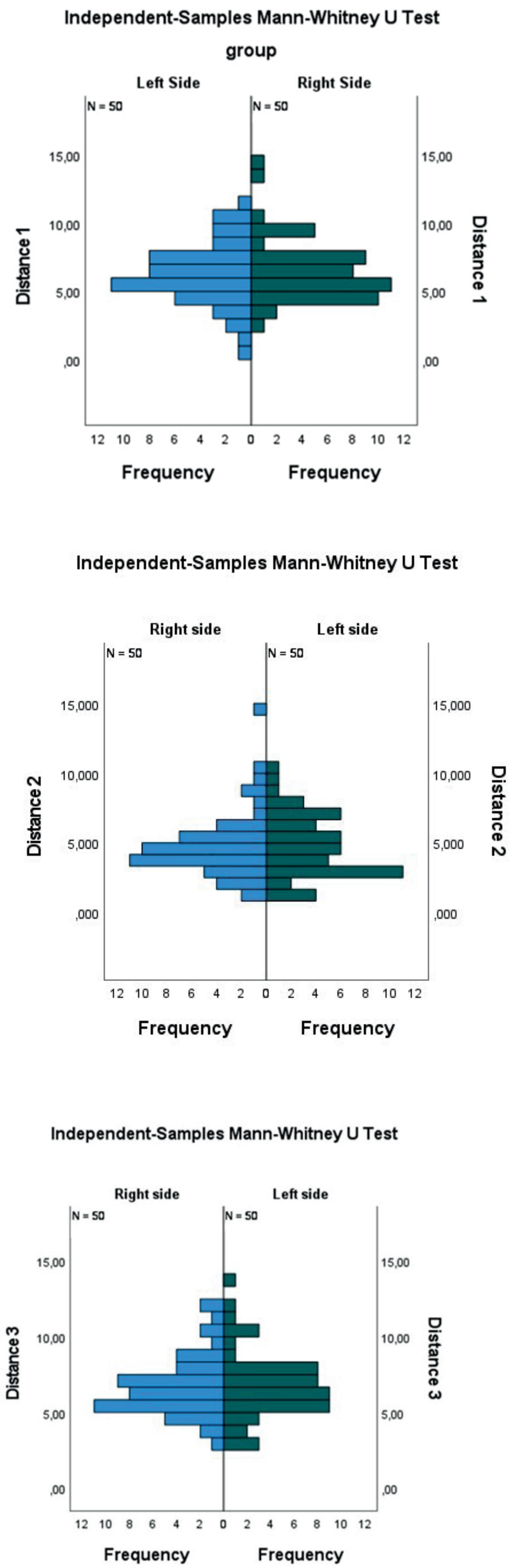

Figure 4. a) Mann-Whitney test results presented in plot. We compared the distance 1 - distance from the superior margin of the shoulder to the descending portion of the ASAN - measured in the right and left side. The distance is measured in millimeters. b) Mann-Whitney test results presented in plot. We compared the distance 2 - relative height of the shoulder in relation to the ASAN - measured in the right and left side. The distance is measured in millimeters. C) Mann-Whitney test results presented in plot. We compared the distance 3 – distance between the junction of the "shoulder" of the inferior turbinate with the frontal process of the maxilla, and pyriform aperture - measured in the right and left side. The distance is measured in millimeters. p=NS.

underwent modified transnasal endoscopic medial maxillectomy through a prelacrimal window approach had hypoesthesia. Injury of the ASAN within the anterior wall of the maxillary sinus causes changes in postoperative somatosensory function after Le Fort I osteotomies, canine fossa puncture or antrostomy (15-18). The identification of ASAN contributes to a reduction of number of patients with facial numbness and facial tingling after dental procedures, and numbness around the upper lip after surgery (19-20).

Given the incidence of postoperative hypoesthesia, the shoulder of the inferior turbinate should be located preoperatively by measuring its distance to the ipsilateral pyriform aperture and determining the distance from the shoulder to the course of the ASAN in the wall of the maxilla. This may help to prevent morbidity after surgery of lateral nasal wall.

All 3 measurements provide knowledge in a three-dimensional way that allows the surgeon to know how best to approach the lateral nasal wall.

Therefore, preoperative assessment of the anatomical relation of the ASAN and clearly define the landmarks is helpful when planning surgery of the anterior third of the medial wall of the maxillary sinus. This analysis is readily performed on the preoperative paranasal sinus CT.

The small distance between the shoulder of the inferior turbinate and the ASAN must be considered when a PLWA or a (modified) medial maxillectomy is performed. The ASAN on the other hand is not at risk when a resection of the inferior turbinate bone is performed medial to the shoulder, for example in PT.

An important finding was the large variation in the distances between these landmarks. This large variation implicates that an individual preoperative CT assessment of the course of the ASAN is mandatory to prevent inadvertent damage to the nerve.

The height of the shoulder of the inferior turbinate from the ASAN can be of clinical importance to address the position of osteotomies when approaching the anterior part of the medial wall of the maxillary sinus.

The surgical implications of this study are based on the finding that the ASAN is near the shoulder of the inferior turbinate. The more anterior and inferior the dissection is performed, the more likely is a lesion of the ASAN. Resection of bone in a PLWA or a medial maxillectomy should be carried out carefully and one can even try to visualize the ASAN to keep it intact, if possible. When the anterior origin of the inferior turbinate is resected (PT), the osteotomy should not include the bone lateral and anterior of the shoulder.

Conclusion

In summary, a preoperative assessment of the course of the ASAN on a CT scan may help to avoid injury of this nerve when performing surgery of the piriform aperture and the anterior medial wall of the maxillary sinus. The shoulder of the inferior turbinate is a useful landmark which can be determined at the CT scan and intraoperative and helps to localize the course of the ASAN.

Authorship contribution

ASM: search, data collection, data analysis, drafting the article, and final approval. DS search, study selection, data collection, revising the article, and final approval. HDB: search, study selection, revising the article, and final approval. BS: data provider, revising the article and final approval.

Conflict of interest

No conflict of interest exists, by any of the authors.

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