Nasolacrimal Canal Morphology With or Without Idiopathic Obstruction in Caucasian Adults: A Multidetector CT Study

Hafize Gokben Ulutas (drgokbenbilek@yahoo.com)
Bursa Yuksek Ihtisas Egitim ve Arastirma Hastanesi https://orcid.org/0000-0002-7961-3664
Bulent Yazici
Uludağ Üniversitesi Tıp Fakültesi: Uludag Universitesi Tip Fakultesi
Emin Ulutas
Uludağ Üniversitesi Tıp Fakültesi: Uludag Universitesi Tip Fakultesi
Zeynep Yazici
Bursa Uludağ Üniversitesi: Bursa Uludag Universitesi

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Abstract

Purpose: To compare the morphological features of the bony nasolacrimal canal (NLC) in Caucasian adults with and without primary acquired nasolacrimal duct obstruction (PANDO).

Methods: The study included one eye each from 38 patients with PANDO and 38 age- and gender-matched controls without PANDO, all of whom underwent multidetector computed tomography. In tomographic images, length, and orientation angles of the NLC, transverse canal diameters at the duct entrance and lower end, and minimum (narrowest) transverse and anterior-posterior canal diameters were measured.

Results: The two groups were similar for NLC length and angulations. The transverse entrance diameter was significantly narrower in the PANDO group (mean, 4.6 mm vs. 5.1 mm) ($p = 0.09$). The narrowest site was most frequently in the middle duct or slightly above the middle in both groups ($p > 0.05$). The minimum canal diameters were significantly smaller in the PANDO group ($p = 0.010$ and $p = 0.003$). When gender subgroups were compared, the significant differences continued for the transverse entrance and minimum diameters in females with PANDO ($p = 0.006$) and for the minimum anterior-posterior diameter in males with PANDO ($p = 0.02$).

Conclusion: Narrowness of the bony NLC may play a role in the etiopathogenesis of PANDO in adult Caucasians.

Introduction

The etiology of primary acquired nasolacrimal duct obstruction (PANDO) has not been fully elucidated; various anatomical, hormonal, environmental, and socioeconomic factors may play a role in the development of inflammatory duct obstruction [1]. The nasolacrimal duct is a narrow structure into which tears are pumped with low pressure. Hypothetically, the bony nasolacrimal canal's (NLC) length, angulation, and lumen diameter may be critical for tear outflow. A relatively long, horizontally inclined, or narrow canal can slow the tear flow and predispose to inflammatory obstruction. The morphology of bony NLC has been previously studied in various radiological or cadaveric studies [2–15]. These studies reported inconsistent results about the dimensions of the NLC and its correlations with variables such as race, age, gender, and the presence of PANDO.

Most previous radiological studies are retrospective and have been performed on subjects without or with an unknown history of lacrimal disease. Conventional computed tomography (CT) images have often been used for canal measurements [6–11]. Few studies have examined the morphology of the NLC in patients with PANDO; all these studies were retrospective [7, 13–15]. This study, for the first time, prospectively compare the NLC morphology in age and gender-matched Caucasian adults with and without PANDO using multidetector computed tomography (MDCT). Unlike conventional CT, reformatted, thin-slice MDCT allows the NLC to be measured in multiple planes and precisely [12].

Methods

For this study, 38 patients with PANDO voluntarily underwent MDCT between January 2010 and March 2016. Patients with a history of sinonasal trauma or surgery, canalicular or partial duct obstruction were excluded. The control group consisted of 38 patients who underwent head MDCT with non-lacrimal indications and had no history of epiphora or craniofacial trauma. These participants did not have any lacrimal abnormality in their examinations, including biomicroscopy and lacrimal irrigation test. Only one eye (right eye) of the patients with bilateral PANDO and the control group was included in the study. Approval was obtained from the institutional ethics committee of Uludag University (2009-7/16) and patients for this study. The tenets of the Declaration of Helsinki were followed.

