

Surgical Anatomy of Nasolacrimal Duct and Sac in Human Cadavers

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ABSTRACT

Background: Surgical importance of the nasolacrimal duct (NLD) for both otolaryngologists and ophthalmologists cannot be overemphasized. Injury to this structure can lead to iatrogenic epiphora, synechiae formation and need for secondary lacrimal diversion procedures.

Materials and methods: The present study was conducted on 27 mid-sagittal sections of head and neck of formalin fixed adult cadavers. The inferior opening of the NLD was identified and exposed. The duct and the lacrimal sac were dissected. Pertinent distances of the inferior opening of the NLD from the easily identifiable surgical landmarks were recorded, so as to accurately locate the inferior opening of the duct using a digital vernier calliper (accuracy 0.02 mm, Mitutoya, Japan). Various dimensions and angulation of the duct and lacrimal sac were measured.

Results: The average length of NLD was 11.42 ± 2.45 mm and it was making an angle of 20° with the vertical plane. The duct was narrowest in caliber in its upper 1/3rd in majority (82%) of the cases. The average diameter of the inferior opening of the NLD was 3.14 mm. In two cases (7.4%), the opening was only 1.8 mm wide. The mean distance of the inferior opening of the duct was 20.7 mm from the columella, 25.5 mm below the skull base and 16.5 mm above the hard palate. The average distance between the inferior opening of the NLD and anterior end of the inferior turbinate was 14.8 mm. The mean A-P diameter of superior opening of NLD was about 3 mm. The average length and width of nasolacrimal sac at its center was 6.95 and 3.24 mm respectively.

Conclusion: Detailed anatomical knowledge of the NLD is of great importance for safe and successful endonasal surgery. The present study attempts to provide useful surgical guidelines by using anatomic and positional relationships between the NLD and the major surrounding landmarks.

Keywords: Nasolacrimal duct, Nasolacrimal sac, Surgical anatomy, Cadavers.

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INTRODUCTION

Nasolacrimal duct obstruction (NLDO) manifesting with epiphora is a common ophthalmic condition.¹ The obstruction can be congenital, most commonly resulting from a persistent membrane at the valve of Hasner;² or acquired, which could be classified as primary or secondary.³ During probing and silicone intubation, the probe may enter the orbit or may lead to false passage formation. However, in patients with an obstruction below the canal entrance, the risk of false passage formation is lower because the obstruction point is surrounded by the bony canal.⁴ This signifies the importance of knowing diameter of canal at different points.

For nearly a century the gold standard treatment for epiphora and nasolacrimal duct obstruction has been dacryocystorhinostomy (DCR). Success rates of endonasal dacryocystorhinostomy should be measured and compared using strict outcome criteria taking in account both functional and anatomical success and an adequate length of follow-up.⁵ Surgeons must confirm the obstruction site with dacryocystography before performing these procedures.

The opening of the nasolacrimal duct (NLD) can also be involved in surgeries of the inferior turbinate and nasal floor, detailed anatomical knowledge of NLD and nasolacrimal sac thus becomes important during these procedures. The current study was designed to provide the anatomical and morphometric measurements of the nasolacrimal system, so that data can be used as a guideline in surgical and radiological procedures.

MATERIALS AND METHODS

Twenty-seven mid-sagittal sections of head and neck of formalin fixed adult cadavers present in the Department of Anatomy, PGIMER, Chandigarh, were studied. None of the cadavers had a history of lacrimal, orbital, maxillofacial, or nasal surgery or trauma. The nasal septum was removed and the inferior and middle

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turbinates were reflected and fixed. The inferior opening of the NLD was identified and exposed.

The duct and the lacrimal sac were dissected. Dimensions of the duct and lacrimal sac were noted using a digital vernier calliper (accuracy 0.02 mm, Mitutoya, Japan). Following measurements were recorded:

1. Inferior opening of NLD
 - i. A-P diameter
 - ii. A-P distance of the inferior opening to the limen nasi, parallel to nasal floor (Fig. 1).
 - iii. A-P distance of the inferior opening to anterior end of the inferior turbinate (Fig. 1).
 - iv. Vertical distance of the inferior opening to floor of nasal cavity (Fig. 1).

