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Research article

Clinical utility of digital radiography dacryocystography for preoperative assessment in nasolacrimal duct obstruction prior to endoscopic dacryocystorhinostomy

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A R T I C L E I N F O

Keywords:
Primary acquired nasolacrimal duct obstruction
Dacryocystography
Epiphora symptom
Lacrimal sac
Age

A B S T R A C T

Purpose: To evaluate the clinical usefulness of digital radiography dacryocystography in patients with primary acquired nasolacrimal duct obstruction prior to endoscopic dacryocystorhinostomy.
Methods: All dacryocystography images from 129 patients with primary acquired nasolacrimal duct obstruction were analyzed. Each group was assessed for postoperative epiphora severity using Munk's score via telephone follow-up three years post-surgery. Receiver operating characteristic (ROC) curve was plotted to obtain a suitable cutoff value of the transverse diameter of the lacrimal sac (LS), used to categorize LS size into small (≤4.350 mm) and large (>4.350 mm).
Results: Analysis of the transverse diameter of the LS among 129 patients showed a negative correlation between it and Munk's score (r = -0.282, p = 0.001). There was a statistical difference between the surgical outcomes and the sizes of the LS (p = 0.041). The ROC curve analysis showed that the transverse diameter of the LS at 4.350 mm was the ideal cutoff value for the outcome of endoscopic dacryocystorhinostomy, with a sensitivity of 42.2 %, and specificity of 92.3 %. After adjusting for the age and sex, the small LS was associated with an increased risk of postoperative failed outcome (adjusted odds ratio [95 % CI]: 8.628 [1.074, 69.335]).
Conclusion: The small LS was independently associated with the failed surgical outcome. Furthermore, the preoperative measurement of the LS transverse diameter serves as one of the reliable predictors for postoperative epiphora severity.

1. Introduction

Epiphora frequently manifests in clinical settings, predominantly due to primary acquired nasolacrimal duct obstruction (PANDO), which has a reported mean annual incidence of 30.47 per 100,000 individuals [1]. Dacryocystorhinostomy (DCR) serves as an effective surgical remedy for obstructions in the lacrimal duct, achieving success rates above 90 % through both endoscopic and external

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techniques [2]. However, neither functional nor anatomical epiphora continues to affect 5%–16 % of patients following a technically successful DCR operation [3–5].

In addressing postoperative epiphora, dacryoscintigraphy has often been advocated to assess the drainage of tears. Due to the long examination time of dacryoscintigraphy, the demanding image acquisition time, and the various factors affecting image quality, and extant research underscores its limited efficacy in guiding the clinical decision to undertake DCR surgery [6]. Therefore, we need a simpler and more economical examination to assess the risk of postoperative epiphora.

Dacryocystography has been used for illustrating the morphological and functional aspects of the lacrimal drainage system, and its combination with different imaging methods can provide additional information about lacrimal passage diseases [7]. Digital radiography dacryocystography (DR-DCG) fulfills both the conditions of obtaining a clear visualization of the lacrimal drainage system and a low radiation exposure. Moreover, a study has demonstrated that dacryocystography emerges as a robust diagnostic modality for both pinpointing and managing lacrimal drainage system obstructions [8]. And recently comment revealed that all patients anticipating DCR surgery need preoperative imaging [9].

This study aimed to scrutinize the anatomical dimensions of the lacrimal sac (LS) via preoperative DR-DCG among patients diagnosed with PANDO. The focus is on the clinical relevance of these dimensions, with a particular emphasis on their predictive value for postoperative epiphora subsequent to endoscopic DCR.