All scans were performed on a 64 MDCT scanner (Siemens SOMATOM Definition AS +, Erlangen, Germany). The patients were in a supine position and scanned in the axial plane. The area between the upper edge of the frontal sinus and the hard plate was scanned in the PANDO group. The scan range for head CT started at the top of the C1 lamina through the top of the calvarium. The protocol for the PANDO group included the settings of 128 x 0.6 mm collimation, 120 kV tube voltage, 80 eff. mAs, pitch of 0.8, and gantry rotation speed of 1.0 second. The scanning parameters were the same for the control group, except that the eff. mAs was 200. The data constructive slice thickness was 0.75 mm, with an increment of 0.5 mm and bone kernel. The data sets were sent to a workstation (Siemens, Syngo CT Work-place, Erlangen, Germany) and were analyzed with multiplanar image reformatting. The morphological measurements were made by a radiologist blinded to the age and gender of each patient.

The orthogonal coronal and sagittal images of NLC were converted from the acquired axial data. True coronal and sagittal views of the bony NLC were reconstructed through the plane oriented along to the central longitudinal axis of NLC as viewed in the orthogonal sagittal and orthogonal coronal planes, respectively (Fig. 1a). The central longitudinal axis of the NLC was determined to minimize measurement errors that may arise from the posterior and medial angulation of the NLC. The length of the bony NLC was measured on true sagittal images (Fig. 1b). The entrance and distal end levels and the visually narrowest site of the NLC were determined on the sagittal images, and axial views of the NLC at these levels were reformatted in a plane perpendicular to the central longitudinal axis of NLC (Fig. 1c and d). In the orthogonal axial plane, the first and last sections of the canal with a fully bony tubular structure were determined as the entrance and distal end levels of the canal, respectively. The anteroposterior and transverse diameters of the NLC were measured on these axial images (Fig. 1d). The coronal angle of the NLC was defined as the angle between the central longitudinal axis of NLC and the midsagittal line perpendicular to the hard plate on a true coronal image of NLC (Fig. 1e). The sagittal angle of the NLC was defined as the angle between the central longitudinal axis of NLC and the line parallel to the hard plate on a true sagittal image of NLC (Fig. 1f). By drawing these lines, coronal, and sagittal angles of the NLC were automatically calculated in the workstation.

The data of the PANDO group and the control group were compared statistically. Gender subgroups were also compared between the PANDO and control groups to eliminate a potential source of bias. The data were examined using the Shapiro-Wilk test to determine whether they showed a normal distribution. Normally distributed data were compared with an independent-sample t-test. Categorical variables were compared using Pearson's chi-square test. The statistical significance level was set at $p < 0.05$.

It was calculated that the study should include a total of 76 patients, 38 patients in each group, in order to have 80% statistical power and 5% significance level. For this calculation, the effect size for the narrowest NLC transverse diameter was calculated according to the pilot study, where a difference of 0.65 mm was required.

Results

Age and gender distributions of the patients (30 female and 8 male; mean age: 52.2 years) and control subjects (28 female and 10 male; mean age: 51.5 years) were similar ($p = 0.828$, $p = 0.589$) (Table 1). The PANDO and control groups were not significantly different in NLC length and anatomical angulations.

Table 1
The length, angulation, and lumen diameter of the bony nasolacrimal canal measured by multidetector computer tomography in the patient and control groups. Mean ± SD (data range)

Anatomic Parameter	PANDO (n = 38)	Control Group (n = 38)	p* Value
NLC Length (mm)	16.2 ± 2.08 (11–20)	15.2 ± 2.8 (9–22)	0.085
NLC Angle (º)			
Sagittal	70.3 ± 18.7 (52–81)	70.8 ± 7.9 (51–83)	0.805
Coronal	5.3 ± 3.5 (0–16)	4.65 ± 2.9 (0–11)	0.383
Transverse Diameter (mm)			
Duct Entrance	4.6 ± 0.6 (3.2–6.0)	5.1 ± 0.8 (2.9–7.0)	0.009
Lower End	4.8 ± 0.9 (2.8–6.6)	4.9 ± 0.9 (3.3–7.7)	0.703
Narrowest Site			
A-P Diameter	5.7 ± 0.8 (3.7–7.5)	6.4 ± 1.2 (4.0–8.5)	0.010
Transvers Diameter	3.8 ± 0.7 (2.4–5.8)	4.4 ± 0.9 (2.4–7.0)	0.003

NLC: Nasolacrimal canal; PANDO: Primary acquired nasolacrimal duct obstruction; A-P: anterior-posterior.

