Chapter

# Study on Physiological Parameters of Lacrimal Obstruction Diseases Based on CT of Lacrimal Passage

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## Abstract

The occurrence of lacrimal passage obstruction diseases is closely related to the physiological parameters of lacrimal passage. The lacrimal passage is divided into membranous lacrimal passage and bony lacrimal passage. Computed tomography (CT) of lacrimal passage can help us understand the situation of bony lacrimal passage and clarify the impact of individual anatomical differences on the occurrence of diseases. The following chapters present the physiological parameters of lacrimal passage measured by lacrimal passage CT and the impact of anatomical structure of lacrimal sac fossa on endoscopic dacryocystisinostomy, and analyze the relevant anatomical parameters of the dacryocystitis patients, including the angle between the nasolacrimal passage and the nasal plane, and the correlation between the deviation of the nasal septum and the occurrence of dacryocystitis.

**Keywords:** CT of lacrimal passage, obstructive disease of lacrimal passage, nasolacrimal passage, dacryocyst, physiological parameter

## 1. Introduction

Lacrimal passage obstruction disease is a common and frequently occurring ophthalmic disease, with main symptoms including lacrimal discharge and pus discharge [1]. In patients with severe diseases, local ulceration of skin caused by acute attack of chronic dacryocystitis may result in fistula, which affects the quality of life of patients [2]. From a diagnostic perspective, computed tomography (CT) of lacrimal passage is one of the commonly used methods for lacrimal passage imaging examination, which combines CT and contrast imaging [3]. The CT examination operation is relatively simple and can observe the direction and morphological changes in the lacrimal passage tissue structure such as the nasolacrimal passage and lacrimal sac in multiple directions [3]. This is of great significance for the measurement of anatomical parameters related to the lacrimal passage and is widely applied in the diagnosis and treatment of chronic dacryocystitis. From a therapeutic perspective, endoscopic dacryocystorhinostomy is one of the effective methods to solve obstruction of the lacrimal passage, and the anatomical structure of the lacrimal sac has a significant impact on endoscopic dacryocystorhinostomy [4].

The osteotomy of the lacrimal sac fossa area is an important component of the successful surgical technique of endoscopic dacryocystorhinostomy. Since the nasal mucosa was separated during the operation, the mandible and lacrimal bone were perforated with a rongeur to expose the location of the dacryocyst. Sinus CT can measure the relevant values of the lacrimal sac fossa, providing accurate basis for clinical doctors' surgical treatment. We have observed through clinical experiments that patients with lacrimal passage obstruction diseases undergo lacrimal passage CT imaging before treatment to analyze the angle between the nasolacrimal passage and the nasal floor plane, the running angle of the nasolacrimal passage, and the deflection of the nasal septum, which is beneficial for doctors to diagnose and treat clinical lacrimal passage obstruction diseases. This chapter explores the physiological parameters of lacrimal passage CT in obstructive diseases through five aspects, including the significance of lacrimal passage CT angiography in lacrimal passage obstruction diseases, the impact of the anatomical structure of the lacrimal sac on endoscopic dacryocystorhinostomy, the study of the diameter of the nasolacrimal passage in patients with obstructive diseases of the nasolacrimal passage, the CT study of the angle between the nasolacrimal passage and the nasal floor in patients with lacrimal passage obstruction diseases, and the CT dacryocystitis angiography analysis of the deflection of the nasal septum in patients with chronic dacryocystitis.

## 2. The significance of lacrimal passage CT angiography in lacrimal passage obstruction disease

Computed tomography image is a gray-scale image composed of a certain number of pixels, which is also a digital image and a reconstructed tomography image [5, 6]. At present, the commonly used CT scan method is spiral CT scan. Its outstanding advantage is rapid volume scan, which can collect uninterrupted data for a long range of the body in a short time and create good conditions for improving the imaging function of CT [6]. Thin-slice CT scan is commonly used in clinical practice, with the layer thickness ≤ 1.25 mm and pitch value less than 1 (the smaller the pitch, the higher the image quality, our hospital generally uses 0.5 mm layer thickness). Spiral CT, especially multislice spiral CT, has broadened the scope of examination and application and changed the way of image display. It not only improves work efficiency, but also improves the level of diagnosis [7].

### 2.1 CT examination techniqu

#### *2.1.1 Common inspection terms*

Plain scan: a plain scan is usually performed without contrast injection.

Enhancement scan: Contrast-enhanced scanning is used to artificially enhance the difference in tissue absorption to X-ray by adding a contrast agent, so as to improve the contrast between tissues in CT images [8].

Because the lacrimal sac is a soft tissue, a contrast medium should be used in the lacrimal sac before lacrimal passage CT, which facilitates the development of the lacrimal sac.

#### *2.1.2 CT value*

Computed tomography value shows the data that detect part of X-ray attenuation, and its unit is Hounsfield unit (HU). The higher the object density, the larger the CT value is; conversely, the lower the density, the smaller the CT value. The CT value of water was set as 0, lung tissue as −1000, and bone tissue as +1000. The relationship between CT value and absorption coefficient is given as follows: CT value (HU) = (U tissue –U water) /U water ×1000, where U is the attenuation coefficient. The formation and observation of CT images are determined by the following key factors [9].

Window width and window position: window width is the CT value range of the displayed image. Appropriate window width can be selected for observing different tissues, which is conducive to the display of different density tissues and lesions. Window position represents the central position of CT value, which can be set according to the need of image display.

The CT value range of known image display is window bit ±1/2 window width. For example, the brain window, with a window width of 80 HU and a window position of 40 HU, can display CT values ranging from 0 to 80 HU. That is, tissues with CT values between 0 and 80 HU (white matter and gray matter) show different gray scales, while those with CT values less than 0 HU (gas) or greater than 80 HU (calcification) show black or white.

Computed tomography (CT) images are reconstructed images consisting of a certain number of pixels with different gray scales from black to white. These pixels reflect the X-ray absorption coefficients of the corresponding voxels. The pixel size and number of images obtained by different CT devices are different. The pixel size can be 1.0 × 1.0 mm or 0.5 × 0.5 mm and the number of images can be 256 × 256 or 512 × 512. The smaller and more pixels are, the more detailed the image will be, that is, the higher the spatial resolution. The spatial resolution of the CT images is lower than that of the X-ray images.