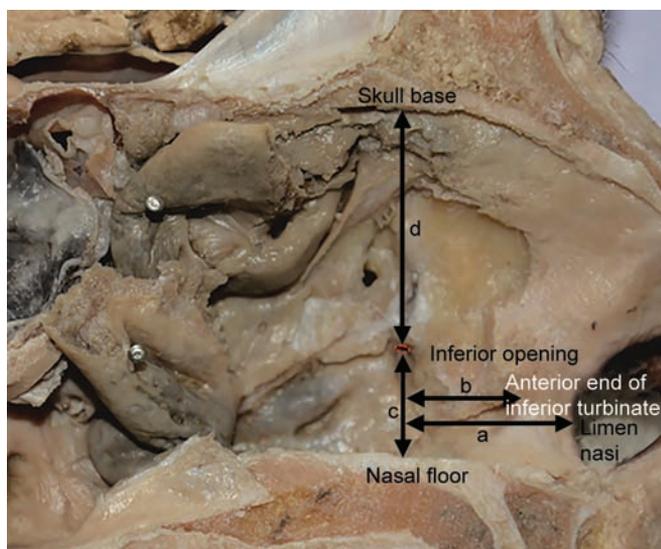


Fig. 1: Distance of the inferior opening of NLD (a) A-P distance parallel to nasal floor of the inferior opening to the limen nasi (b) A-P distance of the inferior opening to anterior end of the inferior turbinate (c) vertical distance of the inferior opening to floor of nasal cavity (d) vertical distance of the inferior opening to base of skull

- v. Vertical distance of the inferior opening to the base of skull (Fig. 1).
2. Angle of longitudinal axis of NLD with vertical plane: Using protractor (Fig. 2).
3. Length of NLD (Fig. 3) — Afterwards deroofing of the NLD was done and following were noted:
4. A-P diameter of the superior opening of NLD
5. Along the length of NLD
 - i. Narrowest A-P diameter
 - ii. Distance of narrowest A-P diameter from the superior opening.
6. Nasolacrimal sac (excluding the dome) (Fig. 4).
 - i. Length of the sac from its medial visible borders (Fig. 4).