* Student's *t*-test

The transverse entrance diameter was significantly narrower in the patient group (mean, 4.6 mm vs. 5.1 mm) ($p = 0.009$). The narrowest site was in the middle duct or slightly above the middle in 32 patients (84.2%) and at the canal entrance in 5 patients (13.2%); the two groups were similar for this parameter (p

= 0.589) (Fig. 2). The mean minimum (narrowest) A-P and transverse diameters were significantly smaller in the patient group ($p = 0.010$ and $p = 0.003$) (Table 1).

The NLC measurements of gender subgroups are shown in Table 2. The minimum transverse diameter was significantly smaller in female patients than in female controls ($p = 0.006$). The minimum A-P diameter was narrower in male patients than in male controls. ($p = 0.02$).

Table 2
Anatomical dimensions of the bony nasolacrimal canal in male and female in the patient and control groups. Mean ± Standard deviation (Range).

	Female			Male		
Anatomic Parameter	**PANDO (n = 30)**	**Control (n = 28)**	**p* Value**	**PANDO (n = 8)**	**Control (n = 10)**	**p* Value**
NLC Length (mm)	15.8 ± 2.0 (11–20)	15.2 ± 2.6 (9–19)	0.289	17.6 ± 1.8 (14–20)	15.3 ± 3.3 (11–22)	0.105
NLC Angle (º)						
Coronal	5.8 ± 3.7 (0–16)	5.2 ± 3.0 (1–11)	0.539	3.3 ± 2.1 (1–6)	2.9 ± 2.1 (0–6)	0.645
Sagittal	69.0 ± 9.2 (52–81)	70.6 ± 8.6 (51–83)	0.488	75.3 ± 3.2 (71–81)	71.3 ± 6.0 (58–78)	0.105
Transverse Diameter (mm)						
Duct Entrance	4.6 ± 0.6 (3.2–6.0)	5.0 ± 0.8 (2.9–6.5)	0.032	4.8 ± 0.5 (4.0–5.8)	5.3 ± 0.8 (3.5–7.0)	0.190
Lower End	4.7 ± 0.9 (2.8–6.1)	4.8 ± 0.8 (3.3–6.4)	0.770	5.3 ± 0.9 (4.0–6.6)	5.3 ± 1.2 (3.5–7.7)	0.989
Narrowest Site						
A-P Diameter	5.8 ± 0.8 (3.7–7.5)	6.3 ± 1.3 (4.0–8.5)	0.083	5.5 ± 0.5 (5.0–6.5)	6.5 ± 0.9 (4.5–8.2)	0.020
Transvers Diameter	3.6 ± 0.7 (2.4–5.2)	4.2 ± 0.8 (2.4–5.8)	0.006	4.2 ± 0.8 (3.3–5.8)	4.7 ± 1.1 (3.0–7.0)	0.309

NLC: Nasolacrimal canal; A-P: Anterior-posterior; PANDO: Primary acquired nasolacrimal duct obstruction.

* Student’s *t*-test

The obstructed and patent NLCs of patients with unilateral PANDO were similar in all anatomical parameters ($p < 0.05$).

Discussion

Hypothetically, bony NLC length, angulation-tortuosity, and lumen diameter can affect tear flow and predispose patients to inflammatory congestion. We found 4 cadaveric and 10 radiological studies evaluating bony NLC morphology (Table 3). Six radiological studies included only healthy subjects or subjects with unknown lacrimal disease history. Four studies assessed the NLC in patients with PANDO. Two of these retrospectively compared NLC dimensions on MDCT images in Caucasian individuals with PANDO and healthy subjects [14, 15]. Although suggested to increase the success of dacryocystorhinostomy, CT dacryocystography is not a routine examination method in patients with PANDO [16, 17]. We used CT to examine the NLC anatomy in consenting patients with PANDO.