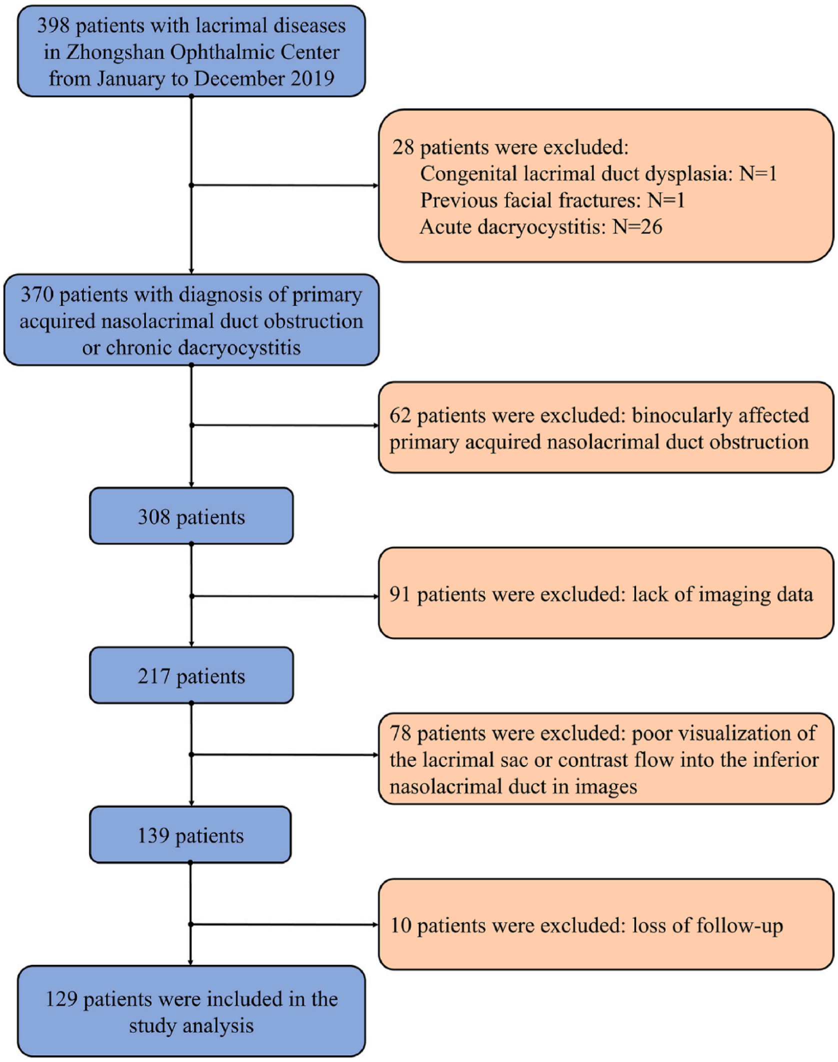

Fig. 1. Flowchart depicting inclusion of participants in this study.

2. Materials and methods

2.1. Study patients

This study was approved by the Ethics Committee of Zhongshan Ophthalmic Center, Sun Yat-sen University (No.2023KYPJ237) and was conducted according to established ethical guidelines. This study was performed in line with the principles of the Declaration of Helsinki. A written informed consent was not obtained from the subjects because of the retrospective nature of this study. This study conducted a retrospective analysis of medical records for patients who underwent endoscopic DCR from January to December 2019.

Inclusion criteria stipulated that participants should exhibit monocular-affected PANDO and display, via DR-DCG, contrast accumulation in the LS without subsequent flow into the inferior nasolacrimal duct. We excluded patients with a previous lacrimal surgery history, acute dacryocystitis, lower eyelid malposition including ectropion or entropion, suspicion of malignancy, post-traumatic bony deformity, any occupying lesions in the lacrimal system and previous facial fractures or nasal diseases. Fig. 1 and Supplementary Table 1 show the inclusion/exclusion flowchart and the baseline characteristics of the subjects.

2.2. Preoperative examination and surgical procedure

Every patient received lacrimal system irrigation and dacryocystography by the same ophthalmologist. Initially, local surface anesthesia is administered to both eyes using proparacaine hydrochloride eye drops. Subsequently, a disposable 5-ml syringe is used to extract approximately 2-ml of saline. A needle is then inserted through the lower lacrimal punctum to inject the saline into the lacrimal system, and the rinsing results are duly recorded. Next, another disposable 5-ml syringe is employed to extract approximately 2-ml of contrast agent, and the needle is once again inserted through the lower lacrimal punctum, pushing it in slowly. This entire process is repeated bilaterally. Immediately following the contrast injection, the patient proceeds to the radiology department. Based on the image of DR-DCG, the site of obstruction is determined by analyzing whether the contrast agent fills the lacrimal sac and whether it flows into the nasolacrimal duct.