#### *2.1.3 Factors that may affect CT imaging*

Black and white CT displays tend to display high CT values as white and low CT values as black. The display has a certain number of gray levels (such as 16 or 64 equivalents). Since human eyes can only distinguish a limited number of gray levels (generally 16 gray levels), it is very important to determine the window width and window position according to the variation range of CT values of the intended display structure [10].

Because the lacrimal sac is a soft tissue cavity and is not significantly distinguished from the surrounding tissue, CT angiography of the lacrimal passage is required before surgery.

### 2.2 Computed tomographic-dacryocystography

Computed tomographic-dacryocystography (CT-DCG) is a method of CT scan after injecting a contrast agent into lacrimal passage. At the same time, high-quality three-dimensional (3D) images and multiplane sectional images can be obtained by using computer and image processing software. It plays an important role in the diagnosis and treatment of chronic dacryocystitis [11].

Computed tomographic (CT) angiography of lacrimal passage before dacryocyst surgery under nasal endoscopy can show the location of lacrimal passage obstruction, the size of dacryocyst, the thickness of lacrimal bone, and the condition of the sinus around dacryocyst, which can help to provide preoperative anatomical details, provide important basis and reliable guarantee for improving the success rate of dacryocystisinostomy under nasal endoscopy, and help to reduce surgical complications.

Contrast agent should be injected into the dacryocyst before CT, and commonly used contrast agents include iodized oil, panchromeglumine, iodide alcohol, and iodohyl alcohol (characteristics of contrast agent). The specific method is generally to first rinse the lacrimal passage, and then reperfuse the contrast agent into the lacrimal sac after rinsing out abnormal secretions in the lacrimal passage.

The contrast agent's density is higher than the bone mineral density, so the contrast agent filling of the lacrimal sac is generally observed on the bone window:

The window width of bone window is 3000–4000 HU, and the window position is 500–700 HU.

The window width of soft tissue window is 300–400 HU, and the window position is 40–50 HU.

*2.2.1 Indications*

1. Patients with lacrimal passage obstruction and chronic dacryocystitis.

2. Patients with complex traumatic lacrimal passage obstruction and traumatic chronic dacryocystitis.

3. Patients with recurrent lacrimal passage obstruction and chronic dacryocystitis.

*2.2.2 Contraindications*

1. Patients with acute inflammation of eye and lacrimal passage.

2. Patients who are allergic to contrast media.

3. Patients with serious cardiopulmonary organic diseases, mental disorders, mental high tension and cannot tolerate examination.

## 3. Impact of anatomical structure of lacrimal sac fossa on endoscopic endonasal dacryocystorhinostomy

An efficient osteotomy is a prerequisite for the endoscopic endonasal dacryocystorhinostomy (DCR). After separating the nasal mucosa, it is necessary to use a nasal rongeur to perforate the maxillary bone and lacrimal bone to expose the location of the lacrimal sac. Therefore, the success of this osteotomy depends primarily on the thickness of the maxillary frontal process and lacrimal bone. The removal of thick bone from the maxillary frontal process is the greatest difficulty during surgery. Existing researches have shown that there are differences in the anatomical structure of the lacrimal sac fossa between different races and genders, which can have varying degrees of impact on the successful implementation of surgery and postoperative outcomes. Ophthalmologists who perform lacrimal passage surgeries must have an understanding of the variations in nasal anatomy among different patients as these subtle differences can often determine the necessary adjustments to the surgical plan.

### 3.1 Anatomy of the lacrimal sac fossa

The lacrimal sac fossa is a depression in the inferomedial aspect of the orbital rim, comprising of a thick maxillary bone and a thin lacrimal bone. It is adjacent to the anterior lacrimal crest of the maxillary frontal process and the posterior lacrimal crest of the lacrimal bone. There is a lacrimo-maxillary suture between the maxillary and lacrimal bones. The length of the adult lacrimal sac fossa is about 16 mm, the width is about 7–10 mm, and the depth is about 2–4 mm [12]. The maxillary and lacrimal bones are separated by the lacrimo-maxillary suture. The proportion of these two bones varies among different races, which has an impact on the positioning of the lacrimal sac and osteotomy. The lacrimal sac fossa is a bony anatomical structure of the lacrimal passage and can be completely displayed by computed tomography (CT) scan of the sinus to show its structure and relationship with adjacent tissues. Therefore, a sinus CT is one of the necessary preoperative preparations, and surgeons can formulate individualized surgical plans for the DCR based on CT images.

### 3.2 Measurement of lacrimal sac fossa anatomical data

Variations in the structure of the lacrimal sac fossa can have a significant impact on DCR. Current researches on the measurement of relevant anatomical data of the maxillary and lacrimal bones help us to have a clearer and more comprehensive understanding of this area. Most measurements are based on sinus or orbital CT, and many countries have conducted relevant data measurements. A study on the Japanese population [13] measured the thickness and length of the maxillary and lacrimal bones, as well as the angle between the lacrimal bone and sagittal plane. Compared to other races, the maxillary bone of Japanese people is thicker, the proportion of lacrimal bone in the lacrimal sac fossa is relatively larger, and the average angle of the lacrimal sac fossa is also larger, making osteotomy easier. Kang et al. [14] measured the midpoint thickness and maximum thickness of the maxillary bone of Korean patients and evaluated the relationship between nasal bone height and maxillary bone thickness in the lacrimal sac fossa. They found that maxillary bone thickness in the lacrimal sac fossa was thicker in males than in females, and aging had a significant positive correlation with maxillary bone thickness. However, nasal bone height and maxillary bone thickness were also not significantly related. Gore et al., in addition to measuring the thickness of the maxillary and lacrimal bones, also evaluated the length of anterior extent of the nasal mucosa [15]. They found that the maximum maxillary thickness was significantly thicker in black Africans as compared with Caucasians, and that the proportion of maxillary bone forming the lacrimal fossa wall was significantly greater in black Africans. However, the length of nasal mucosa available for creation of an anastomosis was significantly greater in Caucasians. A larger proportion of maxillary bone and shorter nasal mucosa are not conducive to osteotomy and creation of an anastomosis in Black Africans' surgical areas during DCR.