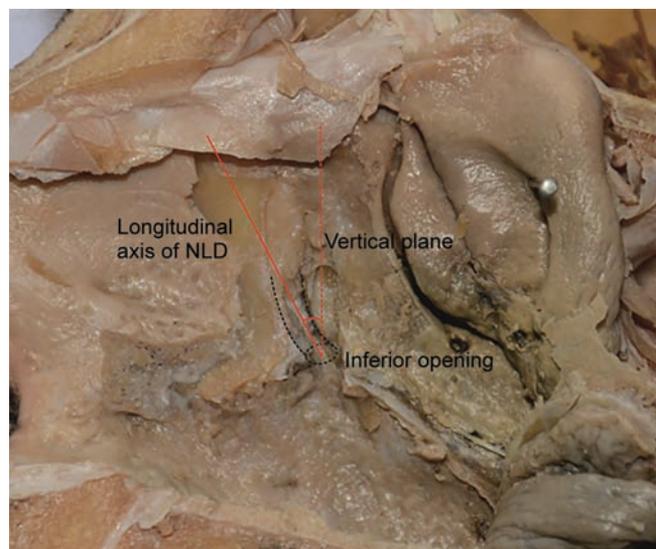


Fig. 2: Angle of longitudinal axis of NLD with vertical plane

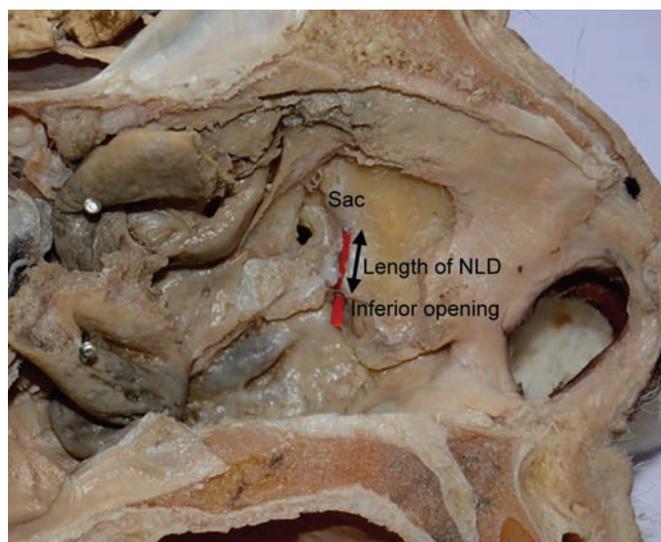


Fig. 3: Length of NLD

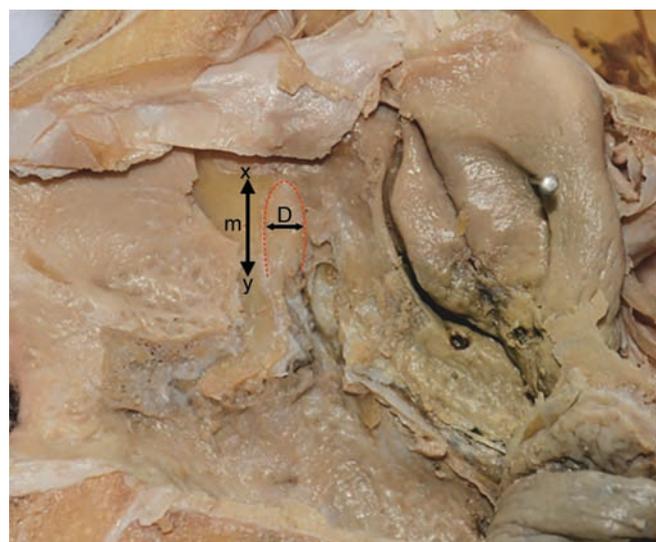


Fig. 4: Nasolacrimal sac (excluding the dome), x-y: Length of sac from its medial visible borders; D: A-P diameter of sac at mid-point; m: length of the sac

Table 1: Measurements of nasolacrimal duct and sac

	Nasolacrimal duct											
	Inferior opening						Superior opening	Narrowest point	Nasolacrimal sac			
	Distance (mm) from								Diameter (mm)	Diameter (mm)	Distance from superior opening (mm)	Length (mm)
	Diameter (mm)	Limen nasi	Nasal cavity floor	Skull base	Anterior end of inferior turbinate	Angle (°)	Length (mm)	Diameter (mm)				
Mean	3.14	20.66	16.48	25.25	14.78	18.93	11.42	2.93	1.96	3.33	6.95	3.24
SD	0.79	2.96	2.67	3.94	2.92	7.30	2.45	0.56	0.56	1.48	0.77	0.78
Minimum	1.75	16.73	12.59	15.36	6.67	5.00	8.23	2.22	1.00	0.00	5.42	1.86
Maximum	4.68	28.49	23.83	30.9	20.64	33.00	18.16	4.77	2.99	7.16	8.9	5.14

- ii. A-P diameter of sac at mid-point (m) of the length of sac (Fig. 4).

RESULTS (TABLE 1)

The average length of NLD was 11.42 ± 2.5 mm (8.2-18.2 mm) and in majority (81%) it was about 1 cm. In 3 out of 27 cadavers (11%) the length of NLD was more than 16 mm. Longitudinal axis of the NLD was making mean angle of $18.9^\circ \pm 7.3^\circ$ (5° - 33°) with the vertical plane.

The mean minimum diameter of the NLD was 1.96 ± 0.6 mm (1.0-3.0 mm) and it lies at an average distance of 3.33 ± 1.5 mm (0.0-7.2 mm) from the superior opening. The duct was narrowest in caliber in its upper 1/3rd in majority of the cases and in only one cadaver the narrowest diameter was at the entrance of the NLD. It was noted that in 6 cadavers (22%) the narrowest diameter was less than 1.5 mm, which can also be as small as ~1 mm (15%).

The diameter of inferior opening is from 2 to 4 mm with an average of 3.14 ± 0.8 mm (1.8-4.7 mm) and in two cases (7.4%), the opening was only 1.8 mm wide.

The mean A-P distance (parallel to nasal cavity) of the inferior opening from limen nasi was 20.7 ± 2.96 mm (16.7-28.5 mm). Vertically inferior opening was located 25.5 ± 3.9 mm (15.4-30.9 mm) below the skull base and 16.5 ± 2.7 mm (12.59-23.83 mm) above the floor of nasal cavity. So in huge majority the inferior opening was situated 2 to 3 cm (88.9%) below the base of skull, 1 to 2 cm (92.6%) above the floor of nasal cavity and 2 to 3 cm (100%) posterior to limen nasi. The average A-P distance between the inferior opening of the NLD and anterior end of the inferior turbinate was 14.8 ± 2.92 mm (6.7-20.5 mm).

The mean A-P diameter of superior opening of NLD was about 3.3 ± 0.6 mm (2.2-4.8 mm). The average length and width of nasolacrimal sac at its center was 6.95 ± 0.8 mm (5.4-8.9 mm) and 3.24 ± 0.78 mm (1.9-5.1 mm) respectively.