All surgeries were performed under general anesthesia by the same experienced surgeon (X.L.). The surgical procedures were then

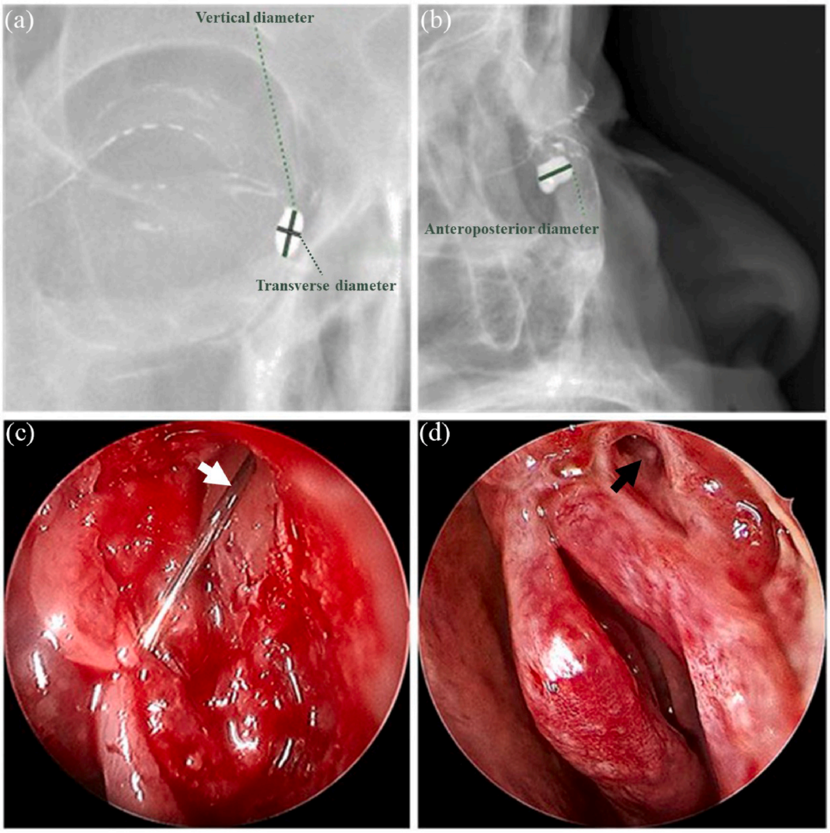

Fig. 2. Typical image of digital radiography dacryocystography. (a) The vertical and transverse diameters of the lacrimal sac on the coronal view; (b) The anteroposterior diameter of the lacrimal sac on the sagittal view. Typical clinical photograph of the endoscopic dacryocystorhinostomy. (c) The white arrow points to the lacrimal probe through the opening of the common lacrimal duct; (d) The black arrow points to the ostium after the endoscopic dacryocystorhinostomy.