### 3.3 Anatomical relationship between the lacrimal sac fossa and surrounding tissues

Accurate positioning of the lacrimal sac fossa on the lateral wall of the nasal cavity under endoscopy, accurate bone removal to expose the lacrimal sac without damaging important structures such as the nasolacrimal passage and lamina papyracea, and a clear understanding of the anatomical relationship between the fossa and surrounding tissues is a key factor in the successful implementation of osteotomy. In osteotomy positioning, the axilla of the middle turbinate corresponds to the central position of the lacrimal sac on the lateral wall of the nasal cavity. However, during DCR, difficulties in using rongeur occur due to the thick bone at the maxillary frontal process [16]. The maxillary line is a longitudinal ridge formed by the maxillary frontal process on the lateral wall of the nasal cavity and is consistent with the direction of the lacrimal-maxillary suture. The maxillary line is the major marker for accurate positioning of the anterior boundary of lacrimal sac. This positioning method also has difficulty in using rongeur due to the bone thickness. The uncinate process of lacrimal bone is an arcuate ridge on the lateral wall of the middle nasal passage. The front part of the uncinate process faces the thinner lacrimal bone. Although the lacrimal bone is thinner, there is an overlap between the uncinate process and the lower part of the lacrimal sac fossa, which makes osteotomy difficult. Woo et al. observed that compared to Europeans, Asian patients do not have an overlap between the uncinate process and lower part of lacrimal sac fossa [17]. Therefore, Asian patients need additional procedures for a sufficient osteotomy in DCR. Another study reached a different conclusion that in Asian populations, there is a greater likelihood of overlap between uncinate process and lower part of lacrimal sac fossa than in Europeans [18]. Due to insufficient numbers of research and inconsistent opinions, whether or not there are racial differences in relative position of uncinate process still needs further verification.

### 3.4 Pathological examination of lacrimal sac fossa bone specimens

In addition to measuring the anatomical data related to the lacrimal sac fossa, pathological examination of bone specimens in the lacrimal sac fossa area provides further microscopic evidence that in addition to pathological changes in soft tissues in the lacrimal sac area during different stages of lacrimal passage disease progression, the bone substance of the lacrimal sac fossa will also change [19]. In early studies, Hinton et al. performed routine histopathological bone analysis on 71 patients undergoing lacrimal passage surgery and found that only 19% showed bone remodeling and no acute or chronic inflammatory infiltration was observed in any specimen [20].

Ali et al. conducted pathological specimen tests on chronic primary acquired nasolacrimal passage obstruction and acute dacryocystitis using four special stains [21]. They found that patients with chronic primary acquired nasolacrimal passage obstruction generally had periosteal thickness and fibrosis, while patients with acute dacryocystitis did not. The study believes that the periosteal thickness and fibrosis in long-term cases are due to repeated inflammatory attacks.

Changes in the periosteum and bone fibrosis will affect the bone hardness, making osteotomy more difficult for patients diagnosed with chronic dacryocystitis than those with acute one.

The lacrimal sac fossa is an important anatomical location for osteotomy during endoscopic endonasal DCR, and CT scan of the sinus is the main basis for measuring relevant values of the lacrimal sac fossa. The above researches have shown that the success of osteotomy is mainly related to the thickness of the maxillary and lacrimal bones, the angle of the lacrimal bone, the positioning of the lacrimal sac fossa, and differences in bone substance. Currently, there are still few studies on the measurement of anatomical structures related to the lacrimal sac fossa. Existing studies mainly focus on racial and gender differences, and there are still no studies on regional or ethnic differences. In clinical observations, it was found that the maxillary bone of people in high-altitude areas is thicker than that of people in low-altitude areas, which makes osteotomy more difficult for the former group. Whether objective factors such as living environment (e.g., altitude, temperature, and diet) have an impact on the formation of the anatomical structure of the lacrimal sac fossa remains to be further discovered and verified.

## 4. Study on the diameter of the nasolacrimal passage in patients with obstructive diseases of the nasolacrimal passage

### 4.1 Objective

The diameter of nasolacrimal duct in patients with nasolacrimal duct obstruction was measured to analyze the differences in transverse diameter of the upper, middle, and lower orifice of the bone nasolacrimal duct between sick eyes and normal eyes, between sick eyes of different genders, and between sick eyes of different ages, and to explore the relationship between transverse diameter of nasolacrimal duct and nasolacrimal duct obstruction.

### 4.2 Method

A total of 152 patients with lacrimal passage obstruction disease (179 sick eyes and 125 normal eyes) were collected from the Ophthalmology Department of the Affiliated Hospital of Chengdu University of Traditional Chinese Medicine from April 2014 to January 2017 [22]. There were 25 males (28 sick eyes and 22 normal eyes) and 127 females (151 sick eyes and 103 normal eyes). The age ranged from 4 to 87 years (mean 53 years). All patients received lacrimal passage irrigation followed by infusion of 30% iodohexol injection and lacrimal passage computed tomography immediately. The nasolacrimal passage structure was reconstructed by three-dimensional (3D) scanning images. The nasolacrimal passage and its adjacent tissue structure in oblique coronal position were observed and measured, and the differences in transverse diameter of the upper, middle, and lower mouth of the bone nasolacrimal passage between the sick eyes and normal eyes, between the eyes of different genders, and between the eyes of different ages were analyzed (**Figure 1**).

Statistical analysis of the data was performed using SPSS 24.0. Measurement data meeting normal distribution and homogeneity of variance between groups were expressed as $\bar{x} \pm s$. Single-factor variance analysis was used to compare the mean of multiple groups. If the difference was statistically significant, the least significant difference (LSD)-t test could be further used to compare the two groups. A value of $P < 0.05$ was considered statistically significant.

**Figure 1.**
*Three-dimensional (3D) structure of nasolacrimal passage. Upper (red), middle (blue), and lower (yellow) nasolacrimal passages represent the transverse diameters of the uppermost, middle, and farthest ends of the bony nasolacrimal passage, respectively.*

## 4.3 Results

There was no significant difference in the transverse diameter values of the upper, middle, and lower mouth between sick eyes and normal eyes, between eyes of different gender, and between eyes of different ages ($P > 0.05$) (**Tables 1–3**). The transverse diameters of the upper, middle, and lower nasolacrimal passages in sick eyes and normal eyes were statistically significant ($P < 0.05$) (**Table 3**).