Table 3
Results of morphological nasolacrimal canal studies in non-PANDO series in the literature.

Study-Year	Method	Lacrimal Disease	Sample Size – Gender	Mean Age (range years)	Anatomic Site	Mean Diameter (range or SD, mm) Transverse	AP	NLC Length (mm)
Takahashi 2011	Cadaver	Unknown	10 F + 19 M	79.5 (61–96)	Duct entrance	5.7	6.9	–
Takahashi, 2013	Cadaver	Unknown	17 F + 12 M	83 (70–99)	Narrowest site	5.6 (5–7)	5.6 (3.5–9)	–
Tao, 2014	Cadaver	Unknown	6F + 14 M	Unknown	Unknown	–	–	13.40 ± 2.68
Ali, 2018	Cadaver	Unknown	6 F + 10 M	76 (59–89)	Duct entrance	5.7 (4–7)	4.7 (4–6)	22.2 (21–24)
Groell, 1997	Conv. CT	No	80 F + 67 M	58 (19–84)	Narrowest site	3.8 (2–7)	–	11.1 (6–21)
Janssen, 2001	Conv. CT	Yes	15 F + 4 M	58 (38–87)	Narrowest site	3.0 (2.0–4.2)	–	–
Shigeta, 2007	Conv. CT	No	112 F + 202 M	49 (8–86)	Duct entrance	5.0 (2.2–8.7)	5.6 (0,4–10,9)	–
Mc Cormick, 2009	Conv CT	Unknown	53 F + 46 M	–	Narrowest site	3.7 (3.5–3.9)	–	–
Lee, 2012	Conv. CT	No	108 F + 120 M	37 (1–86)	Duct entrance	4.5 ± 1.4	6.4 ± 1.8	–
Fasina, 2013	Conv. CT	No	115 F + 286 M	48.5 (16–86)	Narrowest site	3.6	–	–
Ramey, 2013	MDCT	No	36 F + 36 M	59 (?)	Narrowest site	3.8 ± 0.9	-	11.1 ± 2.4
Takahashi, 2014	Conv. CT	Yes	75 F + 26 M	63 (29–90)	Narrowest site	5.1 (2.7–8.6)	6.3 (3.2 – 9.5)	-

Conv. CT: Conventional computer tomography; MDCT: multidetector computer tomography; NLC: nasolacrimal canal; F: female; M: male, SD: standard deviation; mm: milimeter

Study-Year	Method	Lacrimal Disease	Sample Size – Gender	Mean Age (range years)	Anatomic Site	Mean Diameter (range or SD, mm) Transverse	AP	NLC Length (mm)
Estes, 2015	MDCT	Yes	24 F + 11 M	71 (?)	NLC Volume	-	-	-
Bülbül, 2016	MDCT	Yes	24 F + 12 M	60 (?)	Narrowest site	4.1 (3–6.7)	-	11.0 (8.2–13.9)
Current Study	MDCT	Yes	28 F + 10 M	51 (20–79)		4.4 (2.4–7.0)	6.4 (4.0–8.5)	15.2 (9–22)
Conv. CT: Conventional computer tomography; MDCT: multidetector computer tomography; NLC: nasolacrimal canal; F: female; M: male, SD: standard deviation; mm: milimeter								

Previous studies provided a wide variety of data on NLC anatomy and yielded some controversial findings. However, comparisons of these data are difficult due to the methodological differences between these studies (including differences in measurement methods, study designs, race, age, and gender distributions, and anatomical parameters). Cadaveric measurements may be more accurate than radiological measurements. However, the cadaver studies have only been conducted in a small number of elderly population samples with an unknown history of lacrimal disease [2–5]. Most radiological studies were retrospective and examined the nasolacrimal anatomy of non-PANDO subjects using conventional axial CT.[6,8–11] All previous studies, except one[12] do not consider the bias that arose by including both eyes of the same individual in their analysis [2–11, 13–15].