DISCUSSION

Injury to nasolacrimal system can lead to iatrogenic epiphora, synechia formation and need for secondary

lacrimal diversion procedures so knowing the detailed anatomical details of this becomes increasingly important for both otolaryngologists and ophthalmologists. In the present study, average length of NLD was 11.42 ± 2.45 mm (8.23-18.16 mm). Majority (81%) had length of about 1 cm. In Korean cadavers Kim et al⁶ found it to be 16.8 ± 2.4 mm (11.8-21.2 mm). In another study on neolithic skulls length comes to be somewhat shorter among American colored males than white males.⁷ During cannulation of NLD from above or from inferior opening, length becomes important in selecting the probe length so as not to injure the surrounding viscera.

In the present study, the NLD was making an angle of $18.9^\circ \pm 7.3^\circ$ (5° - 33°) with the vertical plane. Takahashi et al⁸ in Japanese cadavers after exposing the posterior halves of the lacrimal fossa (LF) and the bony nasolacrimal canals (BNLC) measured the mean angles of the longitudinal axes of the LF and the BNLC relative to the sagittal line which were 11.9° and 0.1° respectively. In the Japanese study the sagittal plane was the A-P plane while in the present study angle was measured with the vertical plane. In CT evaluation study on Japanese patients, the mean value of the angle between the bony canal and the nasal floor was 78.3° ,⁹ from this angle between the NLD and vertical can be deduced which comes to be 11.7° which is comparable with our study.

A larger bending in the lacrimal passage may cause tear flow stagnation and debris accumulation, resulting in primary acquired nasolacrimal duct obstruction.¹⁰ During probing and intubation, a false passage occasionally occurs at the junction of the lacrimal fossa and the bony nasolacrimal canal¹¹ but lowerdown where the NLD is surrounded by bone the incidence is much less. Together, the results of the present study and previous studies^{8,9} suggest that knowledge of angle is important for preventing rupture of most vulnerable structures by the curved tip of malleable probe.

In the present study, the mean minimum A-P diameter of the NLD was 1.96 ± 0.56 mm (1-3 mm). We found that it can be as small as ~1 mm (11%) which should be considered while selecting the probe size. Takahashi et al¹²

measured this diameter to be 5.6 mm after removing the mucosal wall of the nasolacrimal duct in Japanese cadavers which is higher than the present study, this may be due to the fact that in the present study mucosal wall was intact in the canal during measurements.

In a case series evaluating racial differences by Yong et al¹³ in facial or orbital CT scans using three-dimensional image software the minimum nasolacrimal duct diameter in Asians which were divided into 'group 1' (mongoloid features namely Southeast Asians (SEA), including Chinese, Vietnamese, Malay, Indonesian) and 'group 2' (Caucasianoid features namely South Asians (Indian, Bangladeshi and Pakistani) and Occidental races) were 3.82 ± 0.90 mm and 3.54 ± 1.02 mm respectively. They found NLD diameter was significantly narrower in people with narrower faces and this is the fact that the patients with Caucasianoid features had significantly narrower faces and are more predisposed to NLD obstruction.¹³ In Nigerian population it was found to be 3.52 mm (± 0.69 mm) and 3.36 mm (± 0.64 mm) in male and female patients respectively by CT scans.¹⁴ Janssen et al¹⁵ by using axial CT measured NLD diameter to be 3.5 mm in the control group and 3.0 mm in the patient group (primary acquired nasolacrimal duct obstruction) which was significantly smaller than that in the control group and postulated that the smallest diameter of the bony canal is most relevant for ascertaining the origin of the obstruction of the lacrimal drainage system due to swelling of the mucosa. On the contrary McCormick and Sloan,¹⁶ in a multiracial group study suggested that nasolacrimal canal diameter may not be a major factor for lacrimal drainage obstruction. They found no differences in narrowest NLD diameter between Caucasians and New Zealand Maoris (3.7 mm), but the narrowest NLD was significantly wider in the Pacific race (4.1 mm) compared with the above groups.