## 4.4 Discussion

Some studies believe that the size of the nasolacrimal passage diameter is related to the obstructive disease, while the upper, middle, and lower mouth of the sick eyes included in this study are 5.12 ± 0.13 mm, 4.71 ± 0.13 mm, and 5.33 ± 0.14 mm, and the upper, middle, and lower opening of normal eyes are 4.97 ± 0.13 mm, 4.62 ± 0.13 mm, and 5.29 ± 0.15 mm, respectively [23].

| Gender | The number of eyes | Upper diameter (mm) | Middle diameter (mm) | Lower diameter (mm) |
|---|---|---|---|---|
| female | 151 | 5.07 ± 0.13 | 4.75 ± 0.13 | 5.41 ± 0.15 |
| male | 28 | 5.34 ± 0.14 | 4.43 ± 0.10 | 4.92 ± 0.10 |
| *t* value | — | 1.040 | −1.259 | −1.699 |
| *P* value | — | 0.300 | 0.210 | 0.091 |

**Table 1.**
*Comparison of the diameter of nasolacrimal duct in male and female patients.*

*DOI: http://dx.doi.org/10.5772/intechopen.112071*

| Age (year) | The number of eyes | Upper diameter (mm) | Middle diameter (mm) | Lower diameter (mm) |
|---|---|---|---|---|
| 4 ~ 20 | 4 | 4.43 ± 0.15 | 5.40 ± 0.12 | 5.48 ± 0.14 |
| 21 ~ 40 | 27 | 5.14 ± 0.15 | 4.52 ± 0.11 | 5.05 ± 0.11 |
| 41 ~ 60 | 76 | 4.95 ± 0.11 | 4.58 ± 0.13 | 5.17 ± 0.14 |
| 61 ~ 80 | 67 | 5.30 ± 0.13 | 4.82 ± 0.13 | 5.60 ± 0.15 |
| 81 ~ 87 | 5 | 5.78 ± 0.15 | 5.64 ± 0.11 | 5.42 ± 0.09 |
| *t* value | — | 1.317 | 1.493 | 1.191 |
| *P* value | — | 0.265 | 0.206 | 0.316 |

**Table 2.**
*Comparison of the diameter of the nasolacrimal duct in patients of different ages.*

| Eye contrast | The number of eyes | Upper diameter (mm) | Middle diameter (mm) | Lower diameter (mm) | *F* value | *P* value |
|---|---|---|---|---|---|---|
| Diseased eyes | 179 | 5.12 ± 0.13* | 4.71 ± 0.13 | 5.33 ± 0.14* | 10.311 | <0.001 |
| Normal eyes | 125 | 4.97 ± 0.13* | 4.62 ± 0.13 | 5.29 ± 0.15* | 7.832 | <0.001 |
| *t* value | — | 0.993 | 0.608 | 0.218 | — | — |
| *P* value | — | 0.321 | 0.544 | 0.827 | — | — |

**PS: A value of P < 0.01 represents the comparison of nasolacrimal duct ducts in the same eye contrast.*

**Table 3.**
*Comparison of the nasolacrimal duct diameter between diseased eyes and normal eyes.*

Takahashi et al. found that the transverse diameter of nasolacrimal passage measured on cadavers was 4.0 ~ 10.0 mm (mean 5.7 mm), which was similar to our measurement results [24]. In this study, transverse diameter of bony nasolacrimal passage was compared between sick eyes and normal eyes, and no statistical difference was found between the two, indicating that the size of bony nasolacrimal passage has no significant effect on the occurrence of such diseases. Therefore, the size of bony nasolacrimal passage may not be an important factor causing nasolacrimal passage obstruction.

McCormick et al. found that the diameter of nasolacrimal passage in Oceanians was larger and the operation rate of lacrimal passage was higher, indicating that nasolacrimal passage diameter may not be an important factor in primary nasolacrimal passage obstruction [25]. Nasolacrimal passage includes osseous nasolacrimal passage and membranous nasolacrimal passage. Clinical observation shows that the location of lacrimal passage obstruction may be at the valve. Francisco et al. reported that female lacrimal passage obstruction was mainly located in the Krause valve, while male lacrimal passage obstruction was mainly located in the Hasner valve [26]. The lacrimal passage is connected to the conjunctival sac, and the lower part is connected to the nasal cavity, which is easy to cause infection and inflammation due to bacteria breeding in the conjunctival and nasal cavity, resulting in congestion and edema of the nasolacrimal passage mucosa, narrowing of the duct diameter and causing obstruction. Therefore, inflammation is the most common cause of nasolacrimal passage obstruction [27].

In this study, we found that the upper, middle, and lower mouth diameters of the nasolacrimal passage were inconsistent, and the midorifice diameter of the nasolacrimal passage was relatively small, with a minimum of 1. 1 mm, indicating that the nasolacrimal passage was an irregular tube diameter. In addition, we found that the diameter span of the lower mouth of the nasolacrimal passage is large (0.12 ~ 1.21 cm), which may be related to the position of the lower mouth and the morphological change of the opening, as well as the measurement method, body position, head position, etc. [28]. Studies have shown that the measurement of nasolacrimal passage diameter varies due to different measurement methods, shape of nasolacrimal passage (round or oval), body position, head position, etc. [29]. In addition, when tilted to measure the diameter of nasolacrimal passage, except for the angle of nasolacrimal passage relative to the axial plane, any measurement using the axial plane as the vertical direction of nasolacrimal passage will be affected by neck flexion/extension, resulting in errors in measurement results [30, 31]. In this study, we found that there was no significant difference in nasolacrimal passage diameter between male and female patients, which was consistent with the reports of Czyz et al., Ramey et al., and Janssen et al. [30, 32, 33]. However, Shigeta et al. found that the transverse diameter of nasolacrimal passage in male patients was significantly larger than that in female patients through CT examination [23]. And Groessl et al. found that the incidence of nasolacrimal passage obstruction had certain gender differences [34]. The majority of patients in this study were between 40 and 80 years old, and the analysis showed that there was no statistical difference in the diameter of the bony nasolacrimal passage in patients of all ages, indicating that the axial diameter of the bony nasolacrimal passage in patients with nasolacrimal passage obstruction did not change with age, which was consistent with the conclusion of Ramey et al. that there was no significant difference in the minimum diameter of the nasolacrimal passage between young and elderly patients [30]. Janssen et al. measured the minimum diameter of bone nasolacrimal passage in normal people and in patients with nasolacrimal passage obstruction through CT examination, and found that the older the patients were, the narrower the diameter was, and the diameter of the patients with nasolacrimal passage obstruction was smaller than that of normal people [33]. However, the above conclusions need to be further verified by increasing sample size measurement.

