Original Article

Anatomic study of the lacrimal fossa and lacrimal pathway for bypass surgery with autogenous tissue grafting

Hai Tao, Zhi-zhong Ma[1], Hai-Yang Wu, Peng Wang, Cui Han

Purpose: To study the microsurgical anatomy of the lacrimal drainage system and to provide anatomical evidence for transnasal endoscopic lacrimal drainage system bypass surgery by autogenous tissue grafting. **Materials and Methods:** A total of 20 Chinese adult cadaveric heads in 10% formaldehyde, comprising 40 lacrimal ducts were used. The middle third section of the specimens were examined for the following features: the thickness of the lacrimal fossa at the anterior lacrimal crest, vertical middle line, and posterior lacrimal crest; the cross section of the upper opening, middle part, and lower opening of the nasolacrimal canal; the horizontal, 30° oblique, and 45° oblique distances from the lacrimal caruncle to the nasal cavity; the distance from the lacrimal caruncle to the upper opening of the nasolacrimal duct; and the included angle between the lacrimal caruncle–nasolacrimal duct upper opening junction and Aeby's plane. **Results:** The middle third of the anterior lacrimal crest was significantly thicker than the vertical middle line and the posterior lacrimal crest ($P > 0.05$). The horizontal distance, 30° oblique distance, and 45° oblique distance from the lacrimal caruncle to the nasal cavity exhibited no significant differences ($P > 0.05$). The included angle between the lacrimal caruncle and the lateral wall middle point of the superior opening line of the nasolacrimal duct and Aeby's plane was average (49.9° ± 1.8°). **Conclusion:** The creation of the bony tunnel should start from the middle or posterior middle part of the lacrimal fossa, extending toward the anterior inferior region with an optimal downward oblique angle of 45°.

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Severe superior and inferior lacrimal canaliculi obstruction accompanied by lacrimal sac defects or atrophy and congenital nasolacrimal duct obstruction or dacryostenosis remain a focus of interest in ophthalmology.[1] Several methods, including free skin transplantation,[2] vein grafting,[3] and buccal mucous membrane,[4] have been employed for lacrimal drainage system bypass surgery. However, patients have difficulty accepting such methods because they require facial skin incisions, which causes great injury and the subsequent surgical scars. We applied endoscopic transnasal lacrimal drainage bypass surgery by grafting autogenous tissues and achieved preliminary results.[1] A total of 40 lacrimal ducts from 20 adult cadaveric heads were used for anatomic observation and measurements to obtain anatomic data for developing a novel surgical method.

Materials and Methods

A total of 20 adult cadaveric heads in 10% formaldehyde (14 males and 6 females), comprising 40 lacrimal ducts were obtained. These specimens were harvested from voluntarily donated cadavers. The experimental protocol was in accordance with ethical standards.[5]

The cadaveric heads were split along a line between the superior border of the superciliary arch and 10 mm above the occipital tuberosity. After removing the brain tissue, the heads were decalcified for approximately one week in 10% nitric acid to facilitate surgical cutting without altering the morphologic structure. Following dissection of the facial cranium at the median sagittal plane, the nasal septum was excised to expose the lateral wall of the nasal cavity. The anatomy was observed under an ophthalmic operating microscope (Topcon, Japan). Measurements were conducted using conimeters and a sliding caliper (0.02 mm precision).

Profiles of the lacrimal sac were traced on the lateral wall of the nasal cavity. The shape, length (distance between the dacryon point and upper opening of the nasolacrimal canal), anteroposterior diameter (largest distance between the anterior lacrimal crest and posterior lacrimal crest), and depth of the lacrimal fossa were determined.

The internal wall of the lacrimal fossa was divided into the top third, the middle third, and the bottom third. The thickness of the lacrimal fossa at the anterior lacrimal crest, the vertical middle line, and the posterior lacrimal crest were also measured. The morphology, length, thickness of the internal wall at three sections (upper opening, middle part, and lower opening), and the long and short diameters at three sections of the osseous nasolacrimal canal were determined. The cross section of each part of the osseous nasolacrimal canal was calculated according to the formula, $S = \pi ab$, where S indicates the elliptical area and a and b indicate one-half of the long and short diameters, respectively.