performed as described as follow. The nose was packed with cotton pledgets soaked in 4 ‰ adrenaline, followed by submucosal injection of mepivacaine 20 mg/ml and adrenaline 1:200,000 over the preconceived rhinotomy site. Endoscopy was then performed with a 0° rigid endoscope (Stryker Surgical, Kalamazoo, MI, U.S.A.). The root of the middle turbinate and uncinate process was identified as a surgical landmark. A curvilinear incision was started 6 mm above the insertion of the middle turbinate, and then ceased at the top of inferior turbinate insertion, locating anteriorly to the uncinate process. A parallel curvilinear incision was made about 8 mm distal from the first incision, and then a nearly 15 mm length narrow strip mucosal flap was formed and elevated with a freer elevator. The mucosal flap was about 8 mm (width) × 15 mm (length). Next, the strip mucosal flap was cut in the middle, creating such an "H- shape" flap, in order to expose lacrimal fossa bone. Then a 12mm × 10 mm bony ostium was created with the help of a bone-biting forceps. After the medial sac wall of the lacrimal sac was exposed, we utilized a bowman probe to the medial sac wall. After the LS was fully exposed, the upper or lower canaliculus was probed to tent the medial wall of the lacrimal sac. Ultimately, the medial lacrimal sac mucosa was incised to form a door "]"-shaped flap, and this posteriorly based flap was then reflected onto the residual nasal mucosa. A microneedle with 7–0 Vicryl sutures (Ethicon, USA) was anastomosed the lacrimal sac and nasal mucosal edges under an endoscopic intranasal approach. Finally, the nasal tamponade was placed at the osteotomy site.

2.3. Data recording and processing

The vertical and transverse diameter of the LS were measured on the anterior DR-DCG image, and the anteroposterior diameter of the LS was measured on the lateral DR-DCG image through the IntelliSpace IX workstations (Fig. 2). The vertical diameter of the LS was defined as the longest diameter parallel to the long axis of the LS. The transverse diameter of the LS was defined as the longest diameter perpendicular to the vertical diameter of the LS. The anteroposterior diameter of the LS was defined as the longest transverse diameter perpendicular to the long axis of the LS on lateral DR-DCG.

The size of the LS was divided into small (≤4.350 mm) and large (>4.350 mm) according to the transverse diameter of the LS. In order to exclude the influence of whether the contrast filled the LS on the measurement of the anatomical diameters of the LS, we based our results on the degree of filling LS with contrast, 129 patients were categorized into the entirely exposed group (Group 1) and the partially exposed group (Group 2).

The outcome was evaluated for at least 3 years after the surgery. The primary outcome was followed up by phone calls for epiphora. Success was assessed on epiphora symptoms of patients and evaluated by Munk's score (Table 1). Epiphora of grade 0 or 1 was considered as success, whereas epiphora with a grade ≥2 was defined as failure.

2.4. Statistical analysis

Statistical relationships between the anatomical dimensions of the LS and Munk's score were assessed using Spearman correlation analysis. Receiver operating characteristic (ROC) curve was plotted to obtain a suitable cutoff value of the transverse diameter of the LS to distinguish success from failure of endoscopic DCR (Supplementary Fig. 1). The cutoff value calculated by the Youden index of the transverse diameter of the LS was 4.350 mm. The chi-square test was utilized to evaluate associations between the LS size and Munk's score, different sexes, and various age groups. Additionally, an independent *t*-test and the Mann-Whitney *U* test were employed to contrast the anatomical dimensions of the LS across varying sex and age groups. All analyses were conducted using IBM SPSS Statistics 20. A p-value of less than 0.05 was considered statistically significant. Multiple testing correction was applied where necessary to minimize the risk of Type I error. Descriptive statistics, including means, standard deviations, and frequencies, were calculated for all variables. Additionally, binary logistic regression analysis was used to identify potential predictors of postoperative outcome following endoscopic DCR and results were reported with 95 % confidence intervals (CI) where appropriate. A p-value of <0.05 were considered significant statistically.

3. Results

Table 2 showed the demographic of the included patients. DR-DCG images of 129 patients (17.8%males, 82.2%females) aged 20–79 years (50.68 ± 11.87 years) were analyzed in this study. There were 103 patients with positive sac squeezing test and 23 patients with negative sac squeezing test. During the follow-up, we found four patients who were re-operated for recurrence. However, 13 patients, accounted for 10.1 % with failed endoscopic dacryocystorhinostomy after three years, according to Munk's score.

Analyzing the transverse diameter and anteroposterior diameter of the LS among 129 patients showed a negative correlation between them and Munk's score (Transverse diameter, r = -0.282, p = 0.001; Anteroposterior diameter, $r = -0.291$, $p = 0.002$;

Table 1
Munk's subjective score of epiphora.