This study showed that there was no significant difference in the transverse diameter values of the upper, middle, and lower mouth of the bony nasolacrimal passage between the sick eyes and the normal eyes, between the sick eyes of different genders, and between the sick eyes of different ages, suggesting that the size of the bony nasolacrimal passage is not an important cause of nasolacrimal passage obstruction. The transverse diameters of the nasolacrimal passage in the upper, middle, and lower mouth of the sick eyes and normal eyes were significantly different, and the transverse diameter of the middle mouth was the smallest, indicating that the nasolacrimal passage was irregular. Therefore, in the clinical treatment of nasolacrimal passage obstruction, it is necessary to understand the situation of the bone nasolacrimal passage and pay attention to the protection of the lacrimal passage and nasal mucosa, so as to obtain a better effect.

## 5. Study on the angle between nasolacrimal passage and nasal floor in patients with obstructive diseases of lacrimal passage based on computed tomographic-dacryocystography

Before treatment of patients with lacrimal passage obstruction, the author routinely performed lacrimal passage CT angiography to display nasolacrimal passage to understand nasolacrimal passage condition, and the results showed that not all patients had the same nasolacrimal passage alignment angle. Therefore, this study analyzed the nasolacrimal passage alignment angle by measuring the angle between nasolacrimal passage and nasal base plane, hoping to provide certain guidance for clinical treatment of lacrimal passage obstruction. The results are reported as follows.

### 5.1 Method

#### *5.1.1 General information*

From April 2014 to January 2017, 538 eyes of 269 patients with lacrimal passage obstruction disease (176 healthy eyes and 362 sick eyes) were treated in the Ophthalmology Department of Affiliated Hospital of Chengdu University of Traditional Chinese Medicine with tears or pus as the main complaint. There were 62 male cases with 124 eyes (79 sick eyes), 207 female cases with 414 eyes (283 sick eyes), ranging from 4 to 87 years old, with an average age of 53.87 ± 14.35 years.

Inclusion criteria: (1) Medical history, clear history of tears or pus. (2) Symptoms: patients have tears or discharge of pus. (3) Physical signs, extrusion of purulent secretions in the dacryocyst area or redness, tenderness in the dacryocyst area. (4) Auxiliary examination, lacrimal passage irrigation is not patency. (5) The patient was willing to undergo CT lacrimal passage angiography.

Exclusion criteria: (1) The patient was unwilling to undergo CT lacrimal passage angiography, or was allergic to iodohexol injection, or had a hypersensitive constitution. (2) Patients with conjunctival inflammation, photophobia tears, and other anterior segment diseases. Patients with functional tears such as lower eyelid skin relaxation, conjunctival relaxation, eyelid ectropion, or meibomian gland insufficiency. (3) Auxiliary examination, lacrimal passage flushing up and down or down back, and no purulent secretions. Lacrimal passage flushing and patency. (4) Patients with infectious or serious cardiovascular and cerebrovascular diseases and other general conditions are excluded.

#### *5.1.2 Experimental method*

All patients underwent lacrimal passage irrigation, and 30% iodohexol injection was injected into the lacrimal passage until the purulent secretions were overflowing. CT examination of lacrimal passage was performed immediately. Images were uploaded and a 3D nasolacrimal passage was reconstructed through picture archiving and communication system (PACS) workstation to observe the nasolacrimal passage and its adjacent tissue structure in oblique coronal position. First, a straight line was drawn along the nasal fundus plane, then along the long axis of the bony nasolacrimal passage. Finally, the angle between the two lines was measured. The angle between the right nasolacrimal passage and the nasal fundus plane was recorded on the right side of the horizontal line (**Figure 2A**), and the angle between the left nasolacrimal passage and the nasal fundus plane was recorded on the left side of the horizontal line (**Figure 2B**). Finally, the statistical analysis was performed.

#### *5.1.3 Statistical analysis*

SPSS 21.0 software was used for statistical analysis. If the data met the normal distribution and homogeneity of variance characteristics, independent sample t-test

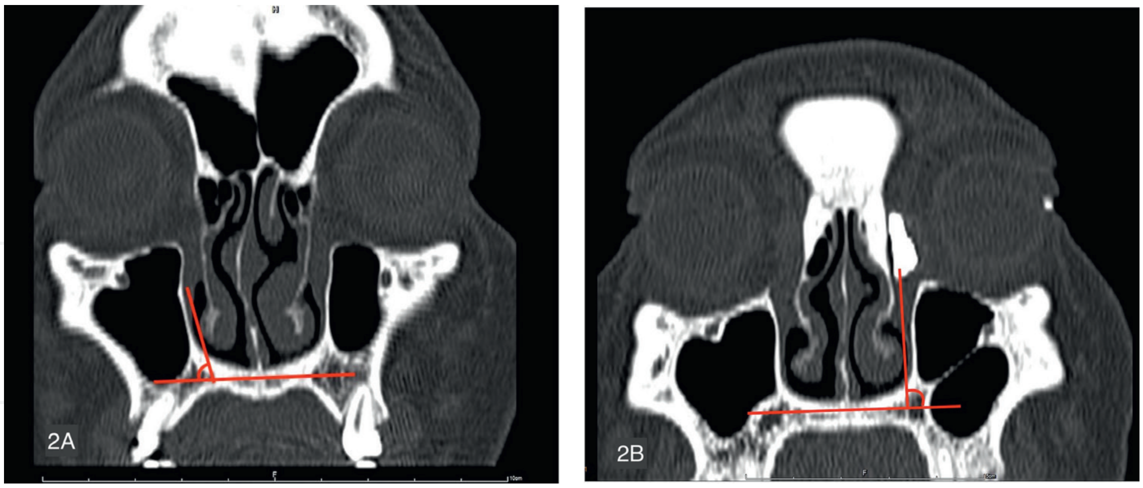


**Figure 2.**
*Computed tomographic (CT) three-dimensional (3D) reconstruction of the nasolacrimal passage (A: Angle between nasolacrimal passage and nasal base plane of right eye. B: Angle between nasolacrimal passage and nasal base plane of left eye.)*

or one-way analysis of variance was used. If the data do not conform to normal distribution or homogeneity of variance, the nonparametric rank sum test is used.
A value of $P < 0.05$ was considered to be statistically significant.