Theoretically, a relatively long canal can create higher resistance to tear outflow. In previous studies, the mean duct length ranged from 11.1 to 22.2 mm in normal Caucasian subjects (Table 3) [5, 6, 12, 15]. A MDCT study [12] examining only the right NLCs of non-PANDO subjects found that the canal was significantly longer in males than in females (mean, 12.3 mm vs. 10.8 mm). Another study using MDCT found that the NLC lengths in the PANDO and control groups were similar (10.5 mm vs. 11.0 mm) [15]. In our study, the mean canal length in normal subjects (15.2 mm) was greater compared to the previous radiological studies (Table 3). The mean canal length in the PANDO group was 1 mm greater, but this difference was statistically insignificant ($p = 0.085$). In assessments with the gender-related subgroups, the mean NLC length was 2.3 mm greater in males with PANDO than in the control group, but this difference did not reach the limit of significance ($p = 0.105$).

Hypothetically, the posterior inclination of the NLC may be significant for tear outflow. In a Japanese conventional CT study, among participants without lacrimal disease, the angle between the bony canal and the nasal floor in sagittal view (sagittal orientation angle) was significantly higher in males (78.7°)

than in females (77.6°), and the angle increased with age [8]. In a Korean conventional CT study, among non-lacrimal patients, the mean canal-floor angle was 63.6°, and there was no difference between genders [10]. However, in that study, 71 of the 228 patients were pediatric, and in patients younger than 10 years of age, the mean duct-floor angle was significantly less (57.3°). In an MDCT study of Caucasian adults, the mean orientation angles in the sagittal view were similar in the PANDO (73.4°) and control (74.5°) groups [15]. The current study supports this observation and suggests that gender-related subgroups were statistically indifferent in NLC angulations (Table 2).

The nasolacrimal duct has a narrow lumen, the tear volume is low, and the impelling force of the lacrimal pump that moves the tears through the canal is weak. Therefore, slight stenosis in the duct lumen can affect tear outflow and cause retention. The narrowest part of the NLC may be the location that creates maximum resistance against tear flow and where the inflammatory stenosis first developed. According to some studies, the narrowest site is at the NLC entrance [3, 6, 13], and in others, it is in the middle [8]. In our study, the narrowest part was mostly slightly below the canal entrance or in the middle. This observation is consistent with the MDCT findings of Ramey et al. in non-lacrimal patients [12].

The narrowest canal diameter is the most frequently studied parameter in literature. In general, radiological canal diameters are smaller than cadaveric measurements. As might be expected, the canal diameters are smaller on conventional axial CT images than on multiplanar reformatted MDCT images, which take into account the oblique course of the canal (Table 3) [6–11]. Previous studies reported controversial results regarding the relationship between minimum canal diameter and variables such as gender, age, race, and PANDO.

In a Japanese study assessing 29 normal cadavers (n = 58 NLCs), the narrowest AP and transverse diameters were frequently (73% and 64%) at the duct entrance [3]. The mean of the narrowest AP and transverse diameters were the same, both 5.6 mm. There was no difference between genders for these dimensions. A study examining 16 adult Caucasian cadavers (n = 20 NLCs) reported a 1-mm difference between the mean transverse (4.7 mm) and AP (5.7 mm) diameters at the canal entrance [5]. In conventional axial CT studies of normal subjects, the mean minimum transverse diameter ranged between 3.5 and 5.0 mm (Table 3) [6–11]. In a Japanese MDCT study, the minimum AP and transverse diameters in 50 normal subjects (n = 100 NLCs) were 6.35 mm and 4.8 mm, respectively [13]. In our study, in 38 normal Caucasian subjects (38 NLCs), these values were 6.4 mm and 4.4 mm, respectively. Therefore, our study does not support that the minimum canal diameter differs in Caucasians and East Asians [9].

The increased prevalence of PANDO in females may be related to morphological differences in the bony NLC. While some studies found the minimum canal diameter to be significantly narrower in females than males [2, 8, 9, 11, 13], others did not confirm this finding [3, 6, 12, 15]. Ramey et al. [12] reported no significant difference in the minimum diameter in 72 non-lacrimal patients between female vs. male and African American vs. Caucasian groups. In a conventional axial CT study, paradoxically, the minimum transverse diameter was larger (4.1 mm vs. 3.7 mm; p = 0.01) in a population group (Pacific people) with a relatively high incidence of DCR than in other populations (Caucasians and Maori) [9].