On analyzing our results the minimum A-P diameter is 2 to 3 mm in 74% of cases which is comparable to above-mentioned reports. So as to prevent complication, narrowest point and its location is important where one can encounter maximum resistance. In the present study it was found that the duct was narrowest in caliber in its upper 1/3rd in majority of the cases (82%). The average distance of the point with narrowest caliber from the superior opening was 3.33 ± 1.48 mm (0.0-7.16 mm) and, in only one case, it was at the superior opening of the canal, while in Japanese cadavers, in 32 of 44 canals (72.7%) it was at the entrance to the canal and, in the rest, it was located at an average of 3.6 mm from the entrance.¹² Groell et al¹⁷ reported it to be located in the middle or upper part of the canal, while Groessl et al¹⁸ showed that the narrowest point was located 3 mm inferior to the canal

entrance. All these are comparable with our study. These may be explained by the great variety of measurement methods used, racial differences and possibly by a wide range in normal diameters (1 to 3 mm in our study). It was believed that direct analysis in cadavers is a more accurate measurement of the morphologic and morphometric parameters of the bony nasolacrimal canal.¹⁰

A clinical study of the incidence of nasolacrimal duct obstruction in different races will be necessary to prove this theory. It is not just the diameter but the angle of bony nasolacrimal canal may also play an important role in the occurrence of NLD obstruction.¹³ The smallest diameter of the bony canal appears to be the most relevant measure for ascertaining the origin of an obstruction of the lacrimal drainage system due to swelling of the mucosa or for choosing a balloon diameter for performing dacryocystoplasty.¹⁵

The diameter of inferior opening is from 2 to 4 mm with an average of 3.14 ± 0.79 mm (1.8-4.7 mm). In two cases (7.4%), the opening was only 1.8 mm wide. In a study on neolithic skulls by Post⁷ measurements of the external opening of the tear duct of American colored males and white males indicate larger apertures among the former at corresponding ages.

The mean A-P distance of the inferior opening from limen nasi parallel to nasal cavity was 20.7 ± 2.96 mm (16.7-28.5 mm). In a cadaveric study of diverse ethnic backgrounds (Caucasian, African-American and Asian), the mean distance from the alar rim to the NLD at the level of maxillary ostium was 43.05 ± 4.76 mm on the right and 41.25 ± 4.56 mm on the left.¹⁹

Vertically, inferior opening was located 25.5 ± 3.9 mm (15.4-30.9 mm) below the skull base and 16.5 ± 2.7 mm (12.59-23.83 mm) above the floor of nasal cavity. In cadavers of Korean descent, it was 10.7 ± 2.7 mm above the floor of the nasal cavity.⁶ All these measurements are from surgically easily identifiable landmarks. This data should aid the surgeon per operatively to easily locate the inferior opening of NLD. In huge majority the inferior opening was situated 2 to 3 cm (88.9%) below the base of skull, 1 to 2 cm (92.6%) above the floor of nasal cavity and 2 to 3 cm (100%) posterior to the limen nasi. The average A-P distance between the inferior opening of the NLD and anterior end of the inferior turbinate was 14.8 ± 2.92 mm (6.7-20.5 mm).

The mean A-P diameter of superior opening of NLD was about 3.3 ± 0.6 mm (2.2-4.8 mm). In one of our case, we found that the superior opening was the narrowest point of nasolacrimal system. In a cadaveric study on Japanese by Takahashi et al,²⁰ they measured it in all subjects, men, and women and values were found to be 6.9, 6.8 and 7.2 mm respectively, which is higher than the present study. This

may be due to the fact that in the present study mucosal wall was not removed before measurements.

The average length and width at center of the nasolacrimal sac was 6.95 ± 0.77 mm (5.42-8.9) and 3.24 ± 0.78 mm (1.9-5.1 mm) respectively. The knowledge of these average dimensions of nasolacrimal sac would provide the clinician and radiologist with baseline data for comparison.

This study provides valuable data for surgical success of external and endo-dacryocystorhinostomy techniques. The limitation of the present study was small sample size.

CONCLUSION

Detailed anatomical knowledge of the NLD is of great importance for safe and successful endonasal surgery. The present study attempts to provide useful surgical guidelines by using anatomic and positional relationships between the NLD and the major surrounding landmarks. The length of the NLD in majority of specimens (81%) was about 1 cm. The diameter of inferior opening was from 2 to 4 mm. Point of minimum A-P diameter was present in upper 1/3rd of the canal, about 3 mm from the superior opening and the diameter at this point in majority (74%) was 2 to 3 mm. The narrowest A-P diameter of the NLD can be as small as ~1 mm (11%) which should be considered while selecting the probe size. In huge majority, the inferior opening was situated on an average 2 cm below the base of skull, 2 cm above the floor of nasal cavity and 2 cm posterior to limen nasi.

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