Three straight lines were traced, each passing through the perpendicular bisector of the lacrimal fossa. The included angles of the three lines and Aeby's plane were 0°, 30°, and 45°, respectively. The horizontal, 30° oblique, and 45° oblique distances from the lacrimal caruncle to the nasal cavity and from the lacrimal caruncle to the lacrimal sac were measured separately.

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The distance from the lacrimal caruncle to the upper opening of the nasolacrimal canal, and the included angle between the lacrimal caruncle–nasolacrimal canal upper opening junction and Aeby's plane were also determined.

Blood vessel distribution in the region between the middle and lower parts of the lacrimal fossa and the lateral wall of the nasal cavity was observed.

The first, second, and third authors designed the present study. The first author anatomized the specimens and evaluated the experimental data.

Statistical analysis was performed by the first author using SPSS 14.0 software via *F* and *Q* tests.

Results

A protuberant "bony crest" is located in the atrium of the middle meatus, which vertically coursed and corresponded to the anterior lacrimal crest, and could therefore be used as a projective marker for the anterior lacrimal sac on the lateral wall of the canal cavity. The posterior lacrimal crest corresponded to the base of the uncinate process on the lateral wall of the nasal cavity. Therefore, the base of the uncinate process could be used as a projective marker for the posterior lacrimal sac on the lateral wall of the nasal cavity. The anterior inferior border of the attachments of the agger nasi and middle nasal concha could be used as a projective marker for the superior lacrimal sac. The anterior superior border of the attachments of the inferior nasal concha could be taken as a projective marker of the inferior lacrimal sac. The entire projections of the lacrimal sac and nasolacrimal duct are shown in Fig. 1.

The distance between the base of the nasal columella and the bottom of the lacrimal sac was 33.24 ± 3.56 mm, and that between the base of the nasal columella and the top of the lacrimal sac was 45.27 ± 4.67 mm. The included angle between the nasal columella base–lacrimal sac junction and Aeby's plane was 48.04° ± 3.88°, whereas that between the nasal columella base–lacrimal sac junction and Aeby's plane was 66.02° ± 4.62°.

The distance from the base of the nasal columella to the anterior uncinate process was 35.74 ± 3.56 mm. The posterior part of the uncinate process had a semilunar hiatus [Fig. 2]. The frontal sinus and the opening of the anterior ethmoid sinus were located in front of the semilunar hiatus, whereas the opening of the maxillary sinus was behind the semilunar hiatus.

The anterior lacrimal crest was solid, whereas the posterior lacrimal crest was fragile. The lamina papyracea was behind the posterior lacrimal crest. The lacrimal fossa was semifunnel shaped, and its inferior border was connected with the superior opening of the nasolacrimal duct [Fig. 3].

The length, anteroposterior diameter, and depth of the lacrimal fossa were 17.85 ± 1.72 mm, 6.74 ± 1.28 mm, and 3.09 ± 0.78 mm, respectively. The thicknesses of the internal wall of the lacrimal fossa at the anterior lacrimal crest, perpendicular bisector, and posterior lacrimal crest are shown in Table 1.

Sclerotin thickness differed significantly between the perpendicular bisector of the lacrimal fossa and the posterior lacrimal crest at each third section (top third, middle third, and bottom third; *F* test, $P < 0.05$). The middle and posterior middle part of the lacrimal fossa were the thinnest areas of the lacrimal fossa.

The superior opening of the osseous nasolacrimal duct was connected with the lacrimal fossa, and its inferior opening was joined with the nasal cavity. Both superior and inferior openings were nearly round or oval [Figs. 3 and 4].

The length of the osseous nasolacrimal duct was 13.40 ± 2.68 mm. The thicknesses of the internal wall of nasolacrimal duct were 1.17 ± 0.48, 0.76 ± 0.39, and 0.40 ± 0.22 mm at the top third, middle third, and bottom third parts, respectively. The inferior opening of the osseous nasolacrimal duct was the largest, followed by the superior opening and the middle part [Table 2].