Four previous studies have compared subjects with and without PANDO for NLC dimensions using CT (Table 3) [7, 13–15]. In a retrospective conventional CT study by Janssen et al. [7] comparing 19 Caucasian patients with PANDO (n = 24 NLCs) with 50 participants (n = 100 NLCs) without epiphora, the mean minimum transverse diameters were 3.0 mm and 3.5 mm in the patient and control groups, respectively (p = 0.001). On the other hand, Takahashi et al. [13] studied CT images of 101 patients with unilateral PANDO and 50 non-lacrimal patients (100 NLCs) in a Japanese population and found no difference in minimum transverse and AP diameters. In that study, the mean minimum transverse diameters were 5.09 mm and 4.80 mm in the PANDO and control groups, respectively. The authors found that the funnel-type NLC, characterized by the duct entrance was the narrowest site, more frequently in the patient group (51% vs. 34%). Two studies examined the anatomy of NLC with MDCT, as in our study [14, 15]. In the study by Estes et al. [14], who retrospectively compared 35 PANDO (n = 70 NLCs) and 35 control patients (n = 70 NLCs), the bony canal volume was significantly larger in female patients than in female controls. The authors conclude that dacryocystocele secondary to the long-term obstruction can lead to enlargement of the bony canal. Bulbul et al. [15] used retrospective comparisons of MDCT data for 39 patients with PANDO and 36 controls and found that the minimum transverse diameter was significantly shorter in the patient group (mean diameter: 3.8 mm vs. 4.1 mm, p < 0.001). The same parameter was also significantly smaller in the present study in the PANDO group (mean diameter: 3.8 mm vs 4.4 mm, 0.003). In our study, other parameters such as the minimum AP and transverse entrance diameters were also measured and found to be significantly shorter in the patient group.

A previous CT study compared gender subgroups in the patient and control group for nasolacrimal canal diameters [14]. There was no difference between the female groups. Surprisingly, the entrance and minimum transverse diameters were found to be significantly wider in male patients. In the current study, the transverse diameters at the entrance and narrowest sites were significantly smaller in females with PANDO than normal females (Table 2). The mean minimum AP diameter was 1 mm narrower in male patients than in normal males, and this difference was also statistically significant (p = 0.020).

In our study, the narrowest part of the nasolacrimal canal had an oval shape with a longer AP distance in all samples in both the control and patient groups. Although the minimum transverse duct diameter was very narrow (2.4 mm), there was an exceptional case with a patent nasolacrimal duct. Other radiological studies have also reported normal subjects with a minimum transverse diameter ranging from 1.5 to 3 mm [6–8, 13, 15]. It would be interesting to investigate whether an idiopathic, inflammatory obstruction would develop in such a narrow canal over time.

In conclusion, this study suggests that bony canal stenosis may play a role in PANDO development. It has strengths such as prospective planning, meticulous sample selection, dedicated imaging, and sensitive and standard measurement techniques for the NLC. However, the small sample size remains an important limitation.

Declarations

Declaration of conflicting interests

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Data availability statement

The data that support the findings of this study are available from the corresponding author [HGU], upon reasonable request.