## 5.2 Results

### 5.2.1 Comparison of the angle between the nasolacrimal passage and the nasal bottom plane in patients and healthy eyes

All data found that the data were not subject to normal distribution with uneven variance, so the nonparametric rank sum test was used. The results showed that the angle between the nasolacrimal passage and the nasal base plane in the patients was smaller than that in the normal eyes, and the difference was statistically significant ($Z = -2.189$, $P < 0.05$) (**Table 4**).

### 5.2.2 Comparison of the angle between the nasolacrimal passage and the nasal base plane between the gender

The t-test found the angle between the nasolacrimal passage and the nasal plane between male and female patients ($P < 0.05$), and the angle between the nasolacrimal passage and the nasal plane in female patients was smaller than in male patients (**Table 5**).

| Groups | The number of eyes | Average angle (°) | *Z* value | *P* value |
|---|---|---|---|---|
| sick eyes | 362 | 85.71 ± 10.90 | −2.189 | 0.029 |
| healthy eyes | 176 | 89.29 ± 16.82 | | |

**Table 4.**
*Comparison of the angle between the nasolacrimal duct and the nasal bottom plane in patients and healthy eyes.*

| Gender | The number of eyes | Average angle (°) | *t* value | *P* value |
|---|---|---|---|---|
| male | 79 | 88.39 ± 15.06 | 2.491 | 0.013 |
| female | 283 | 84.96 ± 9.31 | | |

**Table 5.**
*Comparison of the angle between the nasolacrimal duct and the nasal base plane between the gender.*

#### *5.2.3 Distribution of the angle between the nasolacrimal passage and the nasal base plane of the sick eyes*

Excluding the special shape of the nasolacrimal passage, the distribution of the angle between the nasolacrimal passage and the nasal fundus plane was different in each angle segment of the sick eyes. The results showed that the angle between the nasolacrimal passage and the nasal fundus plane of the patient is mainly in the range of 80 ~ 90°. Patients were divided into three groups according to the range of angles between nasolacrimal passage and nasal base plane, ranging from 60 to 80°, 81 to 100°, and more than 100°. The results show that 72% of patients were in the range of 81–100°.

#### *5.2.4 Distribution of the angle between nasolacrimal passage and nasal fundus plane of sick eyes at different ages*

The results showed that there was no significant difference in the angle between the nasolacrimal passage and the nasal fundus plane among different age groups ($P > 0.05$), the angle between nasolacrimal passage and nasal fundus plane was similar in all age groups, and age did not affect the angle between nasolacrimal passage and nasal fundus plane (**Table 6**).

### 5.3 Discussion

The clinical symptoms of patients with lacrimal passage obstruction disease are tears or discharge of pus, but the symptoms are similar, but the etiology is different. To accurately find the cause, besides conventional lacrimal passage irrigation, the author also performed lacrimal p assage CT angiography to understand the nasolacrimal passage. In the analysis of CT angiography, it was found that not all patients had the same direction of nasolacrimal passage. To analyze whether the direction of

| Age (year) | The number of eyes | Average angle (°) | *F* value | *P* value |
|---|---|---|---|---|
| 4 ~ 20 | 3 | 90.77 ± 4.65 | 0.254 | 0.907 |
| 21 ~ 40 | 46 | 85.11 ± 7.40 | | |
| 41 ~ 60 | 175 | 86.01 ± 12.32 | | |
| 61 ~ 80 | 128 | 85.42 ± 10.21 | | |
| 81 ~ 87 | 10 | 85.30 ± 10.90 | | |

**Table 6.**
*Analysis of the difference in angle between sick eyes at different ages.*

nasolacrimal passage was related to lacrimal passage obstruction diseased, the angle of nasolacrimal passage was studied based on CT angiography, which has a certain guiding role in the clinical treatment of lacrimal passage obstruction diseases.

In this study, the average angle between normal nasolacrimal passage and nasal base plane was (89.29 ± 16.82)°. Yin Liang et al. measured the angle between nasolacrimal passage and nasal base plane on sagittal multiplane reconstruction images of normal people, and found that the angle between nasolacrimal passage and nasal base plane was (69.6 ± 7.2)° [35]. And Janssen et al. reported that the angle between osseous nasolacrimal passage and the line perpendicular to the nasal cavity was 22.5°, which was somewhat different from the measured results in this study [33]. In this study, the mean angle between nasolacrimal passage and nasal fundus plane in patients with lacrimal passage obstruction was (85.71 ± 10.90)°, indicating that the angle between nasolacrimal passage and nasal fundus plane was significantly smaller than that in normal eyes, which is contrary to the result of BulBul et al. who found no significant difference between patients with lacrimal passage obstruction and normal people [36].

In this study, it was also found that the angle between the nasolacrimal passage and the nasal base plane of the sick eyes was discrete between 62.50 and 108.50°, among which 81 ~ 100° accounted for 72%, 60 ~ 80° accounted for 25%, and more than 100° accounted for 3%. In normal eyes, the angle between nasolacrimal passage and nasal fundus plane ranges from 67.20 to 107.90°. Therefore, in clinical lacrimal passage probing treatment, the angle between nasolacrimal passage and nasal base plane should be considered, and the direction of needle injection during lacrimal passage forming surgery should be reduced according to the indicated nasolacrimal passage walking guidance, which is an effective method to judge the preoperative condition and surgical prognosis [37, 38]. If patients with lacrimal passage obstruction undergo blind vertical injection before lacrimal passage CT, there is a risk of forming a false path and resulting in surgical failure. Therefore, it is better to perform CT lacrimal passage angiography if possible, which can improve the cure rate of lacrimal passage operation. However, in primary hospitals or places where CT examination cannot be performed, as well as patients who are not suitable for CT examination due to the large amount of radiation, such as infants and young children. For these patients, surgeons should pay attention to the fact that nasolacrimal passage and nasal floor plane are not necessarily vertical, there may be a certain angle, at the same time, do not forcibly perform probing treatment when encountering resistance.