The horizontal, 30° oblique, and 45° oblique distances from the lacrimal caruncle to the nasal cavity differed significantly ($P < 0.05$). The 30° oblique distance from the lacrimal caruncle to the nasal cavity was the smallest. No significant difference was found between the horizontal distance and 45° oblique distance from the lacrimal caruncle to the nasal cavity ($P > 0.05$). The horizontal and oblique distances from the lacrimal caruncle to the nasal cavity are listed in Table 3.

The distance from the lacrimal caruncle to the midpoint of the lateral wall of the nasolacrimal duct superior opening was 11.86 ± 1.84 mm with a 9.58-13.5 mm range. The included angle between the lacrimal caruncle–nasolacrimal duct superior opening lateral wall junction and Aeby's plane averaged 49.9° ± 1.8°, with a 48.0° to 54° range.

The horizontal and oblique distances from the midpoint of the lateral border of the lacrimal caruncle to the lacrimal sac are shown in Table 4.

The anterior ethmoidal artery originates from the ophthalmic artery and travels to the eye socket through the anterior ethmoidal foramen [Fig. 5]. It then twists in the cerebral cranium through the anterior ethmoid canal and enters the nasal cavity through the minipores on both sides of anterior crest [Fig. 6]. The artery divides into anterior and posterior branches. The anterior branch travel forward and spreads into the anterior superior part on the lateral wall of the nasal cavity, whereas its end part passes through the projective region of the middle and inferior parts of lacrimal sac on the lateral wall of the nasal cavity, which was used as an opening for reconstructing the lacrimal drainage system.

Discussion

The projecting the lacrimal sac on the lateral wall of the nasal cavity and determining the exact location of the lacrimal sac are keys to successful endoscopic transnasal lacrimal surgery.[6-8] In the present study, the projective points of the anterior, posterior, superior, and inferior borders of the internal wall of the lacrimal sac were precisely marked by inserting hypodermic needles perpendicularly into the internal wall of the lacrimal sac through the said borders, piercing through the bony wall and out of the lateral wall of the nasal cavity. The corresponding exit points were marked. The projections of the lacrimal sac and lacrimal duct on the lateral wall of the nasal cavity were marked using the same method. Thus, the middle and inferior parts of the lacrimal fossa determines the region

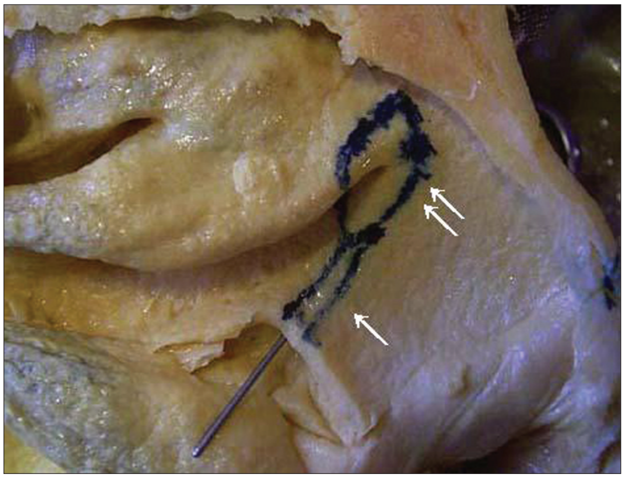

Figure 1: Projections of lacrimal sac (↑↑) and nasolacrimal duct (↑) on the lateral wall of nasal cavity (a probe was positioning in the nasolacrimal duct and the anterior superior border of inferior nasal concha had been dissected)

Figure 2: A semilunar hiatus in the posterior part of uncinate process (lateral wall on the left side)

Figure 3: The lacrimal fossa exhibits semi-funnel-shaped appearance and its inferior border connects with the superior opening (nearly round) of nasolacrimal duct (anterior superior view of left lacrimal fossa)