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Figures

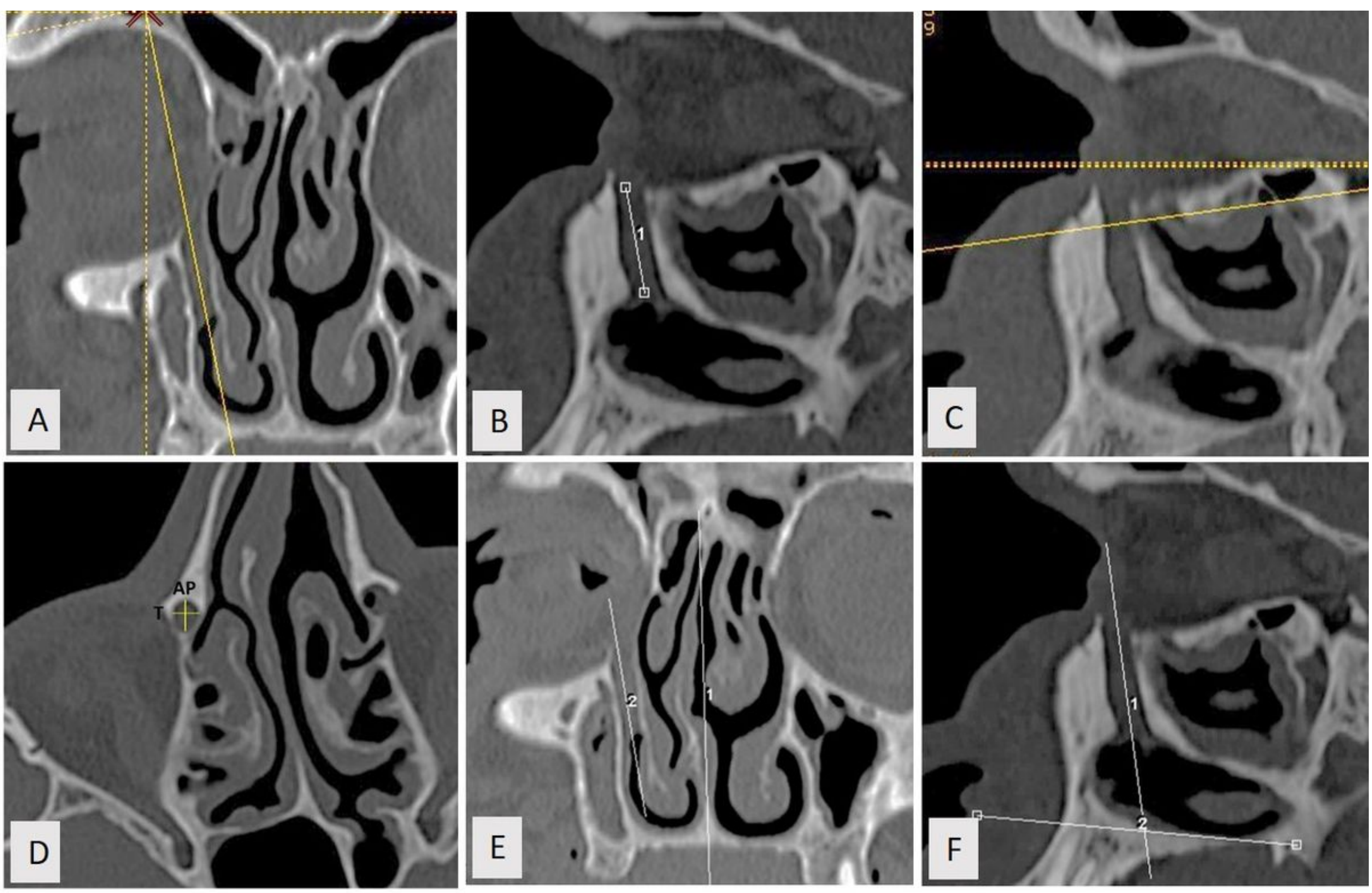

Figure 1

Techniques for measurements of bony NLC dimensions on CT scan. A. On the orthogonal coronal view, a plane (solid line) is adjusted to the central longitudinal axis of the canal. B. True sagittal view of the NLC is reconstructed in this plane. The length of NLC is measured. C. The narrowest site is visually determined on the sagittal image. D. Axial view of the NCL at this level was reformatted in a plane (solid line, C) perpendicular to the longitudinal axis of NLC. The anteroposterior and transverse diameters are measured. E. Coronal angle of the NLC is measured between the central longitudinal axis of NLC and the midsagittal line perpendicular to the hard plate on a true coronal image of NCL. F. Sagittal angle of the NLC is measured between the central longitudinal axis of NLC and the line parallel to the hard plate on a true sagittal image of NLC.