The results of this study showed that the mean included angle of diseased eye in male patients was (88.39 ± 15.06)°, and that in female patients was (84.96 ± 9.31)°. The mean angle of sick eyes in male patients was significantly greater than that in female patients. Shigeta et al. [23] found that the angle between nasolacrimal passage and nasal fundus plane ranged from 64.9 to 89.1°, with an average of 78.3°. The angle of male patients (78.7 ± 4.3)° was significantly greater than that of female patients (77.6 ± 4.4)°. This is the same as the results of this study which found that the angle between the nasolacrimal passage and the nasal base plane was significantly different between the male and female patients.

Lee et al. [29] measured that the angle between nasolacrimal passage and nasal cavity was (63.6 ± 7.6)°, among which the angle between nasolacrimal passage and nasal cavity was (64.78 ± 7.6)° after the age of 10, and the average angle between nasolacrimal passage and nasal cavity was (57.38 ± 4.1)° under the age of 10. However, Levi et al. [39] showed no significant difference in the angle of nasolacrimal passage in horizontal and sagittal positions between normal adults and children, indicating that the direction of nasolacrimal passage would not change with age. Moreover, this study has also found that the angle between nasolacrimal passage and nasal fundus plane did not change with age, which may be related to the small number of patients under 12 years collected in this study. Since facial bone development has matured in patients after 12 years, the angle value after 12 years does not change with age.

The results of this study showed that there were statistical differences in the angle between the nasolacrimal passage and the nasal base plane between the patients with lacrimal passage obstruction disease and the patients with normal eyes, and between the patients with male and female patients, and there was no statistical difference between different age groups. Therefore, in the diagnosis and treatment of patients with these diseases, the orientation of nasolacrimal passage and the angle between nasolacrimal passage and nasal base plane should be considered when the lacrimal passage is forming or probing, which has certain guiding significance for the clinical diagnosis and treatment of this disease and improving the success rate of surgery.

## 6. Analysis of nasal septum deviation in patients with chronic dacryocystitis based on CT dacryocystitis angiography

Some scholars believe that the special anatomical structure of nasolacrimal passage may be related to the occurrence of chronic dacryocystitis. Some studies also mention that people with nasal septal deviation are prone to rhinitis, and the basic lesions of chronic dacryocystitis may be caused by simple rhinitis and hypertrophy rhinitis. Therefore, it can be preliminarily concluded that the occurrence of this disease is related to nasal septum deviation [40–42]. Many patients with lacrimal passage obstruction are complicated by nasal septal deviation. Zhang Jiajia et al. [43] found through clinical studies that patients with lacrimal passage obstruction are often accompanied by nasal septal deviation, which has a certain influence on nasolacrimal passage diseases. Cervelli et al. [44] observed through lacrimal passage angiography that the tear volume of patients with nasal septum deviation was reduced compared with that of normal people, and the reduced tear volume could be restored to normal after the nasal septum deviation was corrected. Gao Ying et al. [45] also found through clinical observation that the occurrence of chronic dacryocystitis is related to the abnormal structure of the nose, and the research results also suggested that the deviation of the nasal septum may be the main cause of chronic dacryocystitis caused by the abnormal structure of the nose.

### 6.1 Method

#### *6.1.1 Study subjects*

A total of 190 cases and 199 eyes were collected from the Ophthalmology Department of the Affiliated Hospital of Chengdu University of Traditional Chinese Medicine from July 2019 to February 2021 and diagnosed with chronic dacryocystitis with repeated tears and pus as the chief complaint, including 20 males and 170 females, ranging in age from 23 to 84 years, with an average age of 54.32 ± 13.15 years. Inclusion criteria: (1) Symptoms of tears and discharge of pus. (2) There was purulent secretion overflow in the compressed dacryocystis. (3) Flushing through the lacrimal passage with purulent secretions. (4) Patients willing to undergo CT lacrimal passage angiography. (5) Informed consent. Exclusion criteria: (1) Iodine allergy or hypersensitivity. (2) Patients with severe systemic diseases. (3) Pregnant and lactating women.

#### *6.1.2 Experimental method*

A history was taken, the anterior segment was examined, and the lacrimal passage was irrigated until no purulent discharge was found. CT-DCG examination was performed immediately after infusion of 1 ~ 2 ml of 30% iodohexol injection into lacrimal passage. CT images were uploaded, and PACS workstation was used for 3D reconstruction for analysis.

#### *6.1.3 Statistical analysis*

Statistical analysis of the data was performed using SPSS 24.0. Measurement data meeting normal distribution and homogeneity of variance between groups were expressed as $\bar{x} \pm s$, and independent sample t-test was used for comparison between two groups. Measurements that did not conform to the normal distribution were expressed as median (interquartile spacing), and the Wilcoxon rank sum test was used to compare the two groups. Counting data were expressed as n (%), and the chi-square test was used for comparison between two groups. A value of $P < 0.05$ was considered statistically significant.

### 6.2 Results

#### *6.2.1 General information of patients*

In this study, the patients had the maximum age of 40–60 years, accounting for about 47.9%. In 190 patients with dacryocystitis, 95.3% were monocular and 4.7% were binocular. Among the 190 patients, 82 patients lived in urban areas for a long time (about 43.2% of the total number of patients) and 108 patients lived in rural areas (about 56.8% of the total number of patients). However, there was no statistical significance in the distribution of male and female patients in living areas.

#### *6.2.2 Deviation of the nasal septum and vertical distance from the top and bottom of the dacryocystitis in patients with dacryocystitis*

Among the patients with chronic dacryocystitis in this study, there were 141 cases and 142 eyes with deviated nasal septum, accounting for 74.2% of the total participants, and 25.8% with undeviated nasal septum. According to the direction of nasal septal deviation, it can be divided into the affected side and the healthy side, among which 80.3% patients show nasal septal deviation to the affected side and 19.7% patients show nasal septal deviation to the healthy side. Therefore, it can be concluded that patients with chronic dacryocystitis are mostly accompanied by nasal septal deviation and multiple nasal septal deviations. In addition, the vertical distance from the top of the affected dacryocyst to the nasal septum was significantly lower in 199 diseased eyes than that from the top of the healthy dacryocyst to the nasal septum ($P < 0.05$).