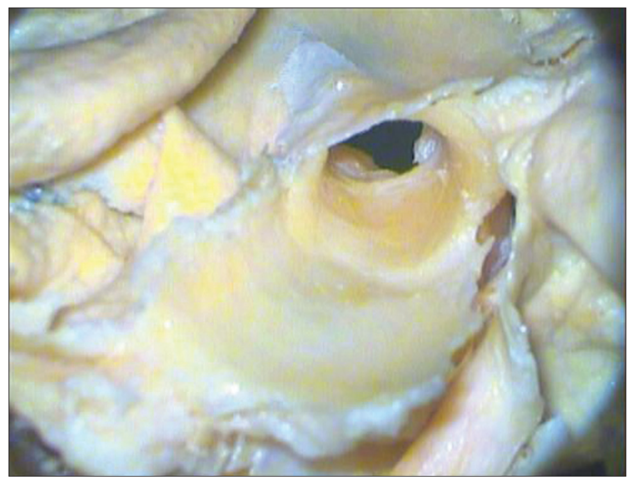

Figure 4: The inferior opening of osseous nasolacrimal duct, appearing oval-shaped

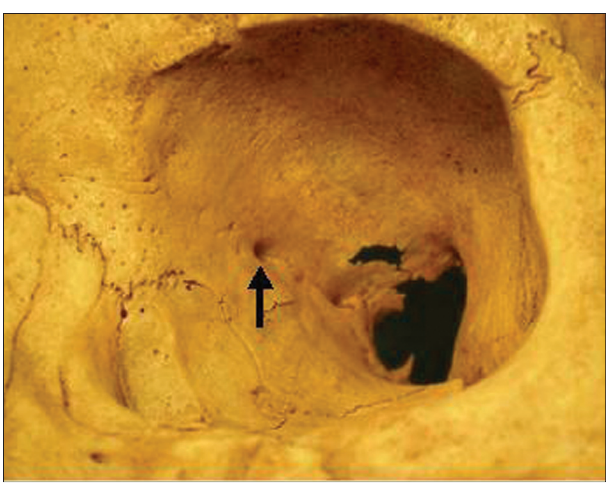

Figure 5: The region for anterior ethmoidal artery out of eye sockets, that is, anterior ethmoidal foramen, as arrow shows

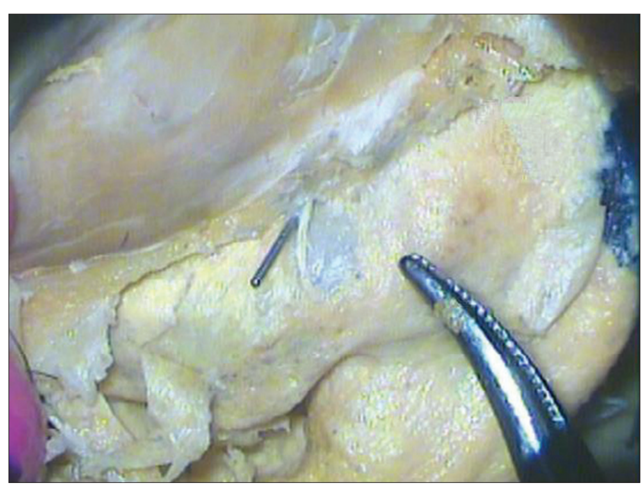

Figure 6: The region for anterior ethmoidal artery entering into the nasal cavity (the part on the left side of probe was the initial part of anterior ethmoidal artery entering into the nasal cavity)

Table 1: Thickness of internal wall of lacrimal fossa at different parts (*n*=40, x±s, mm)

	Anterior lacrimal crest	Perpendicular bisector	Posterior lacrimal crest
Top third	3.23±0.78	2.86±0.58*	1.30±0.46*†
Middle third	4.03±0.89	0.61±0.36*	0.63±0.24*
Bottom third	2.86±0.59	1.17±0.48*	1.46±0.51*†

**P*<0.05, vs. the anterior lacrimal crest, †*P*<0.05, vs. perpendicular bisector

Table 2: The long-diameter, short-diameter, and cross section area of each part of osseous nasolacrima (*n*=40, ±*s*)