Grade	Symptom of epiphora
0	No epiphora
1	Occasional epiphora requiring dabbing less than twice a day
2	Epiphora requiring dabbing 2–4 times per day
3	Epiphora requiring dabbing 5–10 times per day
4	Epiphora requiring more than 10 times per day or constant tearing

Table 2
Demographic of the included patients.

	N (%) or mean (SD)
Age (years)	50.68 (11.87)
Sex	
Male	23 (17.8)
Female	106 (82.2)
IOP (mmHg)	13.42 (2.43)
Visual acuity, logMAR	0.65 (0.34)
Preoperative duration of epiphora (months)	71.87 (73.58)
Preoperative diagnosis	
Chronic dacryocystitis	125 (96.9)
Primary acquired nasolacrimal duct obstruction	4 (3.1)
Sac squeezing	
Positive	103 (81.7)
Negative	23 (18.3)
Insertion of stent	
Yes	9 (7.0)
No	120 (93.0)
Postoperative recurrence	4 (3.1)
All patients	
Entirely exposed group	83 (64.3)
Partially exposed group	46 (35.7)
Three-year postoperative outcome	
Success	116 (89.9)
Failure	13 (10.1)

Abbreviation: SD, standard deviation. N, number of cases. IOP, intraocular pressure. logMAR, logarithm with a minimum angle of resolution.

Table 3
Correlation were calculated for variation in postoperative Munk's score.

Factors	All patients		Entirely exposed group		Partially exposed group	
	r	*p*[a]	*r*	*p*	*r*	*p*[a]
Duration of epiphora, months	−0.149	0.092	−0.075	0.502[a]	−0.335	0.023
Anteroposterior diameter, mm	−0.291	0.002	−0.292	0.014[b]	−0.184	0.226
Vertical diameter, mm	NA	NA	−0.234	0.033[a]	NA	NA
Transverse diameter, mm	−0.282	0.001	−0.373	0.001[a]	−0.057	0.707
Sac squeezing						
Positive	−0.227	0.021	−0.279	0.024[a]	−0.090	0.590
Negative	−0.524	0.010	−0.472	0.076[b]	−0.846	0.082

Abbreviation: NA, not applicable.
[a] Spearman correlation analysis.
[b] Pearson correlation analysis.

Table 3). Among 83 patients (Group 1), the correlation between the anatomical diameters of the LS and aging showed that the mean anatomical diameters of the LS were negatively correlated with the mean age (Anteroposterior diameter, $r = -0.292$, $p = 0.014$; Vertical diameter, $r = -0.234$, $p = 0.033$; Transverse diameter, $r = -0.373$, $p = 0.001$; Table 3); the older the mean age, the smaller the vertical, anteroposterior and transverse diameters of the LS (Fig. 3).

Having observed similar patterns in the changes of both the transverse and anteroposterior diameters of the LS across Group 1 and Group 2, we categorized the 129 patients into younger (20–39 years old) and older (≥40 years old) groups according to the high prevalence age of PANDO. Comparing the anatomical diameters of the LS between different age groups among 129 patients revealed that the transverse and anteroposterior diameters of the LS in older people were smaller than in the younger ones ($p = 0.030$, $p = 0.022$, respectively; Table 4). Additionally, we conducted a thorough analysis of the distinct age subgroups within both groups to gain further insights. While among 83 patients in Group 1 revealed that there were no significant differences in the vertical, transverse, and anteroposterior diameters of the LS ($p = 0.250$, $p = 0.481$, $p = 0.252$, respectively; Table 4).

The ROC curve was constructed to determine the diagnostic accuracy of the transverse diameter of the LS. The area under the ROC (AUROC) curve of the transverse diameter of the LS was 0.655. The transverse diameter of the LS at 4.350 mm was found to be the cutoff value for the outcome of endoscopic DCR, with a sensitivity of 42.2 % and a specificity of 92.3 %.