In this study, there was no statistically significant difference in nasal septum deviation between genders and different areas of residence ($P > 0.05$). There was no significant difference in nasal septum bias between sexes in patients with chronic dacryocystitis ($P > 0.05$). There was no significant difference in the vertical distance

*DOI: http://dx.doi.org/10.5772/intechopen.112071*

between the top and bottom of the healthy dacryocyst and the nasal septum between different genders and different ages ($P > 0.05$). There was no significant difference in the vertical distance between the top and bottom of the affected dacryocyst and the nasal septum between different genders and different ages ($P > 0.05$).

### 6.3 Discussion

The lacrimal sac is located in the medial wall of orbit behind the medial canthus ligament as a fissure-like sac. The top of the dacryocyst is the blind end, and the bottom is continuous with the nasolacrimal passage. Relevant studies have found that the upper part of the dacryocyst is wider than the lower part, and it is trapezoidal [46]. The dacryocyst is a bone fossa with hard bone in the front and thinner bone in the back. The wall of the dacryocyst is composed of spiral elastic connective tissue, which is delicate and easy to stretch. There is no internal muscle fiber in the wall of the dacryocyst, which is strengthened by the lacrimal gland part of the orbicularis oculi muscle fiber [47]. Because the lower end of the dacryocyst is continuous with the nasolacrimal passage, the obstruction or narrowing of the nasolacrimal passage will affect the discharge of tears. When tears accumulate in the dacryocyst, bacteria will grow from it and stimulate the wall of the dacryocyst continuously, resulting in chronic dacryocystitis [47].

The development of chronic dacryocystitis is not negligible in relation to nasal septal deviation. Cervelli et al. [44] observed through lacrimal passage angiography that patients with nasal septal deviation had reduced tear volume compared with normal people, and the reduced tear volume would return to normal when the nasal septal deviation was corrected. Gray et al. [48] also reported relevant studies that the deviation of nasal septum may lead to the reduction in tear flow through the lower nasal passage, and the problem was improved after surgical correction of the deviation of nasal septum. Domestic scholars like Tang Haihong et al. [49] also found that nasal septum correction can solve problem faced by some patients without organic lesions caused by lacrimal discharge. Therefore, when a patient is treated by the otorhinolaryngologist, and if a deviation of the nasal septum is found, the otorhinolaryngologist should judge timely and accurately, analyze the degree of the deviation of the nasal septum, and combine with the thought of whether the patient has the possibility of acquiring any nasolacrimal passage disease, appropriately remind and inform the patient to take active treatment, so as to avoid gradually causing chronic dacryocystitis due to the deviation of the nasal septum. In conclusion, in the early treatment of chronic dacryocystitis, the role of nasal septum deviation in the occurrence and development of the disease should be fully considered, which is of great significance for the clinical prevention and treatment of chronic dacryocystitis.

Nasal septal deviation is a risk factor for recurrence of chronic dacryocystitis after surgery. If the nasal septal deviation is not treated before surgery, close follow-up should be conducted for these patients. With the development of nasal endoscopy technology, dacryocystosinostomy under nasal endoscopy has become the main method for the treatment of chronic dacryocystitis. The main purpose of surgery is to anastomose the dacryocystitis mucosa with the nasal mucosa to complete the reconstruction of the drainage channel, and the re-atresia of the anastomosis is the main cause of postoperative recurrence. In patients with severe deviated nasal septum, due to narrow nasal cavity and poor postoperative drainage, tissue inflammation and granulation hyperplasia and aggravated scar formation are easy to result. Some scholars believe that the most important thing to prevent anastomotic atresia is to reduce the proliferation of granulation tissue and scar formation [50]. Zhang Wenbin et al. [51] also found through their studies that postoperative edema of nasal mucosa in patients with severe nasal septum deviation was easy to produce tissue adhesion with dachrymal cyst flap and nasal mucosal flap at the anastomosis, resulting in anastomotic atresia and postoperative recurrence, which was a risk factor for postoperative recurrence. Therefore, patients with chronic dacryocystitis complicated with nasal septal deviation should be followed up closely after surgery. Studies have shown that regular and timely cleaning of the blood scab, secretions, and granulation tissue around the nasal anastomosis under the nasal endoscope can reduce postoperative recurrence [52]. In addition, other relevant studies [52, 53] have found that nasal septum deviation may affect the surgical treatment effect of chronic dacryocystitis or cause recurrence. However, the combined implementation of nasal disease correction surgery and endoscopic dacryocystial anastomosis of chronic dacryocystitis has improved the success rate of surgery to some extent.

Through the above studies, we can conclude that nasal septum deviation is not only related to the occurrence of chronic dacryocystitis, but also affects the surgical treatment of chronic dacryocystitis to a certain extent. Therefore, this study can guide patients with chronic dacryocystitis to not only conduct a detailed examination of the condition of the lacrimal passage, but also conduct a more comprehensive examination of the nasal cavity. Based on the examination results, specific treatment plans and surgical methods should be formulated. For patients with serious deviation of the nasal septum that may affect the therapeutic effect, nasal septum correction should be considered first. To improve the success rate of surgical treatment of chronic dacryocystitis, reduce the recurrence rate. Patients with nasal septum deviation should also be followed up closely after dacryocystonasal anastomosis under nasal endoscope to clear abnormal secretions in the nasal cavity in time to keep the gouge unobstructed and reduce postoperative recurrence.

Chronic dacryocystitis mainly occurs in middle-aged women, and the prevalence of monocular disease is significantly higher than that of binocular disease, and the prevalence of long-term living in rural areas is higher than that of urban patients. Patients with chronic dacryocystitis are often accompanied by nasal septal deviation, and the direction of nasal septum deviation is mostly consistent with the direction of the sick eye. The vertical distance between the top and bottom of the dacryocyst on the affected side and the nasal septum was significantly lower than that on the healthy side, and the smaller distance was more likely to cause chronic dacryocystitis.

## 7. Conclusion

In summary, the occurrence of lacrimal duct obstruction is closely related to the physiological parameters of lacrimal duct. The application of lacrimal duct CT can comprehensively display the location and relationship with the surrounding structure of lacrimal duct obstruction, providing accurate and detailed imaging information for clinical practice, providing a basis for personalized surgical customization, and greatly improving the success rate of treatment for patients with lacrimal duct obstruction.

## Conflict of interest

The authors declare no conflict of interest.

## Author details

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