	Long diameter (mm)	Short diameter (mm)	Cross section area (mm²)
Superior opening	6.28±2.17	5.89±2.14	29.04±3.40
Middle part	5.86±1.97	5.68±1.90	26.19±2.96
Inferior opening	8.52±3.16	6.50±2.07	43.50±5.60

P<0.01 when a comparison of cross section area was made between any two parts

Table 3: Horizontal distance and oblique distance from lacrimal caruncle to lateral wall of nasal cavity (*n*=40, mm)

	Minimum	Maximum	Mean	Standard deviation
Horizontal distance	15.88	17.92	17.23	0.70
30° oblique distance	12.78	18.98	15.41	1.72
45° oblique distance	13.54	21.22	17.34	2.38

Table 4: The horizontal distance and oblique distance from lacrimal caruncle to lateral wall of lacrimal sac (*n*=40, mm)

	Minimum	Maximum	Mean	Standard deviation
Horizontal distance	8.88	10.28	9.42	0.72
30° oblique distance	8.98	12.10	9.71	1.51
45° oblique distance	9.96	13.20	11.68	1.62

for the surgical opening. This region, similar to the atrium of the middle meatus, has a protuberant "bony crest" posterior of the atrium of the middle meatus, which travels vertically and corresponds to the anterior lacrimal crest. Therefore, the region can be used as a projective marker for the anterior lacrimal sac on the lateral wall of the nasal cavity. The posterior lacrimal crest corresponds to the base of the uncinate process on the lateral wall of the nasal cavity. Therefore, the base of the uncinate process can be used as a projective marker for the posterior lacrimal sac on the lateral wall of the nasal cavity.

The morphology and bony wall measurements of the lacrimal fossa are of instructive clinical significance. The present results show that all lacrimal fossae exhibit a semifunnel shape, which is inconsistent with the report by Ipek *et al.*[9] Further investigations should determine whether ethnicity caused this difference. The middle and posterior middle parts of the lacrimal fossa is the thinnest region; thus, creating a bony tunnel should start from this region and then extend toward the anterior inferior region. Caution should be taken in removing sclerotin from the lacrimal fossa. Gradually abrading the hard nasal process on the maxillary bone using an electric drill is recommended to prevent the orbital complications caused by sclerotin removal using a chisel.[10] In addition, the surgical opening should not be made at the posterior superior region to avoid damaging the stem of the anterior ethmoidal artery, which will cause severe nasal hemorrhage.[11,12]

Selecting the opening on the lateral wall of the nasal cavity during the creation of a tunnel between the lacrimal caruncle and the nasal cavity is very important because the angle and length of the reconstructed lacrimal drainage system are closely related to the position of the opening.[13-15] An excessively high opening will hinder the drainage of lacrimal fluid, whereas an excessively low opening elongates the reconstructed lacrimal drainage system and increases the risk of dacryostenosis and nasolacrimal duct obstruction. A very low opening does not hinder the drainage of lacrimal fluid, but it may injure the maxillary sinus. Therefore, the opening should be placed at a position and angle most suitable for tunnel creation. In the present study, the horizontal and oblique distances from the lacrimal caruncle to nasal cavity and from lacrimal caruncle to lacrimal sac, provide instructive significance for selecting the position of the opening on the lateral wall of the nasal cavity. These distances will also help determine the oblique angle of the tunnel and the length of the autogenous tissue.

In April 2005, we investigated endoscopic transnasal lacrimal drainage system bypass surgery by grafting autogenous tissue to treat severe nasolacrimal duct obstruction or congenital dacryostenosis and achieved preliminary therapeutic results.[1] During the procedure, a subcutaneous tunnel was made between the lacrimal caruncle and the middle and inferior parts of the lacrimal fossa. Using transnasal endoscopy, a pore was created in the middle and inferior parts of the lacrimal fossa, which allowed the tunnel to extend into the nasal cavity. Thereafter, an autogenous graft from the great saphenous vein or lip mucous membrane (curling into a tubular shape) was transplanted into the tunnel to establish a new lumen between the lacrimal lacus and nasal cavity to achieve patency. The surgery was characterized by the absence of surgical scars, minimal trauma, rapid recovery, and favorable reception from patients.[16-18]

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