Table 5 compared the different variables with the surgical outcomes. We found a statistical difference between the surgical outcomes and the sizes of the LS according to the categorization of the transverse diameter of the LS ($p = 0.041$). And after utilizing binary logistic regression analysis to assess the predictive power of different variables for postoperative outcome following endoscopic DCR showed that the small LS was a risk factor for postoperative failed outcome (odds ratio [95 % CI]: 8.776 [1.104, 69.758], Table 6). Additionally, adjusted for the age and sex, the small LS was associated with an increased risk of postoperative failed outcome (adjusted

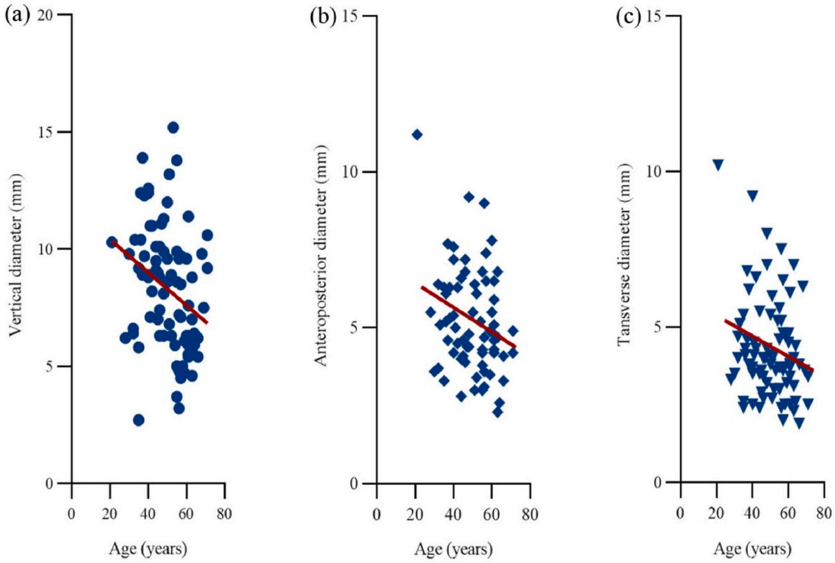

Fig. 3. Scatterplot showing the anatomical diameters of the lacrimal sac with aging in entirely exposed group. (a) Linear relationship between the vertical diameter of the lacrimal sac and aging; (b) Linear relationship between the anteroposterior diameter of the lacrimal sac and aging; (c) Linear relationship between the transverse diameter of the lacrimal sac and aging.

Table 4
Comparison of the anatomical diameters of the lacrimal sac in 20–39 and ≥ 40 years.

	20–39 years	≥40 years	*p*
All patients (SD), mm			
Anteroposterior diameter	6.31 (2.11)	5.22 (1.71)	0.022[a]
Transverse diameter	5.18 (2.09)	4.21 (1.43)	0.030[a]
Entirely exposed group (SD), mm			
Anteroposterior diameter	5.74 (2.00)	5.07 (1.57)	0.252[a]
Vertical diameter	9.00 (2.97)	8.12 (2.58)	0.250[b]
Transverse diameter	4.73 (1.94)	4.15 (1.50)	0.481[a]
Partially exposed group (SD), mm			
Anteroposterior diameter	7.47 (1.96)	5.44 (1.90)	0.014[a]
Transverse diameter	6.13 (2.24)	4.31 (1.31)	0.029[a]

Abbreviation: Data are expressed as the mean ± SD. SD, standard deviation.
[a] Mann-Whitney *U* test.
[b] Independent *t*-test.

Table 5
Comparison of different variables with surgical outcomes in patients.

	Three-year postoperative outcome of endoscopic dacryocystorhinostomy, n (%)		
	Success	Failure	*p*[a]
Age groups			0.577
20–39	21 (16.3)	1 (0.8)	
≥40	95 (73.6)	12 (9.3)	
Sex			0.532
Male	22 (17.1)	1 (0.8)	
Female	94 (72.8)	12 (9.3)	
Size of the LS[b]			0.041
Small	64 (49.6)	11 (8.5)	
Large	52 (40.3)	2 (1.6)	

Abbreviation:
[a] X^2 Test.
[b] Categorization according to the transverse diameter of the lacrimal sac in all patients.