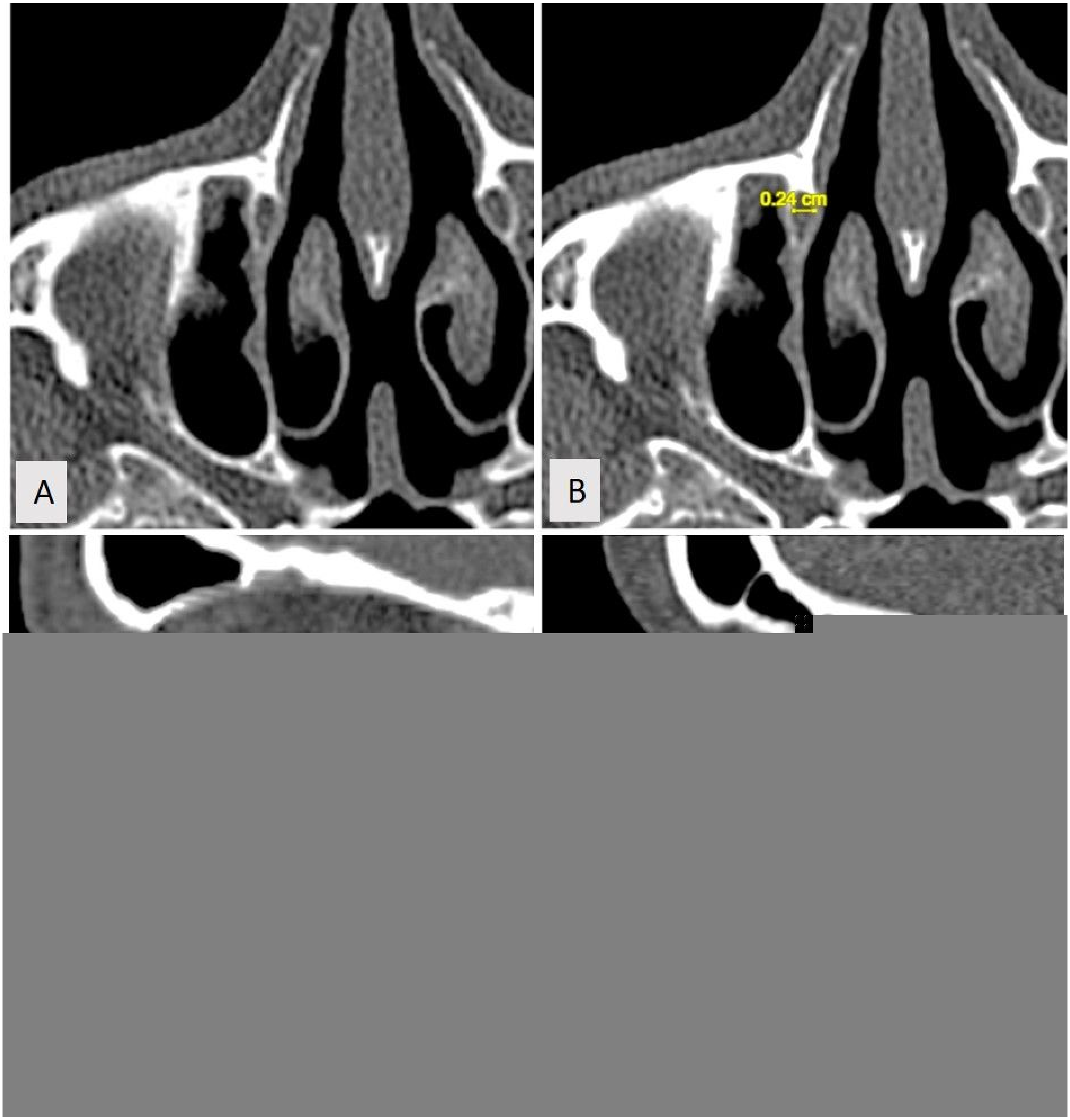

Figure 2

Axial CT views of the narrowest site of the right NLC without (A) and with (B) the measurement. C and D, Sagittal reformatted CT views showing the visually narrowest site at the canal entrance (arrow, C) and in the middle of the canal (arrow, D).