Table 6
Binary logistic regression results of age, sex, size of the lacrimal sac, the transverse diameter of the lacrimal sac, and preoperative duration of epiphora (months) for postoperative outcome following endoscopic dacryocystorhinostomy.

Variables	β	Z	OR (95%CI)	*p*
Age	0.041	2.155	1.042 (0.986, 1.100)	0.142
Sex	−1.033	0.936	0.356 (0.044, 2.885)	0.333
Size of the LS[a]	2.172	4.217	8.776 (1.104, 69.758)	0.040
The transverse diameter of the LS	0.521	3.493	0.594 (0.344, 1.026)	0.062
Preoperative duration of epiphora (months)	0.006	2.847	1.006 (0.999, 1.012)	0.092

Abbreviation:
[a] Categorization according to the transverse diameter of the lacrimal sac in all patients. CI, confidence interval. LS, lacrimal sac.

odds ratio [95 % CI]: 8.628 [1.074, 69.335]).

4. Discussion

This study examined the factors correlated with the severity of postoperative epiphora following DCR to ascertain whether the anatomical dimensions of the LS captured in DR-DCG images could serve as predictive markers for successful DCR outcomes in patients with PANDO. Results revealed that in cases with complete visualization of the LS, the vertical, transverse and anteroposterior dimensions of the LS diminished with age. Furthermore, a negative correlation emerged between these anatomical dimensions and Munk's score, involving the transverse and anteroposterior diameters of the LS.

Munk's score serves as a salient metric to assess the efficacy of DCR, recognized as the gold standard for managing PANDO. Though DCR boasts a commendable success rate, it nevertheless incurs a surgical failure rate of 4–13 % [10]. Longitudinal studies reveal that chronic smoking and premature post-operative evaluations adversely affect long-term outcomes [11,12]. Thus, we evaluated the outcome of endoscopic DCR after three years. This study included younger participants (50.7 vs. 55.5–65 years), failed to identify a conclusive correlation between patient age and surgical success (Table 4). Notably, an in-depth analysis disclosed that surgical failures were concentrated among patients aged 41–79, suggesting a predilection for less favorable outcomes in this older demographic. This finding extended the current literature, which posits that age-related physiological alterations, such as diminished lacrimal drainage, are likely contributors to these adverse outcomes [13–16].

Regarding determinants of surgical failure in DCR, existing research categorizes LS size into three distinct classifications: small (<5 mm), moderate (5–10 mm), and large (>10 mm), based on the vertical diameter [17,18]. These studies suggest that patients with smaller LS dimensions experience extended preoperative epiphora and are more likely to face adverse post-DCR outcomes. This assertion is substantiated by a Turkish study, which found a negative correlation between prolonged obstruction and DCR success [19]. Our present analysis revealed a significantly inverse relationship between the anatomical diameter of the LS and Munk's score: larger LS diameters correlated with lower Munk's score, implying improved postoperative outcomes. And we found that the small LS was independently associated with postoperative failed outcome after adjusting for age and sex. Therefore, the preoperative measurement of LS diameter using DR-DCG can be considered a viable predictive indicator for post-DCR surgical efficacy.

Recent studies have employed intraoperative techniques to measure the vertical diameter of the LS [3,17,18]. Employing calipers or a suction tip, Lee et al. discovered that 95.9 % of cases with lacrimal sac mucus retention had medium-to-large LS dimensions, implying a contributory role for mucus retention in LS enlargement [18]. While no relationship was observed between the LS's vertical diameter and the duration of tearing symptoms among patients with mucus retention, an inverse correlation was discerned when such patients were excluded. Intraoperative measurements of the LS therefore offer a valuable means of isolating the influence of mucus retention on LS size. However, conventional methods, relying on vertical diameter measurements during operation, were performed after full incision of the LS, at which time the LS was deprived of its native tension, which can affect the measurement to some extent. Although intraoperative measurement of the vertical diameter of the LS allowed patients to avoid preoperative DR-DCG, it prevented clinicians from better understanding the morphology of the patient's lacrimal drainage system and the location of the obstruction preoperatively, which in turn affected their assessment of the patient's prognosis and posed challenges in doctor-patient communication.

To improve preoperative patient communication and assessment, this study employed DR-DCG to measure the anatomical diameters of the LS. Contrary to clinical expectations, no correlation between LS size and post-DCR outcomes emerged when vertical diameter categorization was used. However, a significantly negative correlation was identified between the transverse diameter of the LS and postoperative Munk's score, particularly after excluding patients with a positive sac squeezing test. These findings suggest that transverse diameter serves as a more reliable prognostic tool for assessing post-DCR epiphora symptoms than the vertical diameter, especially when sac squeezing is negative.

The strength of the current study lies in its operational simplicity, low radiation exposure, short examination time, and the capacity to predict DCR outcomes by measuring the LS anatomical diameters via DR-DCG. In instances of partial sac visibility, the preoperative assessment centers on the transverse diameter of the LS. Existing literature robustly validates DCG as the authoritative standard for proficiently visualizing the lacrimal drainage system [20,21]. Furthermore, the practicality of X-ray technology becomes particularly invaluable in economically disadvantaged areas that lack expert radiologists [22]. Despite these merits, the study does possess limitations. The overall sample size, while substantial, includes only 13 cases of surgical failure, insufficient for drawing decisive conclusions about the utility of LS measurements. Earlier works by Mann et al. and Chan et al. posit that postoperative ostium dimensions typically shrink to an average of 25 % of their original size [23,24]; however, given this study's retrospective design, its capacity to elucidate postoperative ostium morphological changes remains constrained. Furthermore, by enlarging the sample size and incorporating additional study centers, we will be able to achieve more accurate lacrimal thresholds specifically in Asian populations, thereby enabling a more rigorous assessment of the postoperative efficacy of DCR.

5. Conclusion

The present study elucidates the influence of several key variables—the anatomical dimensions of the LS, age, and sex—on Munk's score following DCR. Utilizing DR-DCG for imaging, the research unveils a notable decline in the LS's anatomical diameters correlated with increasing age. A significant negative association was also observed between the anatomical dimensions of the LS and postoperative Munk's score, with the method of categorizing the LS into small and large using a cutoff value of 4.350 mm for the transverse diameter of the LS suggesting that a small LS would be an independent risk factor for the postoperative outcome. For patients diagnosed with PANDO, a preoperative focus on the transverse diameter of the LS serves as one of the reliable indicators for assessing the severity of postoperative epiphora.

Ethics approval

This study was approved by the Ethics Committee of Zhongshan Ophthalmic Center, Sun Yat-sen University (No.2023KYPJ237) and was conducted according to established ethical guidelines. This study was performed in line with the principles of the Declaration of Helsinki. A written informed consent was not obtained from the subjects because of the retrospective nature of this study.

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Data availability statement

Data will be made available on request, and all the data can be obtained by contacting the corresponding author.

CRediT authorship contribution statement

Shihuai Nie: Writing – original draft, Supervision, Methodology, Data curation, Conceptualization. **Yong Liu:** Writing – original draft, Supervision, Methodology, Data curation, Conceptualization. **Wei Wang:** Writing – original draft, Supervision, Methodology, Data curation, Conceptualization. **Lixu Guo:** Visualization, Software, Resources, Investigation. **Min Zhou:** Visualization, Software, Resources, Investigation. **Yiting Zhang:** Visualization, Software, Resources, Investigation. **Danmei Li:** Visualization, Software, Resources, Investigation. **Qingyu Chen:** Visualization, Software, Resources, Investigation. **Danping Huang:** Writing – review & editing, Validation, Supervision. **Xuanwei Liang:** Writing – original draft, Validation, Supervision. **Rongxin Chen:** Writing – review & editing, Validation, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e31981.

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